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THE REPUBLIC OF THE PHILIPPINES

PLANNING REPORT ON THE PASIG-POTRERO RIVER FLOOD CONTROL AND SABO PROJECT

APPENDIX II

GEOLOGY AND DEBRIS PRODUCTION
SABO PLAN

SEPTEMBER 1978

JAPAN INTERNATIONAL COOPERATION AGENCY

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I GEOLOGY AND DEBRIS PRODUCTION

1.1 Geologic Descriptions

1.1.1 Agglomerates (I) /1

As far as has been observed in the project area, the rocks composing the main body of the Pinatubo Valcano are widely distributed, not only in the project area but also in the board area centering on Mt. Pinatubo.

These rocks consist mainly of following lithologic units and the volcanic breccia is the most easily distinguished among them.

(1) volcanic conglomerates
(2) volcanic breccia
(3) agglomerates /2
(4) tuff breccia
(5) tuff

These show generous bedding dipping to the east (downstream) side.

The volcanic conglomerates portion of this unit is comprised of mainly subangular or subrounded cobble-boulders /3, and the thin beds of the tuff which are incontinuous are frequentry found in them. Intensively weathered tuff lying below the welded tuff (II) at the leftside of the No. 1 river-bed consolidation work and on river bed in the alluvial fan portion, also belongs to this unit.

Erosion of these rocks is advanced due to collapse on the mountainside or rock falls on the valley side. However, because of the high consolidation, resistance to sheet or lateral erosion is markedly strong. And then, the gorge (see FIGURE I-1) has been excavated. In other word, annual erosion volume of this unit by the present river water is so little, may be less than the order of 0.1 cm/yr. in average toward the both sides, that there is little problem regarding Sabo planning. Also this unit is suitable enough for Sabo demsite because of the sufficient hardness and little clack.

1.1.2 Agglomerates (II)

This unit is distributed on the right side in upper-middle stream of the Pasig river, broadly overlying the agglomerates (I), in company with which they compose the mainbody of the Pinatubo volcano. They are thought to be a series of the volcanic products the same as agglomerates (I) comprised from the agglomeratic and pure lava flows and welded tuff which are harder than agglomerates (I) and form the steep cliffs along the river.

/1: in a wide sense
/2: in a narrow sense
/3: These boulders are suitable for concrete aggregate because of the hardness and high gravity but picking them up from the beds may be a problem.

In the downstream from northside of the Mt. Dorst, agglomeratic lava flows can be distinguished, but the pure lava flows, which consist of hornblende dacite with grey color, are more dominant in the upper-stream area boundering a fault across the river.

1.1.3 Welded Tuff (I)

This unit is distributed in a small area only along leftside of the Pasig river between the confluence of the main river and the Timbu river and for about 2 km downstream from this point. Slopes composed of this unit are very smooth and are different from the pyroclastic flow deposits which are distributed around this unit the slopes are rich in small relief and moreover form about 30m higher plains than that of the pyroclastic flow deposits.

This rock which is biotite bg. hornblende dacite and remarkably similar to welded ruff (II) which will be mentioned later is somewhat welded and fairly hard though not enough to be used as macadam for concrete. Thus, the slopes composed of this unit are resistant against lateral or sheet erosion.

1.1.4 Welded Tuff (II)

This rock is distributed on the northernside of the Pasig river, and on both sides of the Timbu river etc. forms the base for pyroclastic flow deposits together with welded tuff (I) mentioned above; and is also biotite by hornblende dacite and is easily distinguishable from the other pyroclastic flows because of the characteristically beautiful colomnar joints. Although no original sedimentary surfaces remain, slopes of this unit are lowly dissected and small in relief. This unit undoubtly covers the agglomerates (I) on the leftside of the middle-stream of the Pasig river and on the rightside of lowerstream of the Timbu river, and is covered with unconsolidated pyroclastic flow deposits (II-b) at the upperstream of the Timbu river where the geomorphologic history can be assumed to be as shown in FIGURE I-2.

This unit is also markedly hard though not enough to be used as macadam for concrete, and the slopes comprised of this rock are significantly resistant to lateral erosion; and little rock fall is evident because of the small relief and gentle slope. Therefore, there is little problem with this unit.

1.1.5 Pyroclastic Flow Deposits (I)

This rocks are distributed in the northernside of the Timbu river centering on Palsapis. The slopes consisting of this unit, gradually dipping from the top of the Sacobia river to the northernside of Cavayan in Angeles city, retain the original sedimentary surface in the eastside of Palsapis and it's neighborhood. Denudation of the slope in the upperstream of Palsapis is relatively advanced, and many small valleys trending toward the east have been formed; and ridges among these valleys continue intermittently as far as the plane at Palsapis and this suggests that of may be comprised of the same sediments.

This rock lies covering the welded tuff (II) in the northernside of the Timbu river and is covered with the pyroclastic flow deposits (II) in the uppermost stream of the river. The flat planes intermittently distributed on the westernside of Palsapis and its neighborhood, are composed both of the original sedimentary surface of this bed and also of the old fan deposits, which have been much flattened due to the fan deposits derived immediately after the sedimentation of this bed.

This unit consists mainly of the sand-cobble size volcanic breccia* (composed of hornblende andesite and porous hornblende dacite) and shows generous bedding though partly massive; and is consolidated so tightly as to be impossible to break by hand.

Although this unit is harder than the pyroclastic flow deposits (II-p, II-s), many coastal collapses are recognizable along the streams. Few collapses are, however, formed in the dry season which is poor in water action because of tightness of this unit. In other words, it seems that the occurrence of the collapses is the most strongly influenced by the lateral erosion due to the river water in the rainy season.

Although most of debris in the Abacan river basin was derived from this unit or old fan deposits which were secondarily derived from this unit, the debris volume supplied is less than that of the Pasig river basin. This is due to the low lateral erosion and low transportation of debris by the water flow due to poor surface water flow because of the high permeability of this unit as well as the nature, mentioned above, of this unit.

1.1.6 <u>Pyroclastic Flow Deposits (II-p)</u>

This rock is distributed on the northernside of the Pasig river composing the gentle slopes in company with I.1.5. Denudation is advanced on the parts fronting the Pasig and Sacobia rivers but there is little in the area between these rivers and then the original sedimentary surface is recognizable.

This unit is composed of little welded pale grey dacitic tuff, porous in the whole body because it contains pumices and markedly massive showing few cracks and no stratification. This suggests that this unit flowed and was deposited as a pyroclastic flow. Its appearance is similar to that of I.1.5 mentioned above, however, there is remarkable differences in low consolidation, due to pumiceous and poverty in lappili; therefore, this rock is very collapsible and has following physical properties.

(1) little resistance to lateral erosion and corrosion
(2) very collapsible at the marginal part of the rock body
(3) considerably high in compression strength at the primary position but changes are remarkably low after disturbance
(4) forms almost vertical cliff easily (being the most stable to erosion in this condition)

Due to such characteristics, this rock area is the largest origin of debris and is the most serious problem in Sabo planning.

1.1.7 Pyroclastic Flow Deposits (II-s)

This rock is petrographically the same as the pyroclastic flow deposits (II-p) mentioned above. Distribution is however, limited to the area between No. 4-A damsite and 2km upstream from there, and the Timbu basin, forming a lower sedimentary plane that unit I.1.5 in both areas. And, the rock body of agglomerates (I) which are at the basement of this area remain as the monadnock in the pyroclastic flow deposits area. Such facts suggest that a part of the pyroclastic flow deposits (II-p) was dammed up, over flowed to Pasig river side, and then a part of them flowed down along main stream of the Pasig river and another part along the Timbu river and to reach the confluence with the Pasig river near the fan top.

