APPENDIX-V

Inundation and Damage

THE STUDY ON SABO AND FLOOD CONTROL
FOR WESTERN RIVER BASINS OF MOUNT PINATUBO
IN THE REPUBLIC OF THE PHILIPPINES

FINAL REPORT

SUPPORTING REPORT

APPENDIX V INUNDATION AND DAMAGE

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1.1 Recorded Flood/Mudflow Inundation after the Eruption in 1991

1.1.1 Bucao River Basin

(1) Changes after Mount Pinatubo Eruption

After the eruption of Mount Pinatubo in 1991, lahars (mudflow with high concentration of sediment) continued to flow until 1995, burying riparian villages along the Upper Bucao and the Balin Buquero River, namely, Malomboy, Poonbato, Maguisguis, Nacolcol, Burgos, Villar, Moraza and other barangays. No lahars have been reported since 1996 except in July 2002, and diluted muddy water in the water course is observed at present. Figure 1.1.1 shows the lahar deposit area in the Bucao River system.

The lahar event observed in July 2002 was due to the collapse of the Maraunot Notch of the Pinatubo Crater Lake. The lake water level suddenly descended down with 23 m, and the flush flood with about 46 million m^3 flew down to the downstream. Un-consolidated riverbed and banks along the Maraunot River were severely scoured/eroded, which was the source of lahar flow. The lahar occurrence in July 2002 was judged as the abnormal event considering the current basin condition in the upstream area, in which the natural vegetation on the slope gradually recovered as it were before the eruption. The study team then consider no more lahar event such as before 1995 would be expected without any abnormal phenomena such as July 2002.

Lahar in July 2002 (Bucao Bridge)

Lahar in July 2002 (Barangay San Juan)

In order to protect a wide lowland area, a dike of 5.8 km in length was constructed just after the eruption of Mount Pinatubo on the right bank of the downstream reaches (from the Bucao Bridge to 5.8 km upstream). The dike was heightened by 3 m in 1997. This dike prevented any overflows from the Bucao River to the residential areas. The maximum difference between the riverbed level and the ground level along the right bank of the Bucao River is 2.8 m and the average is 1.2 m as measured in May 2002. The clearance of the Bucao Bridge has been decreasing every year due to siltation, and at present is approximately 2 m. However, the change has been very slow over the last 5 years.

After the eruption, the intake facilities from the Bucao River for irrigation were buried by lahar deposits and became un-operational. However, many springs and ponds with abundant volumes of water were naturally formed on the inland side due to seepage from the elevated riverbed of the Bucao River, and this water is now being utilized for irrigation.

(2) Current Inundation Area

No dike has been constructed downstream from the Bucao Bridge, and flood water from the Bucao River overflows every year submerging part of a farmland (15 ha) and a few houses along the right bank between the river-mouth and the Bucao Bridge. The area of habitual inundation is shown in Figure 1.1.2.

1.1.2 Maloma River Basin

(1) Changes after Mount Pinatubo Eruption

The pyroclastic flow deposit area in the Maloma River basin is negligible, however, just after the eruption the riverbed of the Maloma River was filled with sediment deposit consisting of volcanic ash.

At present, the sediment deposit in the river courses and flood plain seems to be stable, because no deposit terraces have been formed, and a considerable part of the surface has already been covered with weeds. However, flood inundation is a very severe problem at Barangay Maloma in San Felipe due to the very low capacity of the river channel caused by the raised riverbed.

Concrete faced revetments were constructed at four short sections along the Maloma River between 1998 and 2000.

(2) Current Inundation Area

Along the Maloma River, flood inundation occurs during the rainy season every year, and the actual caused damage is larger than that of the Bucao or Sto. Tomas Rivers.

In the flood in August 2001, extensive inundation damage occurred in and around Barangay Maloma in the vicinity of the Maloma Bridge. The flood inundation lasted for 4 hours with water depth of 1.0 m. A portion of the national highway on the right abutment of the Maloma Bridge was partially damaged due to flooding, and was then restored and raised by 1 m. The number of affected houses amounted to 360 (1,790 people) with 26 ha of damaged agricultural land. One high school and one elementary school with an enrollment of 709 and 410 respectively were also affected. The total inundation area amounted to 350 ha. The inundation area mentioned above is illustrated in Figure 1.1.3.

In July 2002, another flood caused extensive inundation damage along the Maloma River. In this occasion, severe inundation took place only in the upstream portion of Barangay Maloma and submerged wide rice fields. The residential area of the barangay suffered again, although the inundation depth (0.5 m) was shallower compared with that in 2001 because of the attenuation effect of the peak flood discharge caused by the upstream inundation. 90 houses (460 persons) were affected and 120 ha of agricultural land was damaged. The inundation area from this flood in 2002 is illustrated in Figure 1.1.4.

1.1.3 Sto. Tomas River Basin

(1) Changes after Mount Pinatubo Eruption

After the eruption in 1991, the Marella Valley and the Sto.Tomas River was buried by lahars, forming the Mapanuepe Lake in the largest left tributary. The lahars also ruined riparian villages along the Sto. Tomas River, namely, San Rafael, Santa Fe, Umaya, Maculcol and other barangays. A mining company and nearby villages along the Mapanuepe River were also ruined due to formation of the dammed up Mapanuepe Lake. No lahars have been reported since 1996, and flooding is now the main problem.

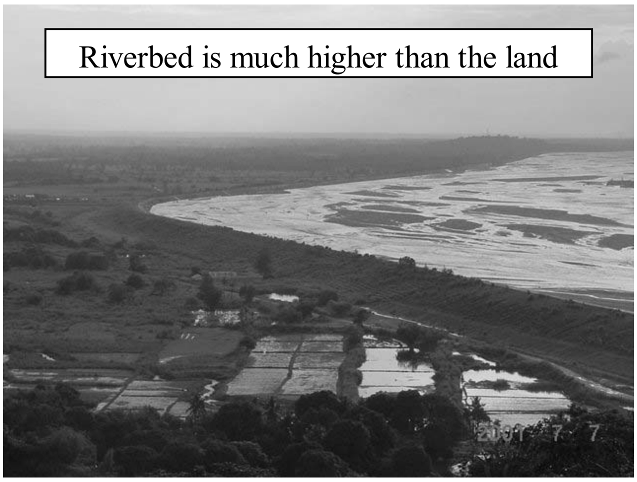
Figure 1.1.5 shows the lahar deposition area in the Sto.Tomas River system.

Before Formation of Mapanuepe Lake

After Formation of Mapanuepe Lake

The construction of dikes along the Sto.Tomas River commenced in 1992. In 1993, the dike on the left bank in the upstream reaches partially breached, causing mudflow inundation on the farmland in and around the San Marcelino municipality. Subsequently, the dike was restored and heightened several times, and the dike reached a maximum height of 13 m. The length of the left bank dike is 18.9 km, and right bank dike is 7.4 km.

In 1992, Dalanawan Channel was excavated through a small hill that is located on the southern side of the original confluence, to facilitate drainage from the Mapanuepe Lake. The lake now serves as a natural retarding reservoir for flood control, and this function is very helpful for reducing the peak flood discharge in the Sto.Tomas River.



The riverbed of the Sto.Tomas River is higher than the ground level by 6.7 m (maximum) or 1.9 m (average) on the left bank side. On the right bank side, the riverbed is higher than the ground level by 2.4 m (maximum) or 0.5 m (average) as at May 2002.

Riverbed excavation works have been performed every year in the short section immediately upstream and downstream of the Maculcol Bridge to secure the required clearance under the bridge girder to enable the flood discharge to pass. The volume of sand excavated in 2000 was recorded as 750,000 m^3. The excavated channel is, however, usually buried immediately after the first flood in rainy season under the current balance of the sediment transportation of the whole river stretch.

The municipality of San Marcelino, which is located at the left bank of the Sto. Tomas River, had wide rice fields and profited from a triple crop before the eruption. At present, a single crop during rainy season is all that is available due to the lack of irrigation water resources. The population of the municipality drastically decreased from 40,000 to 22,000 after the eruption.

(2) Current Inundation Area

Since 1993, dike breaches have occurred in 2000 and 2002. In 2000, the dike breached over 400 m in length at the left bank, 6 km upstream from the river-mouth, causing flood inundation in and around San Narciso and finally reaching the seashore at Barangay Lapaz. The inundation lasted for one week with shallow water depth of 0.2 m. The breached section of the dike was restored the following year using mountain soil and gabions.

After two typhoons in July of 2002, another dike breaching took place on the left bank near the river mouth. A total of 25 houses and 2.5 ha of agricultural land in and around Barangay Alusiis in San Narciso was submerged and buried with sand.

The areas inundated in 2000 and 2002 are shown in Figure 1.1.6

1.2 Permanent Inundation Area due to Lahar Deposition

Channel conditions in the three rivers changed dramatically after the eruption of Mount Pinatubo due to the remarkable volume of lahar deposition along the river channels, particularly in the Bucao and Sto.Tomas Rivers.

The volume of lahar deposition within the Bucao and the Sto.Tomas River areas is estimated at 843 and 818 million m^3 respectively, as shown in Figure 1.2.1. The deposition depth is only a few meters in the lower stretches, however, the thickness increases to approximately 30 m in the upstream reaches. The huge volume of lahar deposition in the channel has significantly affected the surface run-off conditions. A considerable volume of the surface flow infiltrates into the lahar deposition area and the surface run-off ratio is dramatically decreased particularly during flooding periods.

The area converted from riverside farm land or residential area into un-used areas due to the spread of the lahar flow along the river is estimated at 9,461 ha, of which 5,534 ha is along the Bucao and 3,797 ha is along the Sto. Tomas River stretches. Figure 1.2.2 shows the area permanently covered by lahar deposition. The areas are currently confined by dike embankments or surrounded by mountains, and is defined as permanent inundation area by lahar and dammed up lakes.

1.3 Two Dimensional Flood/Mudflow Analysis

1.3.1 Approaches

In order to predict the possible flood inundation area and to assess the hydraulic performance of the existing and proposed structures in the area (as surrounded by dike systems), an extreme sediment transport during a single lahar event was estimated using a two-dimensional flow and sediment transport model. It is very important to predict the flood depth and the depth of deposited materials, because the extreme re-mobilization or deposition of sediment may increase the possibility of inundation outside the dike system or breaching of the dike.

The simulation was done using the hydrographs obtained in Appendix III (Meteorology and Hydrology). For the numerical simulation, the two-dimensional mudflow model developed by Public Works Research Institute and Sabo and Landslide Technical Center of Japan and improved by Nippon Koei Co., Ltd., was used.

1.3.2 Methodology

(1) Two-dimensional flow and Sediment Transport model

In the two-dimensional mudflow model, water depth for the average flow was calculated by applying a two-dimensional shallow water flow equation, while the bed fluctuation was calculated using the continuity equation for bed load transport.

The entire study area is divided into meshes with a size of proper length. The finite difference forms of the above flow and sediment transport equations were derived from the staggered mesh system and are solved explicitly using the Leap-Frog scheme. The calculation procedure is shown in Figure 1.3.1.

(2) Topographic data

Topographic data was produced from a DTM (Digital Topographic Map of 1:10,000 scale) in 2002 using a GIS (Geographical Information System). The model domain was divided into a 40 m square grid of data segments. Where the river channel or a dike was located in the grid segment, the elevation of this feature was selected as the representative value for the grid segment. In another grid segment, the elevation at the center point of the block was selected.

(3) Sediment Hydraulic Parameters

The sediment hydraulic parameters for the simulation are summarized as follows:

Density of water, $\rho = 1.0$ g/cm^3 (in lahar event ~1.6 g/cm^3)
Specific gravity of sediment, $\sigma_s=2.6$ g/cm^3
Grain sizes of sediment: $d_{60} = 0.5$ mm (for the Bucao River)
$d_{60} = 0.3$ mm (for the Sto. Tomas River)
Manning's roughness coefficient, n = 0.03 (average value for natural rivers)
Max erosion depth, max=10.0 m

The specific gravity (σ_s) and the grain size distribution curve were obtained from the laboratory test results of the sediment sampling for the Bucao and Sto. Tomas Rivers, performed in 2002. The mean grain size of the sediment (d_{60}) was used. The density of water (ρ) was estimated at 1.0 g/cm^3 for usual flood flow and at more than 1.0 g/cm^3 (up to 1.6 g/cm^3) for the hyper-concentrated flow (40% is the popular concentration as Mount Pinatubo lahar): 2.6 g/cm^3 (specific gravity of sediment) x 0.4 +1.0 g/cm^3 (density of pure water) x 0.6 = 1.6 g/cm^3.

(4) Formulation of Flood Inundation Scenario

Setting the flood inundation scenario is the most important aspect for the project evaluation by which the results of feasibility study are much affected. For plan formulation of flood/mudflow control, it is important that probable maximum damages should be always considered under the theoretical assumptions for flood and mudflow inundation analysis.

Principal factors to be determined for flood and mudflow inundation analysis are as follows:

a) Setting inundation block,
b) Estimation of safety discharge (damage-less discharge),
c) Setting dike breach points,

The detailed procedures as for the above principal factors are described below:

a) Setting Inundation Block

Inundation block should be identified considering the topographic conditions, inundation characteristics and patterns based on the present conditions of the river channel and flood control structures.

For the Bucao River, the inundation area is located only at the right side of downstream stretch. The mountain range is located along the left side and the both sides upstream from the Bucao-Baquilan Rivers confluence, and no remarkable inundation area exist. Considering the characteristics, one inundation block on the right side downstream portion is identified as for the Bucao River.

For the Maloma River, the river flows down from the eastern mountain toward westward to South China Sea, and inundation area is located only along the downstream stretch near the National Highway No.7. There would be two inundation blocks in the downstream stretch for the Maloma River, but only one inundation block was set on the right bank side because the inundation block on the left side is too small to evaluate and the mountain range is located on the left side just along the river stretch.

For the Sto.Tomas River, the large flood plain is developed on the left bank side along the middle and the lower stretches. The inundation characteristics on the left side are different between the middle and the lower stretch, because, the Vega hill located at 12 km upstream from the river month on the left side separates the flood inundation area into two parts.

The right bank side in the downstream stretch is also identified as the inundation block. Accordingly, three inundation blocks are identified for the Sto.Tomas River to conduct flood/mudflow inundation analysis.

b) Estimation of Safety Discharge

To determine the criteria on dike breach for flood/mudflow inundation analysis, it is necessary to estimate the safety discharge, which is defined as the maximum capacity of the river by which no any damages are expected to flood prone area. The safety discharge is generally assumed as follows:

The safety discharge is identified as the lower value of Q1 or Q2.

Q1: The discharge which can pass within the flow area of the existing river channel and dike with deduction of freeboard and other defects factors of the existing river facilities: (Defined as Q1)

Q2: The discharge of which water level is lower than the existing elevation of land side area protected by the dike: (Defined as Q2).

For the Bucao River, almost all the existing dike on the left bank side were severely damaged on the revetment works. The clearance between the dike crest and the existing riverbed is less than the freeboard of 1.2 m further riverbed aggradation is taken into account. Accordingly, the safety discharge Q1 can be defined as zero. For the estimation of safety discharge Q2, it is also defined as zero as the existing riverbed elevation is higher than the elevation of the flood prone area protected by the existing dike. Definition of safety discharge and change in safety discharge in the river basins of western Pinatubo area are illustrated in Figure 1.3.2.