Thus, this unit is one of the largest sources of debris as well as unit I.1.6 and is a serious problem to Sabo planning.

1.1.8 Old Fan Deposits

The flat plane gradually dipping toward the east from the top of western part of Palsapis, located in the northernside of Pasig river is an ancient alluvial fan. As shown in many points in the Abacan river, basin, this bed is distributed covering the pyroclastic flow deposits described in I.1.5. Moreover, thickness of the bed increases toward the east (Angelus side). Although this fan is considerably dissected already and formed many radial valleys, the original sedimentary surfaces widely remain.

The surfacial part of 70cm ± in this bed is weathered and has changed into soil. This unit is well bedded being 5 - 10m in thickness and has a tendency to be rougher than the finer, upper part of the bed; the lower part consists of subrounded - subangular cobble and angular pebble in the upper part. Both parts are poor in consolidation, though better than alluvial fan deposits, and make vertical cliff easily due to their falling together with pyroclastic flow deposits (I) of lower horizon. This unit, however, supplies not so much debris into the river as the pyroclastic flow deposits (II-p, II-s) or alluvial fan deposits (I-III).

1.1.9 Fan Deposits (I-III)

The Pasig alluvial fan built by debris derived from the Pasig river is divided into three planes formed from the older one. The main plain of this fan consists of alluvial fan deposits (I) and the newest contemporary fan deposits (flood plane deposits) are next to these.

Alluvial fan deposits consist mainly of sand and pebble and generally show fine stratification parallel to surfacial inclination. The ancient river-bed deposits which are intermittently distributed along the coast of the Pasig river were also shown as the alluvial fan deposits in the geologic map, but strictry speaking, they should be called terrace deposits which are the small local remnant of the thick ancient river-bed deposits built by dumming-up at the narrow of the river (see FIGURE I-2).

All of them are unconsolidated though there are differences in the sedimentation manner, and very collapsible. Then, the coast of the terrace facing to the river is daily collapsing, and the produced debris is building the talus reach to 10m at the top of the fan. Such talus will flow out easily due to the rise of the water level in the rainy season.

1.2 The Waste Types and Debris Discharge Mechanism

The types of mountain waste were described in I.6.1 of the main report. Details of their characteristics and the debris discharge mechanism of every type will be described as follows.

1.2.1 The Waste Types

(1) The collapse of mountain slope based on coast erosion in pyroclastic flow deposits area

Although (1) the pyroclastic flow deposits and (2) the fan or terrace deposits are remarkably similar in appearance, there is a difference in regard to which are primary deposits or secondary ones and this controls the nature and the waste type of the deposits.

The pyroclastic flow deposits are half-consolidated, rock falls or failures do not occur daily, but occur due to a strong proximate cause, such as heavy rainfall.

While, since fan or terrace deposits are almost unconsolidated, rock falls or failures continue daily, whether in the dry or the wet season are especially frequent in the dry season, in which the slope of the cliff is apt to be dry. The scale of the falls or failures is, however, rather small. The collapsed materials both of (1) and (2) have sometimes directly flowed into the river, but in many cases, have built talus cones at the foot of the slope, then have flowed out with the next flood flow.

Thus, the erosion in the pyroclastic flow deposits and fan or terrace deposits has been advanced by the following processes.

Occurrence of the collapses → building the talus cone → out flow by running water (or flow-into the main river)
(Occurrence of the collapses → out flow by running water (or flow-into the main river))

(2) Surface erosion on a collapsed slope

This type can occur on every existing collapsed slope, especially on the pyroclastic flow deposits and fan or terrace deposits because of their low consolidation. On the existing collapse on the left coast of the Buobuo river, both of types shown in (1) and this type are proceeding parallel to each other. Debris production in this waste type seems to commonly happen when the precipitation reaches more than a certain level (about 50mm/day?). However, the debris volume produced on the agglomerate (I), (II) or welded ruff areas, which are essentially hard is markedly small.

In many cases, produced debris has flowed into the triburary or main river, as the traction or debris flow, but sometimes it has built small debris cones temporally at the mouth of the stream without direct outflow to the river, and then, flowed out with the next flood water.

Occurrence of the collapses → surface erosion (sheet erosion) → building the debris cone at the mouth of the stream → flowing into the main river or a triburary
(surface erosion (sheet erosion) → flowing into the main river or a triburary)

(3) Gully erosion

Gully erosion, which is a characteristic type, in the youthful stage, in the erosional cycle is commonly recognized in the new fan deposits. Such erosion has advanced mainly due to (1) the valley top erosion, due to the surface water accumulated on the flat plane of the fan, and (2) the erosion due to the spring-out of the underflow water that flowed down into the fan deposits.

Debris produced by gully erosion has directly flowed into main river, or has secondarily flowed there, after building the small alluvial cones at the river coast as recognized on the right coast and in the neighbourhood downstream of the No. 1-A river consolidation work.

Occurrence of the collapses → gully erosion → building the small alluvial cones → flowing into the main river or a tributary
(gully erosion → flowing into the main river or a tributary)

(4) Landslide or landslide liked collapse (massive collapse)

Landslides or landslide liked collapses (massive collapses), which slipped down as a big mass in a short time, are recognized at one place on the pyroclastic flow deposits along the Bucbuc river and at two places on the agglomerates (II) along the Papatac river, and have markedly narrowed the river bed as a result.

Slided masses which are exposed to the erosion at the river side are hard to flow out because of less shearing ability not as in common collapsed materials.

Occurrence of the collapses (or landslides) ⟶ lateral erosion of collapsed masses ⟶ flowing into the main river or a tributary

(5) Small scale collapses occuring signly

This type is characteristically recognized in the agglomerates (I), (II) area. If collapses of this type occur, they don't spread because of its hard basement, gradually reduced with the lapse of time and restored in about three years by invading plants.

Collapsed materials are gradually transported downstream after once forming the river-or stream-bed deposits.

Occurrence of the collapses ⟶ formation of river-or stream-bed deposits ⟶ flowing into the main river or tributary

1.2.2 <u>Debris Discharge Mechanism</u>

Macroic consideration aboutthe debris discharge mechanism, as the whole mountain range, in upperstream of the control point for Sabo planning, will be described in this section.

Even though in any kind of waste type, the produced debris has not always directly flowed into the main river of the tributary when the collapses have occurred in the mountainous area, a part of them were temporarily stored as a talus deposits, small debris cones or river-or stream-bed deposit near the spots (so called "river control phenomenon"). Namely, there is a time lag between the occurrence of a collapse and the outflow of the collapsed materials. When such mechanism of debris discharge is considered as a big system, debris movement is able to express variations related to the following criteria.

(1) precipiration (P)
(2) produced debris volume (A)
(3) eroded debris volume of river-bed (B)

(4) controlled debris volume on the river-or stream-bed, mountainslope etc. (C)

(5) debris discharge from the standard point (D)

As the available data in this project area, is limited to these investigation results, it was impossible to quantatively clarify the relation between them. Qualitatively consideringthe results of the field investigations and the photointerpreration using photographs from two periods, the following conclusions have been reached (see FUGURE I-3).

1) Produced debris volume (A)

When the big catastrophical collapses have occurred in occasions of the maximum flood and mountain slopes have been destroyed, the produced debris volume of the following year has markedly increased due to easy gully erosion and sheet erosion. At the same time, cliff failure on the river coast in the fan area has daily advanced and there has not always been a remarkable increase on an occasion of macimum flood.

2) Eroded debris volume of river bed (B)

It can be thought that the erosible debris volume of the existing river-bed deposits (unstable debris volume in the river) is in proportion to river-bed inclination and discharge.