For the Maloma River, flooding is observed every year as the existing river capacity is too small. The bank-full discharge is estimated at 60 m^3/s on the left side of the confluence with the Gorongoro River where the existing dike on the left bank side was disconnected because the dike was partially washed out and no repair works are still conducted. Accordingly, the safety discharge for the Maloma River can be defined as 60 m^3/s.

For the Sto.Tomas River, safety discharge Q1 can be defined as zero for the downstream stretch from the Vega Hill. Because the existing clearance between the dike crest and the riverbed is insufficient if the future riverbed aggradation is taken into account. In addition, the dike frequently breached on the both side even non-peak time of flooding such as in the year 2002 and 2000. For the safety discharge Q2, it can be also defined as zero for the whole stretch as the riverbed elevation is much higher than the land elevation protected by the existing dike.

c) Setting Dike Breach Points

Since the safety discharge for all the three river basins are defined as zero, a single 2-day hydrograph, 2-year to 100-year probable floods are applied for the flood inundation analysis under the assumptions that the flood/mudflow inundation would occur on the all the inundation blocks caused by the breach of dike. The breaching points of the dike were determined based on the maximum damages on the respective inundation blocks. Based on the topographic conditions of the river stretch and flood prone area, the upstream end portion of the respective inundation block was defined as the breaching points of the dike. In addition, the disconnected portion of the existing dike along the left side of the Maloma River is also considered as the breaching point of the dike for flood inundation analysis.

The inundation blocks and the breaching points of the dike is shown in Figure 1.3.3 for the Bucao and the Maloma Rivers and in Figure 1.3.4 for the Sto.Tomas River.

1.4 Flood / Mudflow Hazard Area

1.4.1 Bucao River Basin

(1) River Conditions

The Bucao River basin (655 km^2) extends in a northwesterly direction from Mount Pinatubo and southwesterly from the Zambales Mountains to the South China Sea. The basin incorporates the Bucao River and its two major tributaries, the Balin-Baquero and Balintawak Rivers.

The headwater of the Bucao River originates approximately 3 km north of the crater at an elevation of 800 m. The river flows in a generally westerly direction through rugged terrain for 30 km to its confluence with the Balintawak River at an elevation of 50 m. The Bucao River then enters a broad flat valley and continues to flow in a western direction for approximately 4 km to its confluence with the Balin-Baquero River. In 1991, the upper reaches of the Bucao River basin were covered with thick pyroclastic flow deposits with a volume of 3.1 billion m^3.

(2) Existing Structure

The construction of a protection dike was executed by DPWH in accordance with the alignment proposed in the study (USACE, 1993). The protection dike was constructed along the right bank in the lower stretch of the Bucao River. The dike is 4 m high and 6 km long.

(3) Breach of the Mudflow Protection Dike

A mudflow simulation was carried out to test the effects of the upstream portion of the dike (5 km upstream from the Bucao Bridge) collapsing during a large-scale mudflow of various return periods. The length of the breach (L_b) was estimated by the empirical equation:

$$L_b = 1.6 \times (\mathrm{Log}_{10} W_r)^{3.8} + 62$$

where, L_b : length of breach (m), and

W_r : width of river (m)

The discharge through the breached portion was calculated by Honma's equation:

$$Qw = 0.35\, L_b\, h_l \sqrt{2gh_l}$$

where, h_l : water depth at breached point (m)

(4) Results of Simulation

Figure 1.4.1 shows the results of the mudflow hazard area. The simulated hazard area for each return period is enumerated below:

Probable Mudflow Hazard Area in the Bucao River Basin

Return Period (years)	2	5	10	20	30	50	100
Peak discharge (m^3/sec)	1,600	2,500	3,100	3,800	4,300	4,900	5,800
Hazard area (km^2)	7.67	8.69	9.56	11.12	11.85	12.92	14.43

During the 100-year probable flood, the peak discharge through the breached portion is 720 m^3/sec and the town of Botolan is wholly inundated with the highest inundation depth of 3.5 m.

1.4.2 Maloma River Basin

(1) River Conditions

The Maloma River basin (152 km^2) originates to the southwest of Mount Pinatubo and extends westerly to the South China Sea. The river basin includes two major rivers, the Maloma and the Gorongoro Rivers, which join each other approximately 6 km upstream of the Maloma Bridge on the Highway Route No.7.

The Maloma River basin is essentially a relatively narrow valley through mountainous. Most of the sediment in the basin came from ash deposition immediately after the eruption. There has been no lahar occurrence since 1992.

(2) Existing Structure

The mudflow protection dike was constructed along the right bank of the lower stretch of the Maloma River. The dike is 4 m high and 1.6 km long.

(3) Simulation

A two-dimensional mudflow analysis was carried out based on the existing topographical conditions. The Maloma River channel has low flow capacity; namely, less than a 2-year return period event. The floods spill out approximately 3.5 km upstream of the Maloma Bridge will spilled water spreading mainly over the right bank, overflowing the National Road No.7 and finally pouring into the sea. The disaster map during the previous flood on 8 July 2002 is shown in Figure 1.1.4.

The flow conditions were simulated based on the observations made during the previous flood. Figure 1.4.2 shows the results of the mudflow hazard area. The simulated hazard area for each return period is enumerated below:

Probable Mudflow Hazard Area of The Maloma River Basin

Return Period (years)	2	5	10	20	30	50	100
Peak discharge (m^3/sec)	310	490	640	810	920	1,100	1,300
Hazard area (km^2)	4.80	5.14	5.29	5.45	5.55	5.71	5.86

1.4.3 Sto. Tomas River Basin

(1) River Conditions

The Sto. Tomas River basin (262 km^2) extends in a southwesterly direction from Mount Pinatubo to the South China Sea. Two tributaries, the Mapanuepe and Marella Rivers, converge to form the main channel of the Sto. Tomas River.

The headwater of the Marella River originates near the crater of Mount Pinatubo at an elevation of approximately 1,500 m. The Marella River drains the southwest slopes of Mount Pinatubo, which were covered with thick pyroclastic flow deposits of 1.3 billion m^3.

The Marella River combined with the Mapanuepe River at an elevation of approximately 120 m in 2002. The sub-basin of the Mapanuepe River includes a large mine site, a mine tailings dam, and the Lake Mapanuepe, which was dammed up with the lahar deposition from the Marella River.

(2) Existing Structure

A mudflow protection dike of 7.4 km in length was constructed along the right bank in the lower stretch of the Sto. Tomas River, while a protection dike of 18.9 km was constructed along the left bank.

(3) Simulation

A two-dimensional mudflow analysis was carried out based on the condition that there is a possibility of breach along the entire stretch of the dike. Since the present riverbed elevation is higher than the inland elevation, the discharge through a breached dike is assumed to be equivalent to the probable peak flood discharge.

Figure 1.4.3 shows the results of the mudflow hazard area. The simulated hazard area for each return period is enumerated below:

Probable Mudflow Hazard Area of The Sto. Tomas River Basin

Return Period (years)	2	5	10	20	30	50	100
Peak discharge (m^3/sec)	440	710	940	1,200	1,400	1,600	2,000
Hazard area (km^2)	39.85	48.49	53.95	58.94	62.20	65.89	71.04

Note : Flood retarding effect of the Lake Mapanuepe is considered for the estimation of the peak discharge.

CHAPTER 2 FLOOD/MUDFLOW DAMAGES

2.1 Recorded Damages in Zambales after the Eruption

The damages due to ash fall, pyroclastic flow and lahar flow in Zambales was tremendous. According to the PDCC in Zambales, the 19 barangays were completely buried due to the pyroclastic flow and the lahar flow after the eruption. The affected families in Zambales are estimated at about 66% of the total in Zambales. One-third of the houses in Zambales were totally damaged, and another one-third of houses were partially damaged due to the event of disasters caused by the eruption of Mount Pinatubo in 1991.

It is reported that 215 persons were dead and 157 persons were injured in Zambales in the course of Mount Pinatubo disasters as of 2000.

During the height of Mount Pinatubo calamity period, there were 70 evacuation centers in Zambales. Total evacuees were estimated at 260,000, which is about 60% of the provincial population of Zambales. Among them, 55,000 were evacuated inside of evacuation centers, and the rest were evacuated other places. The additional expenses due to the evacuation are estimated at P.7.00/day/person.

The damages to the infrastructures were also quite serious. The estimated damage amount of the infrastructures is at 206 million pesos in 1991. The 75% of the irrigation facilities were un-functionable, and the production in the irrigation area was reduced by 64%. The farm land was reduced by 57%, which was buried by the deposition of pyroclastic materials.

The rehabilitation / reconstruction of the area was immediately planned by Mount Pinatubo Commission in the area of Zambales with the following budget schedule:

Proposed Budged for Rehabilitation Program in Zambales

No.	Item	Amount (Million Pesos)
1	Infrastructures	
	a) Roads	268.7
	b) Bridges	31.5
	c) School Buildings	512.2
	d) Health Facilities	28.5
	e) Public Buildings	69.8
	f) Irrigation	110.0
	g) Water Supply	36.1
	h) Flood Control	423.0
	i) Others	91.6
	Sub-Total	1,573.4
2	Livelihood	
	a) Livestock/Poultry	3.7
	b) Crop Production	5.9
	c) Agro-Forestry	13.2
	d) Others	5.3
	Sub-Total	28.0
3	TOTAL	1,601.4

The above budget is however not timely released and the major rehabilitation activities are still not commenced yet due to mainly financial constraints.

2.2 Methodology on Flood/Mudflow Damage Estimation

2.2.1 Damage Estimation Procedures

This section describes the procedure and method of estimation of Flood/Mudflow damages.

The purpose of damage estimation is to evaluate probable damage amount in monetary term under the with- and without-Flood/Mudflow control works under the present condition vis-a-vis the future. Accordingly, the difference of flood inundation condition between with and without flood/mudflow control works should be estimated by means of simulation model analysis. The mitigation effects on damages can be considered as the benefit of the works, which would be compared with the economic cost of the works for assessment of the feasibility.

Flood/Mudflow damages will be calculated with the Geographic Information System (GIS) by: basin and administrative unit under present and future conditions. The GIS database is composed of several input files including social capital data, digitized topographical map, land use, population, results of simulation which will be calculated by numerical mudflow simulation model, unit value of each item, and damage rates required. A flow chart of flood control damages / benefit and economic evaluation is described in Figure 2.2.1.

2.2.2 Characteristics of Damages in the Study Area

As mentioned in Chapter 1, a remarkable volume of lahar was deposited within the river area, and the current riverbed elevation is higher than the adjacent land at the lower stretches. It means that the river water level is always higher than the land level even no flooding period and there is a certain risk that the flood/mudflow may attack to the adjacent community if the existing dike is broken by seepage or scouring actions.

Once dike is broken, it is expected that the mudflow will be spread to the flood prone area widely due to the topographic characteristics. As the flood prone area is much lower than the riverbed elevation, the lahar material deposited in the river area will be transported together with the flood flow and spread and deposit on the whole flood prone area.

Figure 2.2.2 shows photographs of the flooding area due to the breach of the left dike at the downstream portion of the Sto. Tomas River, which occurred on 23 July 2002, in which no big flood is observed. After the flood had receded from the prone area, lahar with more than 1 m in thickness remained over the entire flooded area. All the houses required re-constructed and the damaged farm lands and fishponds can no longer be used without excavation. The remarkable amount of lahar deposition is generally left on the flood prone area, which is one of the major characteristics of damages in the study area.

Considering to the above, the damage estimation for the area should be based on the actual damage condition. The damage curves established in the JICA East Pinatubo River Basin Study undertaken in 1996 for flood, sediment and lahar are shown in Figure 2.2.3. Of the three damages curves, the damage rates for lahar should be applied for the damage estimation the Bucao and the Sto. Thomas Rivers. These rivers contain a remarkable volume of lahar deposit within the river area, and the riverbed elevation is rather higher than the mudflow prone area. On the other hand, the damage estimation of the Maloma River can be applied for flood, as most of the lahar material within the river channel has been transported to the sea and no remarkable riverbed aggradation is observed.

2.2.3 Classification of Damage by Flood /Mudflow

Generally, damages due to flooding and sediment are classified into three types, direct damage, indirect damage, and intangible damage.

Direct damage consists of losses of social capital such as existing public and private buildings, agricultural products, and infrastructure assets. Indirect damage is expenses of emergency activities and loss due to suspension of business activity. On the other hand, intangible damage is loss of life, psychological stress of people concerned and so forth, which is not quantifiable. Thus, this study analyzes direct damage and indirect damage. The constitution of damage losses is illustrated in Table 2.2.1.

2.3 Direct Damage by Flood/Mudflow

In estimating the value of damageable properties in the probable inundation area, a barangay database was established in the GIS (Geographic Information System). All the data needed for estimating damage including the area, farmland by crop type (for the master plan only paddy was evaluated), population, number of households, number of building, infrastructure such as roads and bridges, and irrigation canals of each barangay were input into this database.

The probable inundation areas were specified for the three river basins from a hydrological simulation study for return periods of 2, 5, 10, 20, 50 and 100 years.

Damage curves were generated based on the results of flood inundation analysis and the GIS database for major property items such as buildings, including residential and non-residential, roads and paddy fields. The damage curves are shown in Figure 2.3.1 for the Bucao River basin, Figure 2.3.2 for the Maloma River basin and Figure 2.3.3 for the Sto. Tomas River basin, respectively.

2.4 Indirect Damage by Flood/Mudflow

Indirect damages are estimated considering to the aerial and damage characteristics of the flood prone area. In this study the following indirect damages are considered.

(1) Extra Cost due to Traffic Disruption

There are three bridges across over the Bucao, the Maloma and the Sto.Tomas Rivers. All the bridges would have insufficient of the clearance for flood flow if the further riverbed aggradation is taken into account. All the bridges will be definitely required to be heightened when the dike raising / strengthening works are conducted.

In the view of the flood control aspects, the bridges which would have insufficient clearance to flow down the design flood are required to be heighten. The benefit for heightening the bridge is estimated as extra cost for detour if the bridges are fallen down due to insufficient flow capacity at the bridge portion.

The detouring cost is estimated based on the existing flow capacity, detour distance, and the period of re-construction of the bridges.

Based on the present riverbed condition, the flow capacities at the three bridges are defined as follows in the planning viewpoints for flood control:

1) Bucao Bridge in the Bucao River: 50- to 100-year flood,
2) Maloma Bridge in the Maloma River: 5- to 10-year flood,
3) Maculcol Bridge in the Sto.Tomas River: 10- to 20-year flood.

Detouring cost is therefore taken into account only for the flood exceeding the probable floods mentioned above.

For estimation of detour distance, the additional distance of the alternative route is considered. In the case of the three bridges along national highway No.7, there is no alternative route nearby, and only the route along the eastern side of Mount Pinatubo is available if the bridges are fallen down. The alternative route from Olongapo to Lingayen through Pampanga, Bataan and Tarlac is therefore considered as detour route as shown in Figure 2.4.1. The detour distance is therefore defined as 279 km.

For estimation of detouring period, the construction period for temporary bridges is taken into account. The period for the re-construction including the procurement of construction material for four months is estimated as follows:

1) Bucao Bridge at the Bucao River: 10.5 months
2) Maloma Bridge at the Maloma River: 6 months
3) Maculcol Bridge at the Sto.Tomas River: 9 months

Based on the above, extra cost due to detouring is estimated. The detailed estimation is described in Appendix-XII in this report.

(2) Loss of Economic Activities

The loss of production through interruption of economic activities caused by flood and mudflow can be considered as indirect damages. Whole economic activities would be stopped due to absence of workers in the inundation area. Only non-agriculture sectors are considered as the indirect damage as the agriculture sector was considered in the direct damages.