3) Controlled debris volume on the river-bed or the mountain slope (C)

Much volume of debris was stored when many collapses have occurred on the river-bed (controlled debris volume on the river-bed), however, these were conversely re-eroded in the following year.

4) Debris discharge from the sub control point (D)

The following formular will be available for calculating this debris volume.

$D = A + B - C$

1.3 <u>Waste Condition of the Fan Area</u>

1.3.1 <u>Division and Formative History of the Fan and the Terraces</u>

Detailed investigation of the fan deposits area has been very effective in clarifying the following factors.

1) the variations of debris descharge from the mountainous range in a long time scale.

2) the variations of balance between the debris volume flowed into the fan area and the discharge debris volume.

3) the debris transportation manner.

Therefore, the series of the fans in the project area is divided into as follows based on (a) the height from the river-bed of fan area, (b) the erosional condition of the fan surface and (c) the depositional morphology and grain-size of composing materials.

(1) fan deposits I
(2) fan deposits II-a
(3) fan deposits II-b
(4) fan deposits II-c
(5) fan deposits III-a
(6) fan deposits III-b
(7) present flood plane deposits

Considering the distribution of the fan deposits (including the terrace deposits) and the microtopography on the fan surface, the formation of the Pasig alluvial fan is divided into following two periods.

(1) the formation (sedimentation) period of the main body of the fan
(2) the erosion period (that is formation period of fan deposits II, III and present flood plane)

In the sedimentation period of the fan deposits (I), the debris supplied upstream was more than that discharged downstream. However, other fan units display terrace liked landforms and this suggest that the debris volume discharged downstream is more than that supplied upstream. Namely, the river-bed has a tendency to sink annually after sedimentation of the fan deposits and also in the present conditions has been laid on its extentions. But, such tendencies come from only a conclusion taking into account the long time scale.

1.3.2 Characteristics and Position in the Formative History of the Pasig Fan of the Present Flood Plane

The fan under construction at present, that is the flood plane, has the following two characteristics.

(1) Considering the river-trend (ENE direction) at the end of the mountainous range and morphology of the existing fan surface, the formation of the present fan should trend toward Abgeles in natural conditions. However, the present flood plane and stream course are markedly biased toward the south. This may be caused by control by the welded tuff mass located locally at the left bank of the No. 1 river-bed consolidation work: the running water flowed down toward ENE runs against this welded tuff (I) and is forced to curve in a southerly direction due to the obstruction and change its course toward the present sedimentary area (see FIGURE I-5).

(2) At the same time that the newest fan was built, the older fans were gradually deepened by the corrosion of the river course and the lower river-bed changes.

Under the long time scale, this indicates that the debris supplied from upstream had been gradually decreased compared to the former stages in the formation of the fan. Then, the deep river (present Pasig river) which excavates the fan surface was constructed and the flooding changed hard to occur according to the increase of the height between the river-bed and the fan surface. This fact is also indicated by the distribution of the fans and flood traces recognizable in the aerial photographs. And the floods at least for this 70-80 years occurred only downstream from station 23 point (which correspond to the fan top of the newest fan)*. Namely, advancing the downward erosion of the river-bed, the beginning point of overflow of the flood water onto the fan surface was gradually moved to the downstream side, and then the overflowed area, where the range is covered with "neck-shaking phenomana" on the fan, was also narrowed (see FIGURE I-5). Such narrowing naturally continues as long as the advancing of the downward erosion. In other words, as the river-bed is lowered, the beginning point of overflow of the flood water is moved downstream and the flood range narrows.

* Supposing that the lateral erosion so far is the same as in the present condition, remarkable erosion must have began about 43 years ago —— in other words the present flood plane began to be built. Actually, however, as the annual erosion in the early stage may be weaker than that of the contemporary one, it is reasonable to estimate that the remarkable downward erosion began from more early times. Estimating by the formula shwon in FIGURE I-7, downward erosion seems to have greatly changed.

* Flooding in 1913, 1934 etc. occurred in roughly same area as at present (according to the public information and photointerpretation).

1.3.3 Characteristics of the Present Sedimentary Position of Debris

The newest fan on the Pasig alluvial fan is morphologically divided into three parts as follows.

(1) the fixed part of river course between the confluence of the Timbu river and Papatac rivers and nearby station 23 point.
(2) considering the background so far, the part where the flooding is repeated though the river course seems to be fixed
(3) the part where river course is roughly fixed and little flood of debris onto the fan surface has occurred

In the area shown in (1), the height between river-bed and the fan surface reachs 10-20m, then, flooding onto the fan surface is impossible considering the time scale for civil engineering. Although, there is no evidence of flood onto the fan surface during the past past years on the aerial photometer pretation. Bank cliff of the river has, however, constantly repeated to collapse and to erode and river is increasing its width.

The river course has rather meandered in this part. And the lowest meandered part (a, b, c, in FIGURE I-8) is closely related to the debris flooding in next section (2) mentioned above. Namely, flood II shown in FIGURE I-8 due to the flowing-down of the flood water along a . b, a' . b' and flood IV due to the flow down of the flood water along b . c, b' . c'. The flood plane (I) is considered to have been flooded due to the flood water along the river course of upstream of curve a. Thus, the flooding onto the fan surface is closely controlled by the meandering of the fixed river course/1. Therefore, in this section (2), the flooding onto the fan surface will continue as long as the river course near the end of section (1) and section (2) is left in it is present state. Considering such factors, the following basic flood counterplan to prevent flooding shall be considered in the river planning of this fan area.

(a) to provide enough cross sectional area of the river to prevent overflow
(b) to regulate the meandered river course near the end of section (1) and the upper half of section (2)/2
(c) to make strong the existing dike on the upper half of section (2)/3

In the section (2), little flooded debris reached downstream of the Mancatian bridge, but only the water flow, after making deposition of debris reaches there.

Flood water flows down along one of the following three courses (see FIGURE III-6 in main report).

1) the course along the stream through Maniban (in case of overflow to the left bank side)
2) the course along the main Pasig river
3) the course along the low-land across nearby 500m south of Mancatian bridge (in case of overflow to the right bank side)

The river course downstream from the 2km downstream of Mancatian bridge, is almost fixed. And the flood water flows down along the two flood course 1) and 3) mentioned above to join the main river downstream on the Pasig river.

/1: Flood plane controlled the upper meander, seems to be older.
/2: Regulation shown here means to smooth the curve due to the too heavy meandering.
/3: Both of height and strength of the dike shall be considered.

1.4 Opinions about the Sabo-countermeasures

1.4.1 The Bucbuc River and the Papatac River

On observing the series of collapsed areas at the right side of the Bucbuc river, it is clear that to prevent collapsing itself occurring in the mountainous area is very difficult. Moreover, it does not seem worthwhile to spend the time and money for prevention of collapse due to the following reasons.

(1) The collapse itself has not directly affected the social-life.

(2) Debris discharge as the debris flow which occurs in the collapsed area as a primary or secondary phonomena and brings the fatal damages is extremely little, and if the debris flow occurs, it will be limited within the upper area only, therefore it is not directly concerned the damages to social life at all /1

(3) It cannot be seen that the development of the collapse itself on the mountain side will lead this area to fatal destruction.

It is more important to control the debris discharge produced on the waste mountain area which is not to be linked to the disaster in the downstream area.

As the thickness of the present river-bed deposits is more than 20-30m /2, good basement rock which is suitable for foundation of debris control dam is not expected at the shallow level in the river-bed deposits.

Therefore, so called floating type foundations will be adopted for the planned dam in many cases. Generally the dam of this type is in danger of destruction when the vertical erosion on the river-bed of downstream side is advanced. Then, also the countermeasures to destruction due to the extraordinary decline of the river-bed shall be considered and the arrangement of Sabo facilities shall be considered as one set, from upper to lower stream, in the debris control plan, by the debris control dam. This is one of the most important things to be considered in the Sabo planning for the Pasig river basin.

/1: Although the volume of debris discharge will reach to a large quantity, it will be transported as traction.

/2: According to the result of drilling, it is more than 35m at the No.5 damsite.

1.4.2 The Timbu River Basin

Also the problems in the Timbu river basin are basically almost the same as the ones of the Bucbuc river basin. Additionally, in the Timbu river basin, however, a water fall, about 8m in height, which acts as a steadfast "national dam" is located near the lowest part of the Timbu river. Moreover, the basement rock of the fall consisted of agglomerates (I) is very hard. Therefore, if a debris control dam is constructed on the upper side of this fall and controls the debris, the river-bed on the lower side of the dam will not decline so remarkably. In short, the debris control dam which will be located at the No.5 damsite in the Timbu river has little probability of being destroyed because of the small amount of vertical erosion on the river-bed of the lower side of the dam.

1.4.3 The Fan Area

1.4.3,(1) In the Pasig alluvial fan, the upper stream area of the present flood plane is undoubtedly the source of the debris production, as well as the mountainous area and the mean annual eroded volume in this area comes up to approximately 147,000 m^3. Such debris production in fan area is caused as follows:

(1) Fan deposits are very loose and collapse daily due to consolidation.

(2) As the river-bed tends to decline, the foot of the cliff of the river bank is markedly erosive. Therefore, the countermeasures for preventing such erosion, that is revetment work, is necessary for stabilizing the river-channel in the fan area. Considering the facts that the present floods in this fan are influenced by the excessively meandered river course (see FIGURE I-8) in the countermeasure works it is desirable to include river-channel improvement.

1.4.3,(2) In present, the river-bed of the fan area is tending downward (see FIGURE I-8). Although this conclusion was based on the long time scale, Sabo planning which is ordinally based on such a long time scale of 100 year shall be planned considering this tendency. Judging from the relationship to other facilities such as bridges, levees etc., it will only produce problems to let the river-bed continue to decline, thus, "maintenance of the status quo" will be desirable after a certain time. For such maintenance, the constant debris discharge demanded to maintain the river-bed in the fan and the downstream area or the fixation of the riber-bed shall be provided for after a certain time. That control will be the most important point in the Sabo planning.

1.4.3,(3) In the usual conditions, the debris is transported to the lower or median areas of the fan and deposited on the river-bed near the upper area of the underflow point of the river-water in the rainy season or in the dry season while it is still rich in water.

With the decrease of the river-water, the depositional area is gradually moved to the upperstream, mainly located between the Papatac river and nearby the No.2-A damsite in about December - February, and the river-bed which was eroded downward in rainy season and rugged is reclaimed and becomes extremely smooth. Such a change is repeated in one year cycle. These facts shall be considered sufficiently in river-channel planning of the fan area.

1.4.3,(4) As discussed in 1.3, the present flood water in the Pasig fan flows down along one of three courses (see FIGURE III-6 in main report). At the point near the fan top of the present flood plane, when flood water overflows from the left bank, it will flow down toward Manibang, and from the right bank, toward Porac and almost along the Pasig river course (a medium-small scale flood which does not overflow). Countermeasures to flooding shall be established with the most suitable measures in these three flood courses.

1.4.3,(5) According to the public information on the Pasig alluvial fan, the stagnate of the flood water is extremely long in spite of considerable steep inclination (approx. 2^{o}) of fan surface; usually the water stagnation reaches for about one week but for 1.5 months in 1972. The greatest cause for such conditions exists in the bad drainage conditions on the lower area of the fan. Therefore, besides the countermeasure to flooding, also a speeded up system of drainage (i.e. improvement of sub-channel) for the sake of unavailable flood, shall be considered.

1.4.3,(6) Approx. 800,000m^3/yr. debris has been excavated /1 now. Judging from the social, economic and the inhabitant's emotional aspects, it is necessary that a debris discharge which is able to maintain the above volume without excess, decline of the river-bed (controlling the river-bed decline) is provided for from the upstream area. Conversely speaking, the debris which shall be treated in the Sabo planning (that is the "excess debris volume") will be equivalent to "debris volume in which the excavated and demanded debris volume for the river-bed decline /2 in the downstream area are deducted from the total discharge debris volume".

In addition, systematic debris excavation is necessary following the program of river-channel planning.

/1: Based on the result by river investigation group of this project.

/2: As the condition in which river-bed level is more little lower than in present one may be thought as the best condition.

1.5 Calculation of Debris Volume

1.5.1 Produced Debris Volume in the Mountainous Area

The debris volume produced in the mountainous area is usually measured by accurate comparative interpretation of the aerial photographs taken at more than two different times. In this investigation, however, the eroded volume for 10 years between 1966-1977 was calculated and the average was found and then "annual mean denudation rate per present wasted area" was provided (see TABLE I-1).

By means of the calculation of each river multiplying mean denudation ratio shown in TABLE I-1 in present wasted area, annual mean debris volume of the whole basin amounts to about 328,000m^3 (see FIGURE III-5 in main report). It is apparent in the same table that about 80% of the total volume of them (261,000m^3) is produced in the Bucbuc River basin, for the Timbu River about 51,000m^3 per year, following the Bucbuc River. Neither in the Yangca River nor the Papatac River does it amount to 10,000m^3.

The debris is not produced and discharged on an average every year, but in concentration at some time of uncommon precipitation as in the 1972 disaster. Comparing the aerial photographs of 1972 with 1966 and 1976, about 80% of debris might probably have been produced during the 1972 disaster. This fact is almost proved also by the comparison of precipitation during the disaster and in usual times (TABLE I-2).

According to public information, the 1972 disaster was the largest one remembered by the inhabitants. For this reason, it is suitable for the debris control plan to use this volume as the produced debris volume of the largest flood.

1.5.2 Supplied Debris Volume to the Fan Area

The debris volume flowing into the fan area (FI) is calculated as a balance of following three volumes (FI = A + B - C).

(1) debris volume produced on the hillsides (A)
(2) debris volume produced on the present river-bed (unstable debris volume in the river-bed) (B)
(3) debris volume possible to be stored on the present river-bed (river control debris volume) (C)

Considering the very long time scale (for example; some hundreds of year's order), produced debris volume on hillsides equals the volume flowed into the fan area. However, considering only one particular period such as "the largest flood", these are not always equal. With comparative interpretation of the aerial photographs in 1966 and in 1976, the width of the river become wider in the all sections, which shows significantly large channel storage.

On the other hand, the river-bed deposits with 1.5m± thick or average of that flood remain such as the terraces along the river. This suggests occurrence of the reverse phenomenon, in which the stored debris at the large flood is eroded, and transported during a small or medium flood. This phenomenon cannot be observed on the small stream. From those facts, assuming that the debris storage in large rivers like the main river or a large tributary (river-bed control) is made about 1.5m thick! but there is no control at small or medium rivers, the debris volume controlled in the river-bed comes to about 2,580,000m^3. While, assuming that the debris volume which will be eroded on the river-bed is individually 1.0m (width was 5m in average), it amounts to 1,810,000m^3.

Accordingly, under natural conditions without debris control facility, the debris of 1,850,000m^3 given as these debris balance will be discharged into the fan area at the time of maximum flood.

1.5.3 Eroded Debris Volume at the River Course of the Fan Area between 1966-1976

The change of the river-channel or river course in the fan area in 10 years is clarified by FIGURE I-8 in the main report etc. Out of such change, the following debris volumes derived from fan area itself* by the lateral erosion have been measured.