The detailed estimation is described in Appendix-XII in this report.

(3) Evacuation Cost

The frequency of evacuation actions in the inundation area can be decreased by implementation of the flood / mudflow control works. The saving cost for evacuation can be therefore considered as the indirect benefit due to provision of the flood/mudflow control structural measures.

The detailed estimation is described in Appendix-XII in this report.

(4) Emergency Clean-up Cost

The cost for emergency clean-up the buildings in the inundation area can also be considered as the indirect damage. The period required to clean-up is estimated based on “Manual for Economic Study on Flood Control, 1999, Ministry of Land, Infrastructure and Transport, Japan”. Unit cleaning cost is estimated at 230 Pesos/day based on the JICA Easter Pinatubo Study in 1995.

The detailed estimation is described in Appendix-XII in this report.

Tables

Table 2.2.1 Classification of Flood/Mudflow Damages and Benefit

Classification					Benefit	Considered in this
Damage Mitigation / Protection Benefit	Direct damages	Effects on damage mitigation to Assets in the Flood Prone Area	General Assets	Residential buildings	Damage mitigation to the residential buildings by reducing the inundation period and depth	Applied
				Household properties	Damage mitigation to the house properties, assets, private vehicles by reducing the opportunities of flood inundation.	Applied
				Public/Commercial buildings	Damage mitigation to the public / commercial buildings by reducing the inundation period and depth.	Applied
				Public/Businness properties	Damage mitigation to the commercial stocks and other assets for business promotion by reducing the flood inundation opportunities.	Applied
			Agriculture Products		Damage mitigation to the agriculture products by reducing inundation period and depth.	Applied
			Public Infrastructures	Road, Bridge, urban infra, electricity, gas, communication, railway, irrigation facilities, and so on	Damage mitigation to the public infrastructures due by reducing inundation period and depth as well as frequencies.	Applied
		Effects on human life security			To minimize/eliminate loss of human life	Not applied
	Indirect damages	Loss of Opportunities	Loss of Economic Activities	Family Income	Damages due to loss of opportunities for house maintenance activities, lesure, shopping and other activities. Decrease of income due to absent from the works.	Not applied
				Business Activities	Damages due to loss of working days. Decrease of products due to close of the factory, shops and so on.	Applied
				Public Services	Damages due to loss of opportunities for public services	Not applied
		Extra activities due to flood damages	Emergency Activities for Disaster Management	Family Income	Additional expenses to secure drinking water, emergency food, goods and so on.	Applied
				Business Activities	Same as family activities.	Applied
				Public Services	Additional expenses to provide emergency service and calamity fund.	Not applied
			Damages due to traffic disturbance	Road, Railway, Airport, Port	Extra cost due to detouring activities	Applied
			Damages due to disconnection of	Electricity, Gas, Water supply,	Extra cost to secure alternate source of lifeline, or loss of opportunities to access the lifeline	Not applied
			The ripple effects on loss of economic activities		Damages on public / private social /economic activities in adjacent of flood prone area, due to disturbance the commodity flow.	Not applied
		Incidental damages to the general assets damages			Mental damages to damages general assets	Not applied
		Incidental damages to loss of economic activities			Mental damages due to loss of economic activities	Not applied
		Incidental damages to loss of human life			Mental damages due to loss of human life	Not applied
		Incidental damages to cleaning activities			Mental damages due to emergency actions, evacuation, and cleaning activities.	Not applied
Development Benefit					Upgrading the land value, stimulating economic actuvities, increase population due to upgrading security against flood / mudflow	Not applied

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Figures

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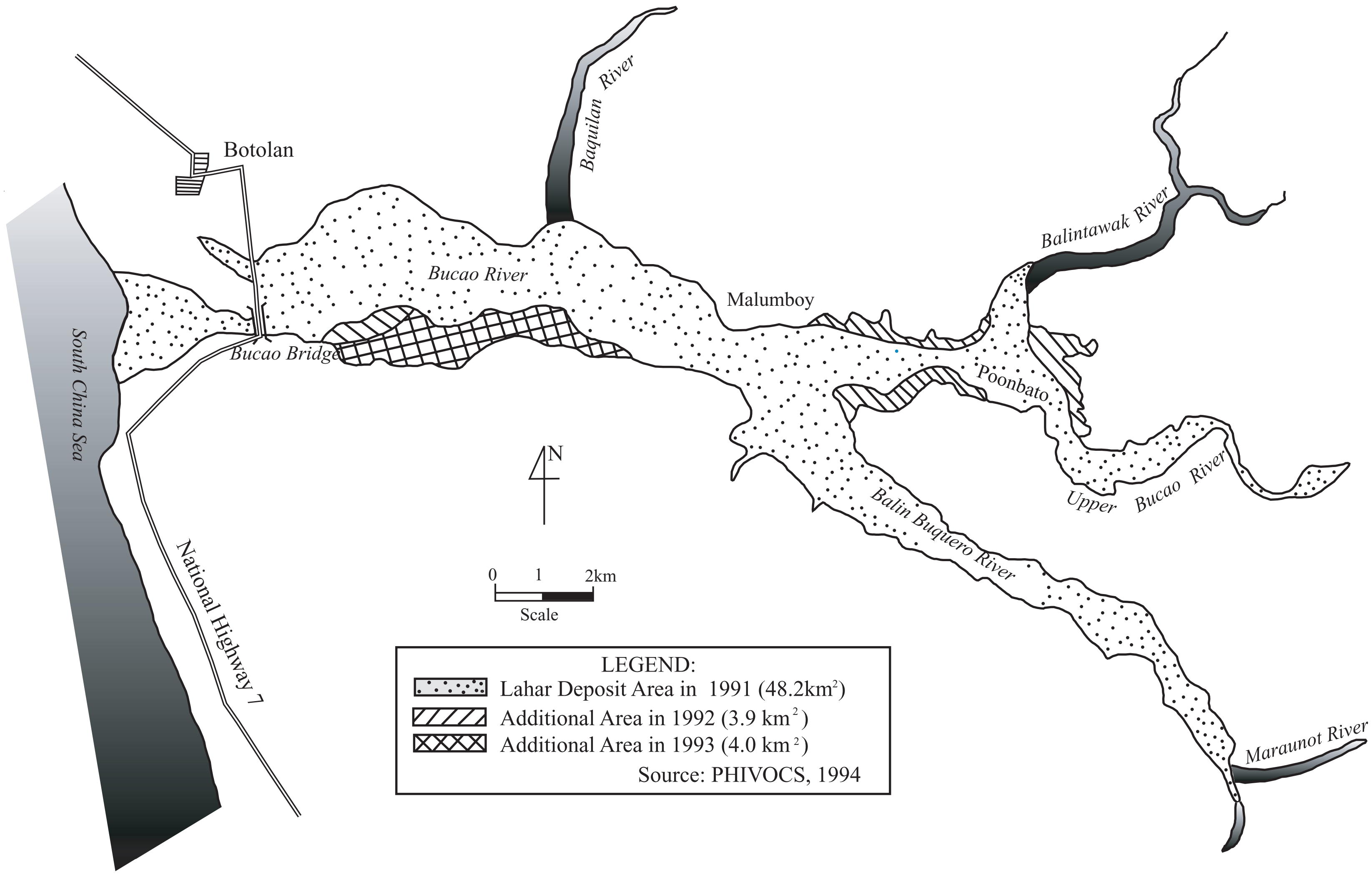