1) fan trench area	846,800	Total
2) recent flood area	469,000	1,465,400m^3
3) downstream area of Mancatian bridge	149,600	(146,500m^3/yr)

This volume is equivalent to about 45% of the produced debris in the whole mountainous area and to 56% of that in the Bucbuc River basin, moreover is not stored on the river-bed in the mountainous area but directly transported downstream.

Debris volume produced in the upstream basin and debris volume for Sabo planning in each basin are presented in TABLE I-3 and I-4.

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* The area between the confluence of the Timbu River and the Papatao River and 2.1km downstream of Mancatian bridge.

<u>References</u>

1) Department of Agriculture and Natural Resources, Bureaw of Mines (1968), Geologic Investigation of Placer Claims of Porac Concrete Corporation in Floridablanca and Porac, Pampanga (by Pascual H. LINGAT).

2) Commission of Volcanologry

a) Distinct record of earthquakes of major intensity (1619 - 1954).

b) Catalogue of Philippine Earthquakes (1907 - 1964)

c) PDE data (1975 - Feb. 1977)

TABLE I-1 ANNUAL MEAN DENUDATION RATE OF EVERY WASTING TYPE

wasting type	explanation	annual mean denudation rate
I-a	the type with large produced debris volume in active collapse	0.500 (m/year)
I-b	the type with small produced debris volume in active collapse	0.200
II	unactive collapse supplies little debris now	0.020
III	in the area distributed by pyroclastic flow deposits except I-a, I-b and II	0.010
IV	very cliffy part of 70 - 90 degrees gradient	0.001
V	mountainous part except I-a -- IV above	0.00
Rb	in present river bed	-

TABLE I-2 MONTHLY PRECIPITATION (1969-1976)

(STATION STA. CRUZ TOWN PORAC)

YEAR / MONTH	1969	1970	1971	1972	1973	1974	1975	1976
1	*	0^{mm}	20.0^{mm}	24.9^{mm}	1.0^{mm}	2.0^{mm}	19.2^{mm}	*
2	16.8	*	2.5	17.9	0	23.1	28.5	14.3
3	20.7	4.5	23.0	20.2	2.0	52.0	6.6	14.6
4	4.8	30.0	3.1	29.4	*	165.4	17.4	54.6
5	28.7	30.4	*	133.2	53.0	*	139.5	869.2
6	91.5	235.6	295.8	372.2	131.3	379.7	175.1	485.9
7	203.2	257.0	518.0	2,274.5	331.7	274.1	123.4	*
8	*	273.4	43.3	916.6	406.6	665.6	286.2	319.2
9	263.3	257.7	339.2	171.0	219.1	152.4	121.6	528.8
10	102.7	*	411.8	15.2	226.9	343.6	321.6	16.6
11	81.5	*	172.9	13.1	75.8	311.8	51.2	2.8
12	22.1	*	84.4	12.6	4.8	56.7	127.2	39.2
Total	835.3	1,088.5	1,914.0	4, 00.8	1,452.2	2,428.4	1,417.5	2,345.2

TABLE I-3 DEBRIS VOLUME PRODUCED IN THE UPPERSTREAM BASIN AT EACH DEBRIS CONTROL DAM

1) Dam No.2

Waste type	Area (m^2)	Average erosion depth (m/yr.)	Produced deb-Volume (m^3/yr.)
I-a	401,700	0.5	200,900
I-b	202,200	0.2	40,500
II	407,200	0.02	8,200
III	2,181,700	0.01	21,800
IV	718,000	0.001	700
V	11,636,700	0	0
River bed	1,252,500		
Total	16,800,000		272,100

2) Dam No.3

Waste type	Area (m^2)	Average erosion depth (m/yr.)	Produced deb-Volume (m^3/yr.)
I-a	401,700	0.5	200,900
I-b	200,900	0.2	40,200
II	403,000	0.02	8,100
III	2,173,700	0.01	21,700
IV	398,000	0.001	400
V	9,642,200	0	0
River bed	1,080,500		
Total	14,300,000		271,300

(to be continued)

3) Dam No.4

Waste type	Area (m)	Average erosion depth (m/yr.)	Produced debris Volume (m^2/yr.)
I-a	391,000	0.5	195,500
I-b	186,300	0.2	37,300
II	402,200	0.01	8,000
III	1,692,700	0.001	17,000
IV	380,000	0.001	400
V	5,158,500	0	0
River bed	989,300		
Total	9,200,000		258,200

4) Dams No.5

Waste type	Area (m^2)	Average erosion depth (m/yr.)	Produced deb- Volume (m^3/yr.)
I-a	20,500	0.5	10,300
I-b	28,800	0.2	5,800
II	45,900	0.2	900
III	2,396,300	0.01	24,000
IV	169,700	0.001	200
V	1,367,500	0	0
River bed	271,300		
Total	4,300,000		41,200

TABLE I-4 DEBRIS VOLUMES FOR SABO PLANNING IN EACH BASIN

Basin / Criteria	Bucbuc River	Yangea River	Papatac River	Timbu River	Total
Debris volume produced in the mountainous area (m^3): (1)	2,091,200	49,600	73,000	407,200	2,621,600
Debris volume produced in the river bed (m^3): (2)	1,068,100	40,400	388,000	353,800	1,810,300
Proposed objective debris volume for the Sabo planning (m^3): A ((1) + (2))	3,159,300	90,000	421,600	761,000	4,431,900
Estimated debris control volume on the river bed (m^3): B	1,563,900	29,850	499,500	489,450	2,582,700
Design sediment (debris) discharge (m^3): C (A - B)	1,595,400	60,150	-77,900	271,550	1,849,200
Exceed sediment (debris) discharge (m^3): D					835,000
Proposed sediment (debris) control volume					1,014,200

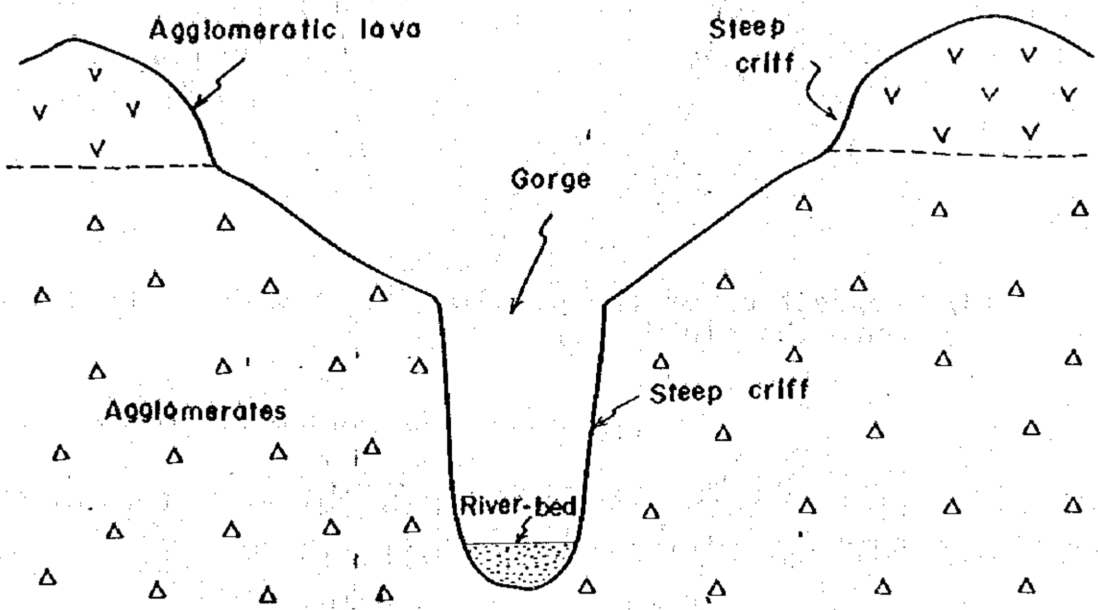
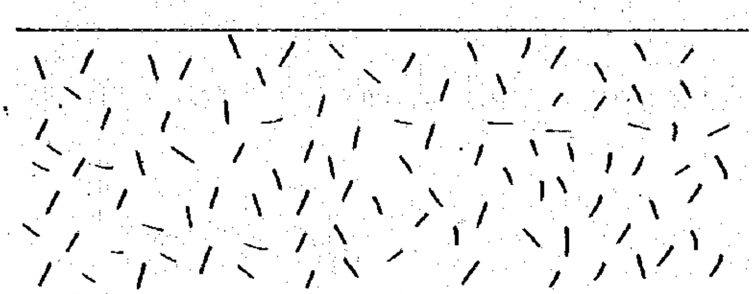