Source: PHIVOCS, 1994

Figure 1.1.1
Lahar Deposit Area in the Bucao River System

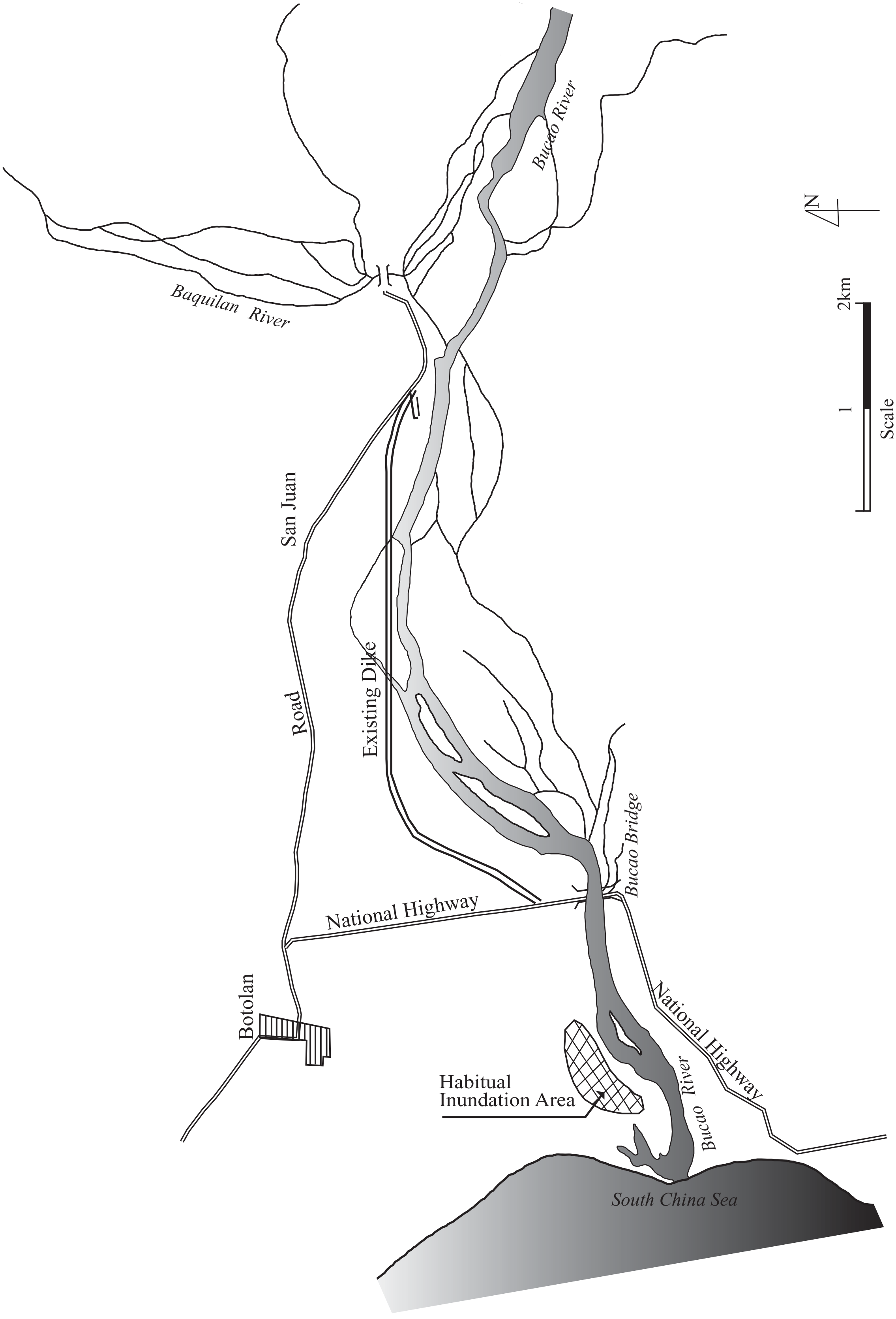

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Figure 1.1.2

Habitual Inundation Area along the Bucao River

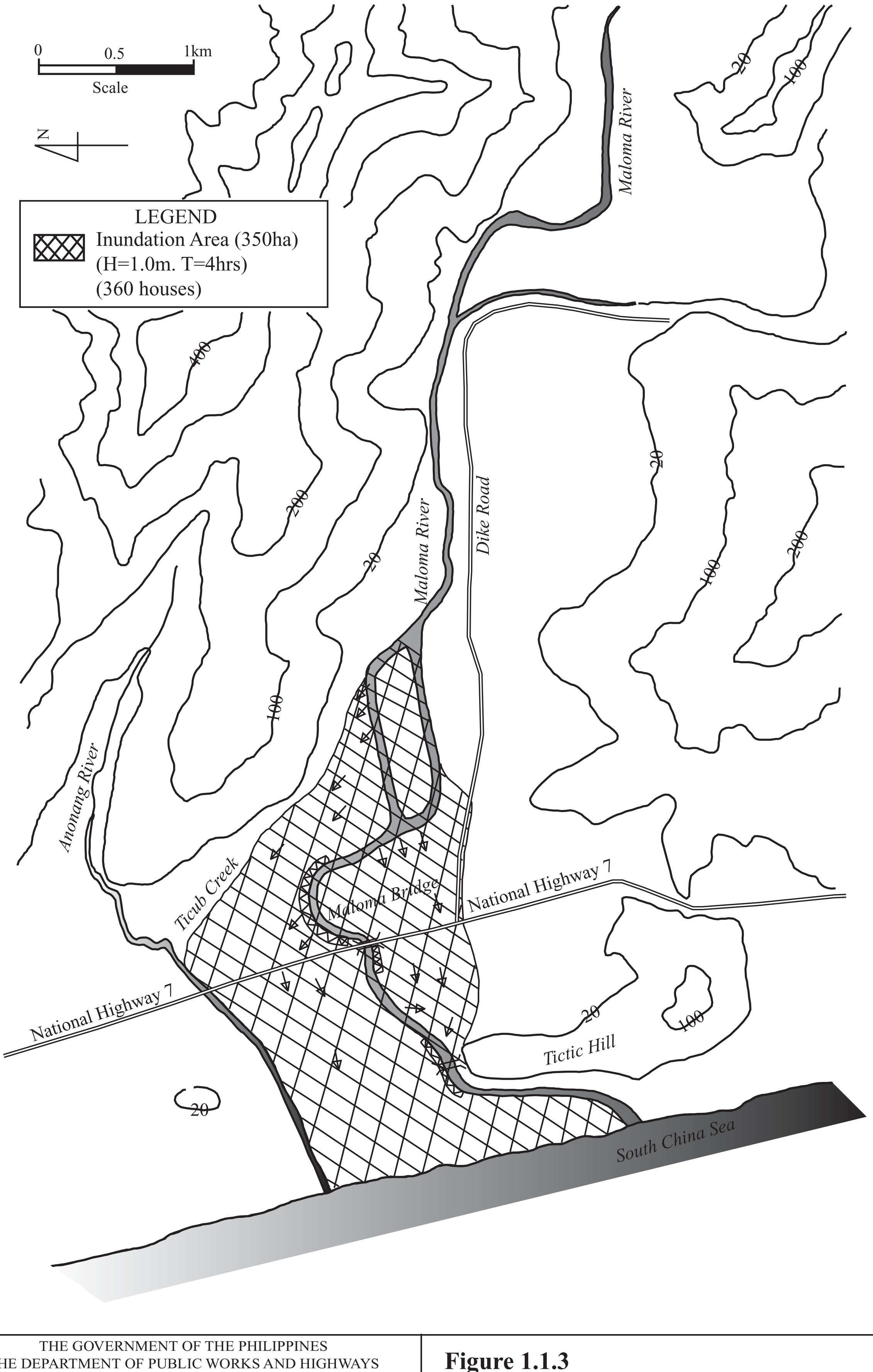

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Figure 1.1.3