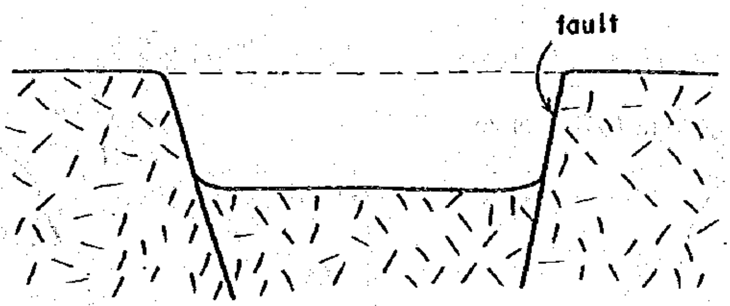
FIGURE I - I

SCHEMATIC REPRESENTATION OF THE GEOLOGIC PROFILE ACROSS THE PAPAFAC RIVER.

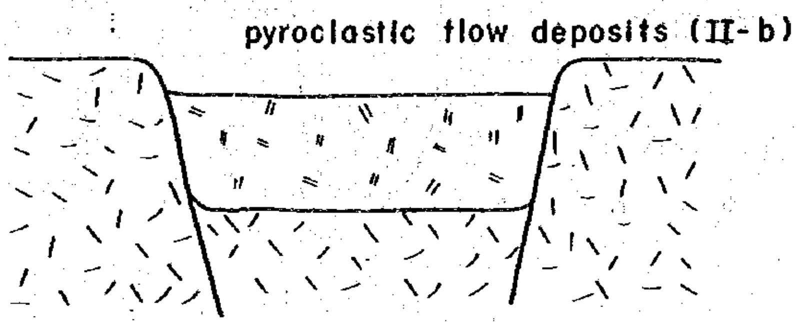
(1) Deposition of welded tuff (II)



(2) Formation of old valley
(due to fault and erosion)



(3) Deposition of the pyroclastic flow deposits (II-b)
onto the old valley



(4) Formation of the present valley

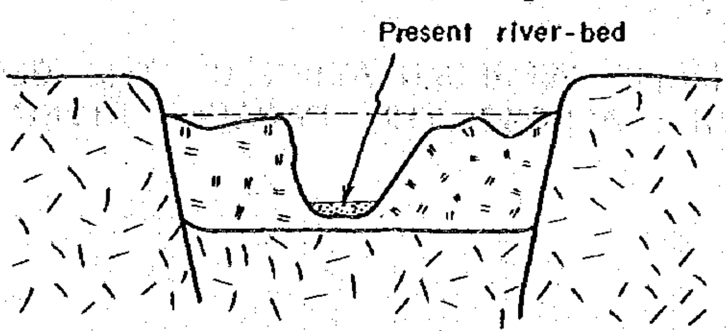


FIGURE I-2 SCHEMATIC REPRESENTATION OF THE GEOMORPHOLOGICAL DEVELOPMENT ON THE UPPRESTREAM AREA OF THE TIMBU RIVER.

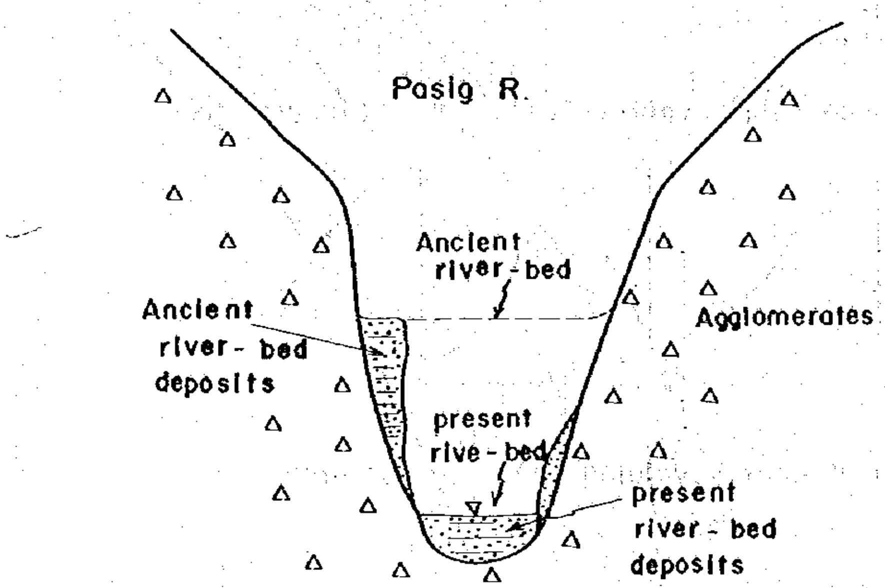


FIGURE I - 3 ANCIENT RIVER-BED DEPOSITS REMAINED ON THE RIVER-COAST ALONG THE PASIG RIVER.

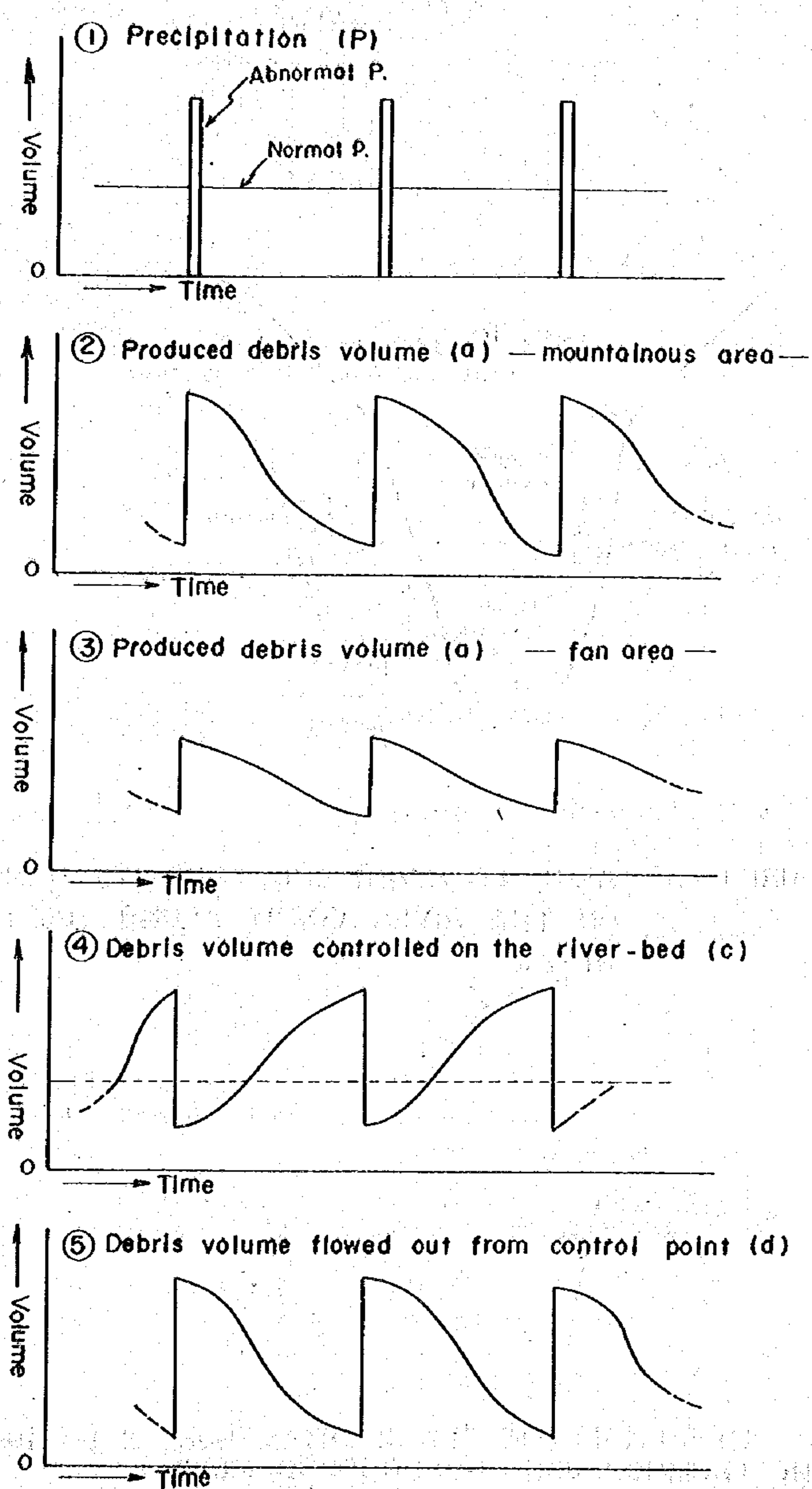


FIGURE I -4 CONCEPTIONAL REPRESENTATION SHOWING THE QUANTITATIVE DEBRIS VARIATION.