Inundation Area along the Maloma River in August 2001

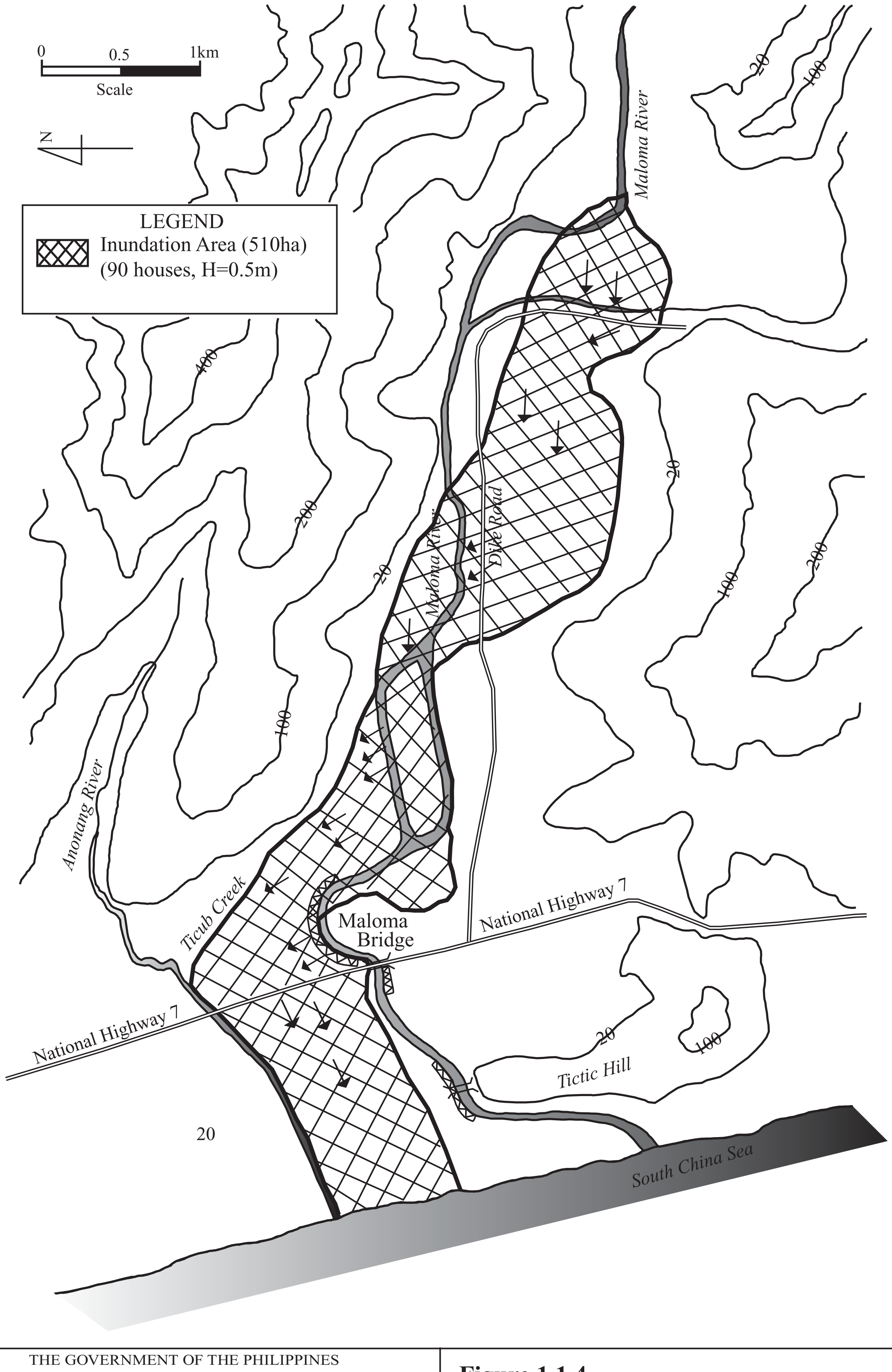

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Figure 1.1.4

Inundation Area along the Maloma River in July 2002

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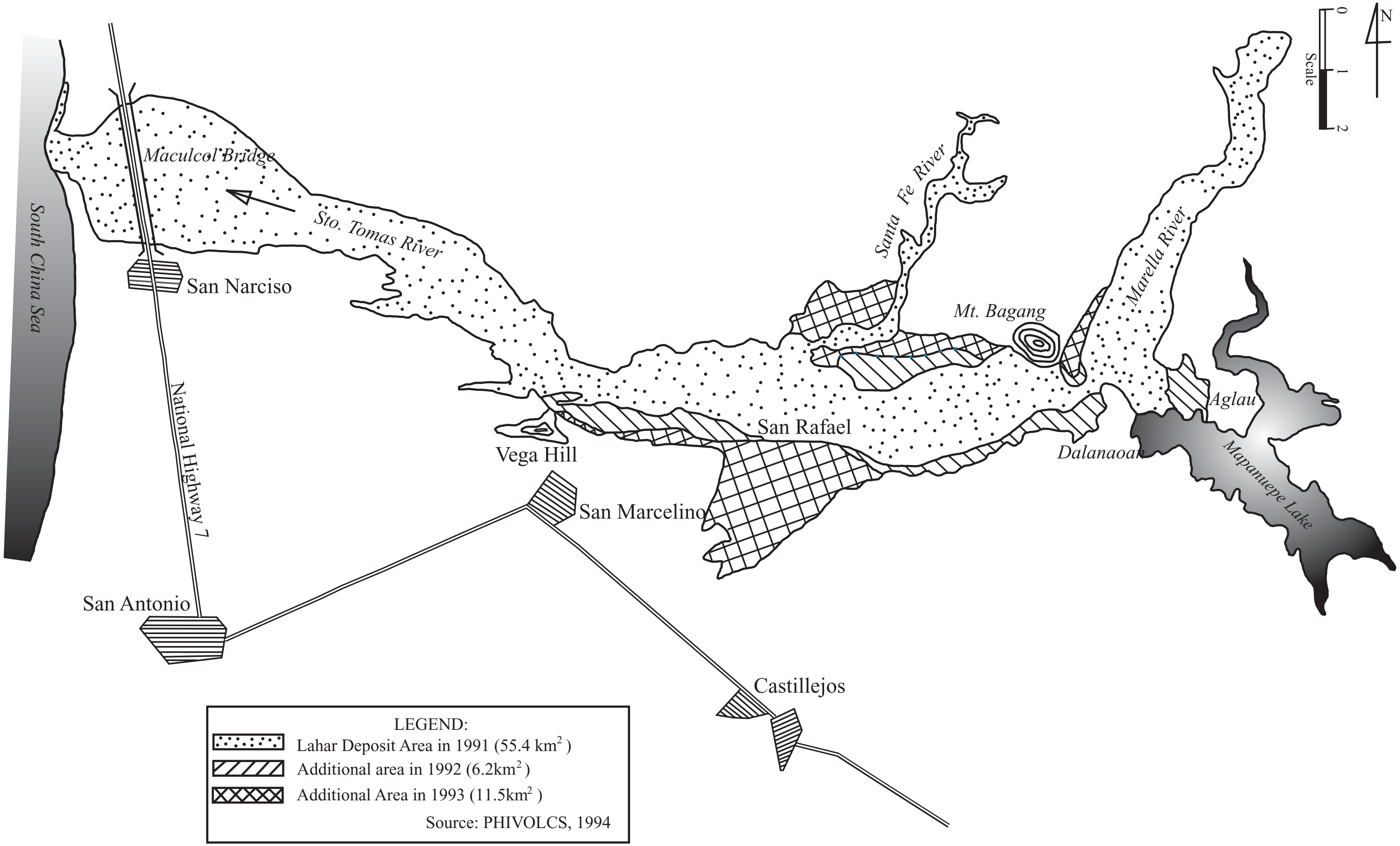