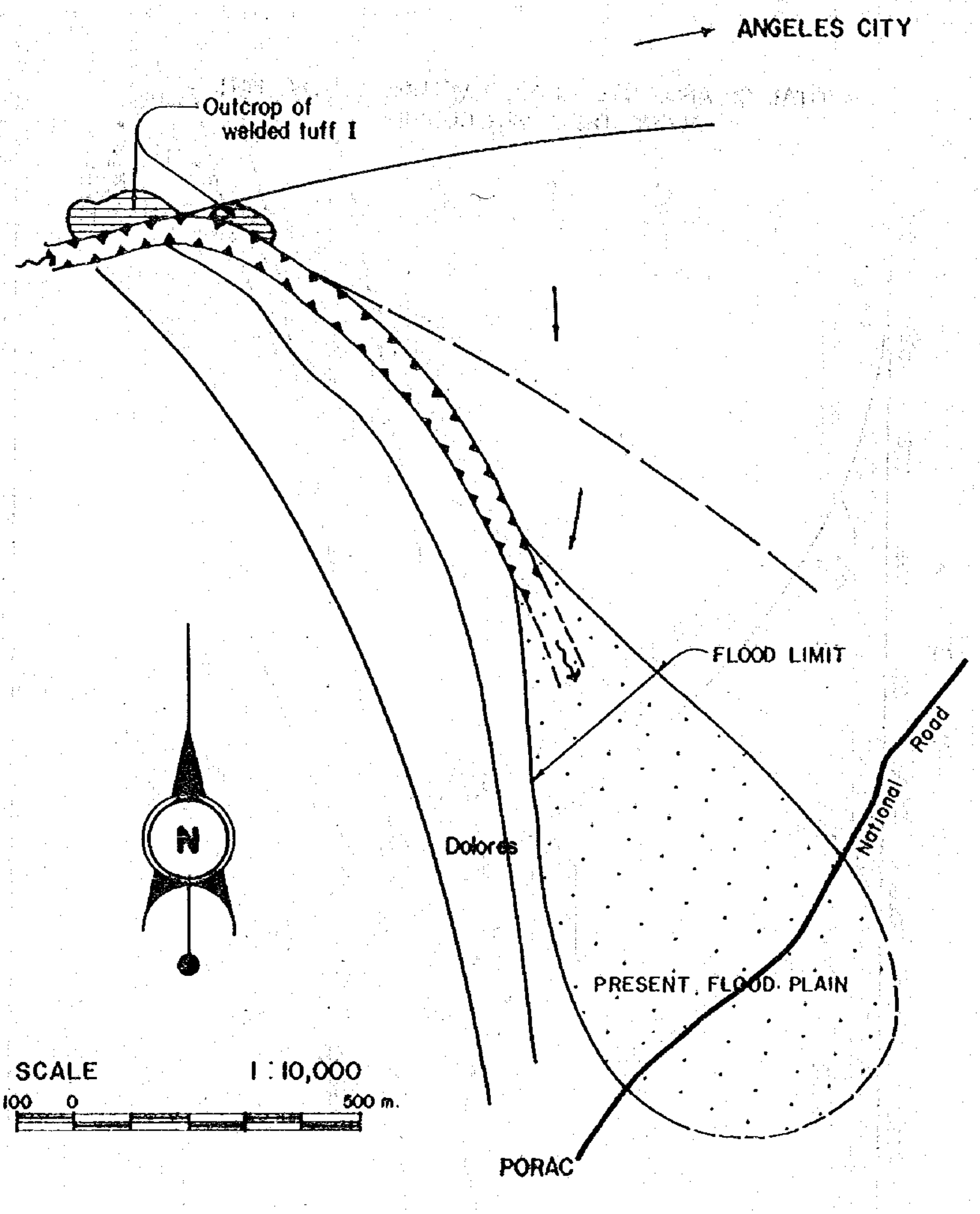


FIGURE I -5

PRESENT CONDITION OF THE FLOOD PLAIN IN THE PASIG ALLUVIAL FAN

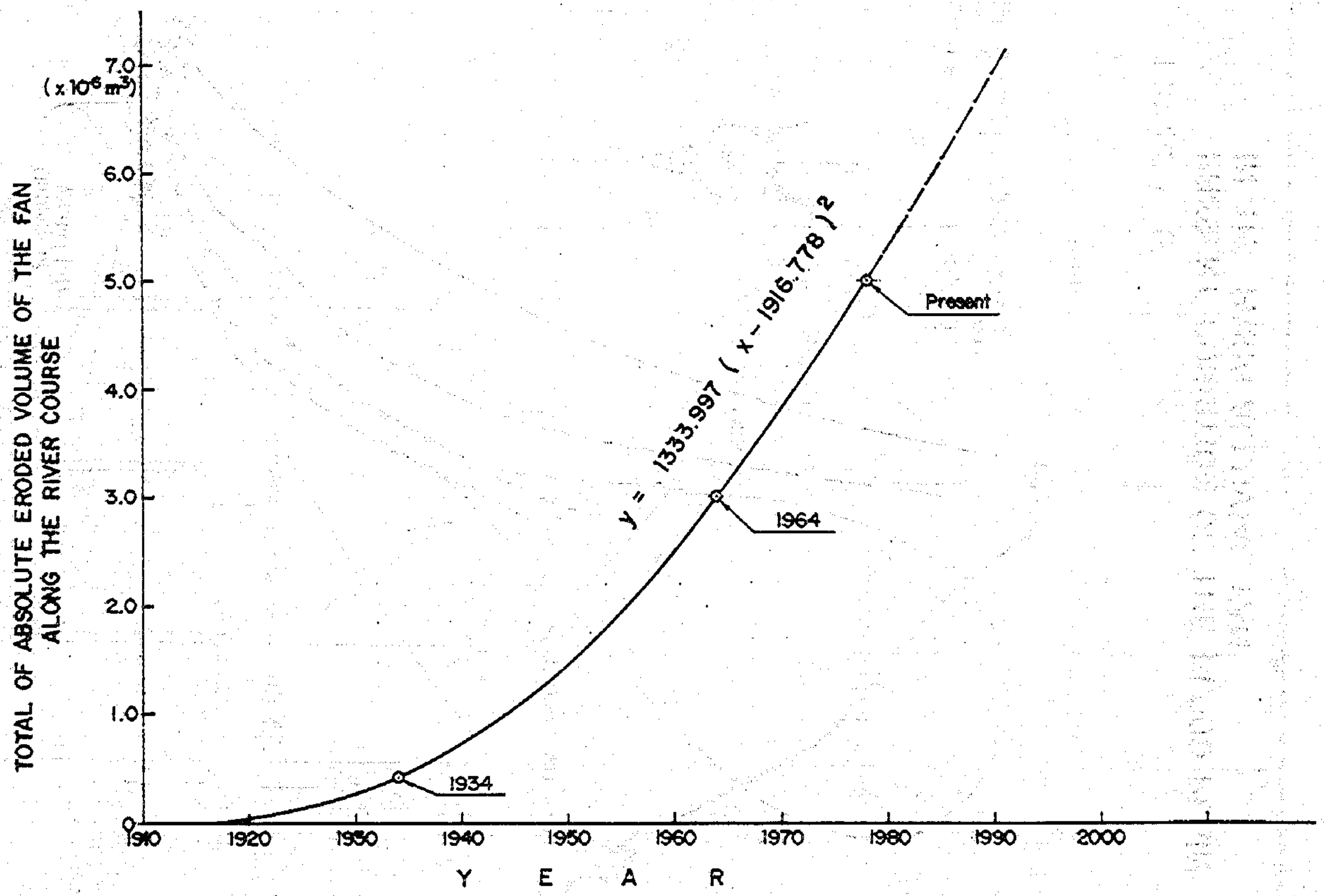


FIGURE II-7
ANNUAL VARIATION OF ABSOLUTE ERODED VOLUME ALONG THE PASIG RIVER

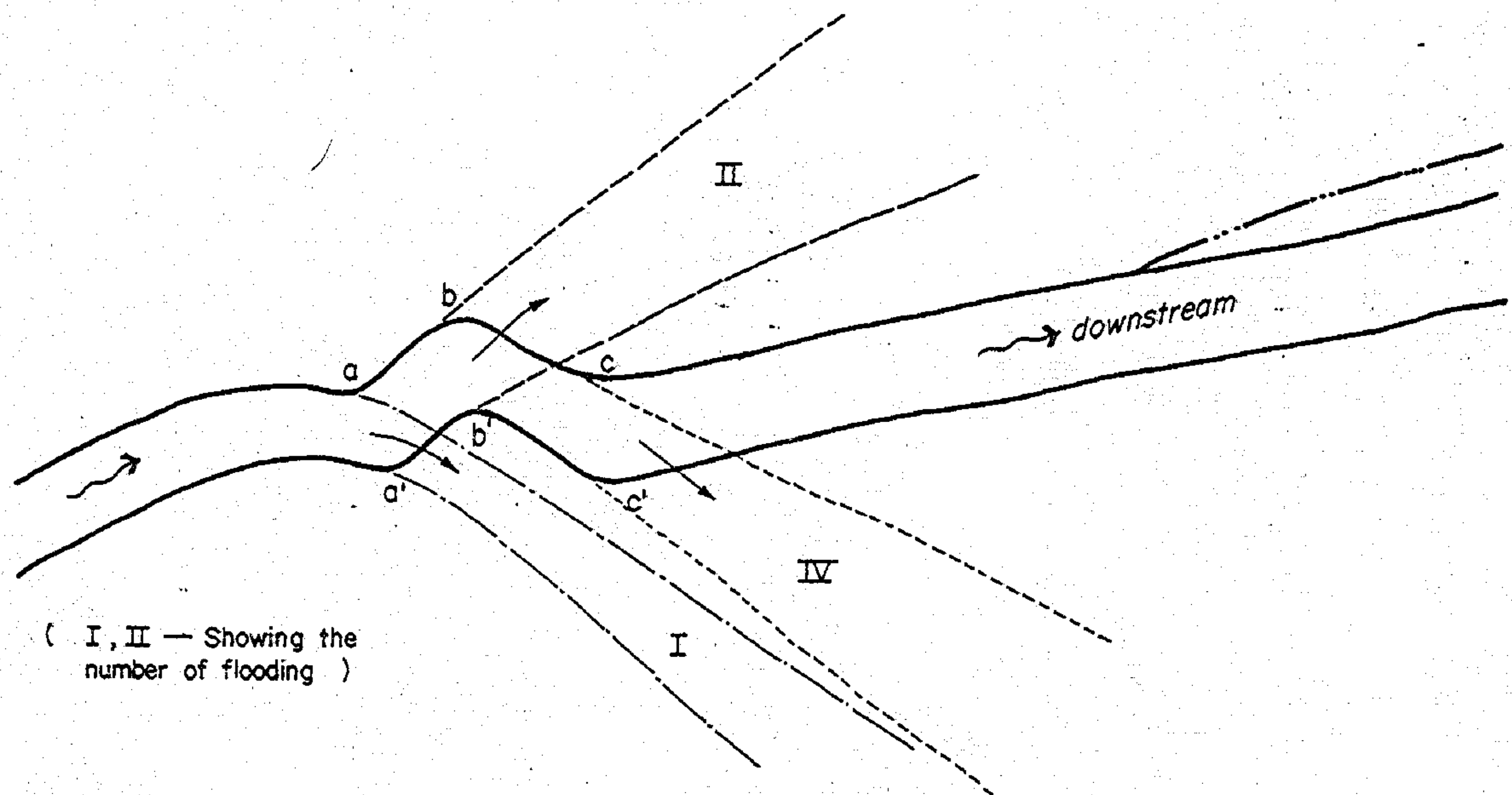


FIGURE I - 8

SCHEMATIC REPRESENTION SHOWING THE RELATION BETWEEN MORPHOLOGICAL CHARACTERISTICS OF MEANDERED RIVER COURSE AND FLOODING ON THE FAN SURFACE IN THE PASIG RIVER.

SABO PLAN

II. SABO PLAN

2.1 General

2.1.1 The Fundamental Idea of the Sabo Project

Inundation of flood accompany a disaster by both water and sediment is caused by abnormal rise of the downstream river-bed due to production of sediment and its run-off within the catchment.

The Sabo project aims to establish a sediment project reating rationally and effectively such harmful sediment which may bring a disaster to the river basin directly or indirectly. The above mentioned harmful sediment includes the following 2 kinds:

(1) The maximum flood run-off sediment

During the maximum flood, a large quantity of sediment is rapidly flowed down and the river-bed is raised and results in overflow of sediment and flood water causing a disaster.

(2) The annual average run-off sediment

During medium and small floods, sediment is flowed down and is accumulated on the downstream river-bed worsening the river condition to a disaster due to rise of the river-bed.

2.1.2 The Sub-control Point

The sub-control point is the point at where sediment quantity is determined to be handled in the Sabo fundamental planning, and is located at the lowest site of the Sabo project area considering the relation between the river improvement plan and the local speciality. (Ref. FIGURE