Source: PHIVOLCS, 1994

Figure 1.1.5
Lahar Deposit Area in the Sto. Tomas River System

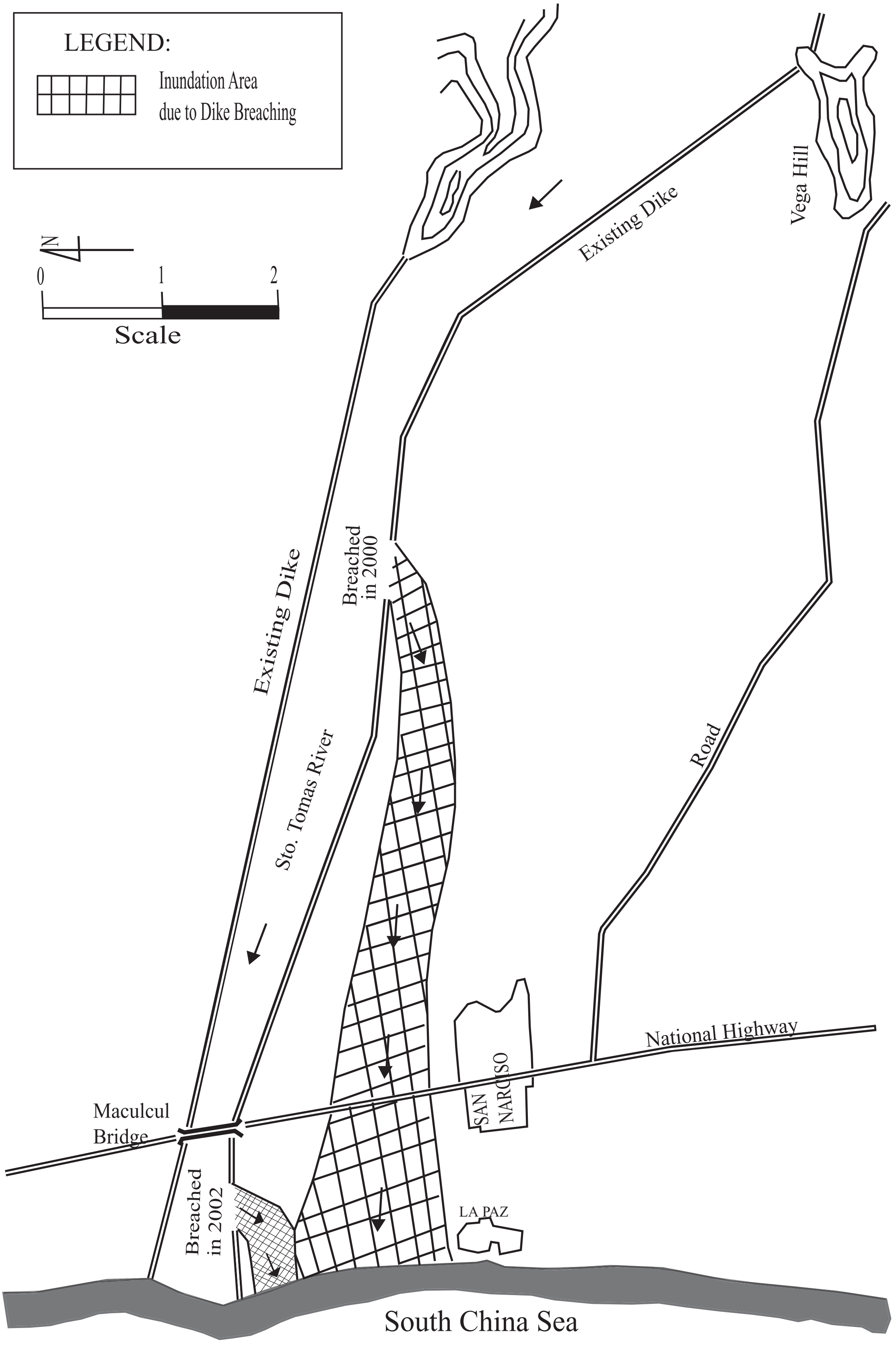

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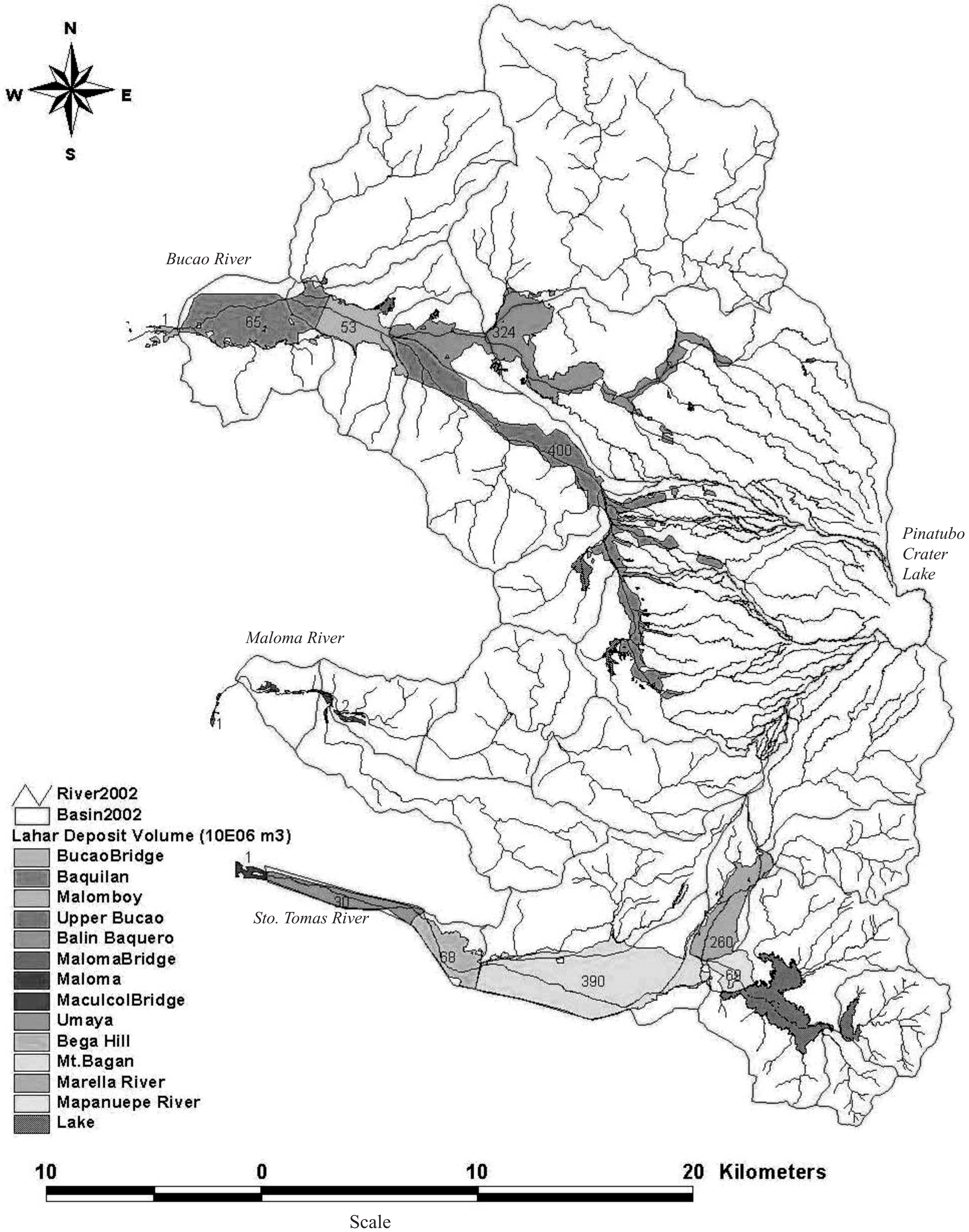
Figure 1.1.6

Inundation Area along the Sto. Tomas River in 2000 and 2002



Source: JICA Study Team

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Figure 1.2.1

Volume of Lahar Deposition along River Channels