APPENDIX-III

Meteorology and Hydrology

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 III METEOROLOGY AND HYDROLOGY

Table of Contents

List of Tables

List of Figures

CHAPTER 1 METEOROLOGY AND HYDROLOGY

1.1 Description of Basins

The major three river basins in the study area, the Bucao, Maloma and Sto. Tomas River basins, are situated geographically on the western-most part of Luzon Island in the Philippines. The locations of all three river basins are shown in Figure 1.1.1. The basins form part of the Zambales mountain range, which overlook the South China Sea to the west. Land use along the low-lying coastline area consists of small residential communities and agricultural land use. On the other hand, eastward towards the interior, the area is mainly uninhabited except for local barangay (villages) which are scattered throughout the range.

The mountains themselves are either covered with thick brush or are bare from forest fire and intentional burning. Prior to the 1991 eruption, the highest peak in the range was Mount Pinatubo (EL. 1,745 m). However, at present, the highest peak is Mount Negron (EL. 1,583 m), while the peak of Mount Pinatubo is 1,449 m.

1.1.1 Bucao River Basin

The northern most basin, the Bucao River basin, is the largest with a catchment area of 655 km^2 (15° 07' - 15° 36'N, 120° 02' - 120° 30'E). A number of tributaries are originated close to the summit and include the Balin-Baquero, Heleng, Lubao and Maraunot Rivers. These rivers generally flow west to northwestward. They join other large rivers such as the Balintawak, Baquilan and the main Bucao River, flowing past the No.7 National Highway at the Bucao Bridge and eventually discharge to the South China Sea.

1.1.2 Maloma River Basin

South of the Bucao River basin lies the Maloma River basin with a catchment area of 152 km2. (15° 02' - 15° 13'N, 120° 04' - 120° 26'E). The basin does not run directly off the slopes of Mount Pinatubo, but starts approximately 7 km to the south-west and flows westward. The major tributary, the Gorongorong River, runs roughly parallel to the Maloma and joins immediately upstream of Maloma Barangay. The river continues to flow westward before flowing past the No.7 National Highway at the Maloma Bridge and ultimately discharges to the South China Sea.

1.1.3 Sto. Tomas River Basin

Further south lies the Sto. Tomas River basin with a catchment area of 262 km^2. (14° 54'N - 15° 12'N, 120° 06' 120° 32'E). The upper most tributary, the Marella River, runs directly off the Pinatubo summit towards the south-west. To the south-east portion of the basin lies Mapanuepe Lake, a lahar induced lake. While inflow into the lake comes from i) the surrounding catchments and ii) direct rainfall into the lake, the only outflow is from a single artificial outlet channel at the western edge of the lake. At the end of the channel outlet, the river name changes to the Sto. Tomas River, confluences with the Santa Fe River flowing to the west until reaching the South China Sea.

This sector report presents a review of the existing hydrological data, rainfall analysis and flood analysis, the establishment of rating curves for the three rivers, examination of the historical and present water quality of the rivers and description of the newly installed hydrological equipment in the study area.

1.2 Climate and Meteorology

Tropical cyclones, categorized as tropical depressions, tropical storms or typhoons depending on their wind speed, all follow a similar route in the Philippines. The eye of the storm initially heads westward towards Luzon Island, followed by a swerving to the northeast away from the Philippines. As it swerves, the pull of the winds are said to induce the southwest monsoon winds that are typically encountered in western Luzon Island.

The climate in the study area is classified as Type I climate in the Philippines. It is characterized by a pronounced wet season between May and October and a distinct dry season from November to April. Table 1.2.1 and Figure 1.2.1 present the monthly mean rainfall, temperature and relative humidity at Iba Station. Regional data from synoptic stations at Dagupan to the north, Cabanatuan to the east and Manila Port to the southeast are shown for reference. All figures are based on 30 years of data from 1971 and 2000.

(1) Rainfall

Heavy rains occur between June and September, which are commonly induced by southwest monsoon winds and tropical cyclones. Rainfall is minimal during the dry season from December to April due to reversal of monsoon wind direction. It is noted that with the exception of Baguio, the annual rainfall is significantly less than that of Iba. The monthly mean rainfall at Iba ranges from 3 mm in January to 1,020 mm in August with mean annual rainfall of 3,600 mm.

Comparing the amount of rainfall on the western slope of Mount Pinatubo to the eastern slope, it can be said that the western slope has far greater rainfall. Figure 1.2.2 shows recorded rainfall in July 2002 which indicates that 1.5 times as much rainfall fell on the western slope. This is because of the predominant southwest monsoon winds containing a large amount of moisture from the South China Sea and the shielding effect of the Zambales mountains.

An isohyetal map was prepared based on 1995 annual rainfall data as shown in Figure 1.2.3. Assuming the map is indicative of rainfall in the region, then three major points are recognized. First, the western slopes of Mount Pinatubo have a far greater amount of rainfall than the eastern slopes. Second, the western coastal area rainfall is lower than the western mountain rainfall. Third, the larger amount of rainfall is concentrated more towards the southwestern side as opposed to the northwestern side.

(2) Temperature

Air temperature ranges between a minimum of 25.6℃ in January and a maximum of 28.1℃ in April with a mean of 26.8℃ at Iba, Zambales as shown in Figure 1.2.1. The highest temperature occurs at the end of the dry season, typically in April, while the lowest is between December and February, however there is no significant change in temperature between the dry and wet season. Temperature at Iba has a similar trend to Manila and Cabanatuan in Central Luzon. Baguio has lower temperature due to its high elevation.

(3) Relative Humidity

Average annual relative humidity at Iba is considerably high at 79%. Humidity becomes the highest during the wet season at 86% while it becomes the lowest during the dry season at 73% as shown in Figure 1.2.1.

(4) Wind Speed and Direction

Wind speed and direction data was collected in the form of a windrose diagram. A windrose is a diagram showing the predominant wind direction and wind speed at a location on a circular plane. 40 years of data at Iba Synoptic Station was available. In attempts to determine any long-term trends from the eruption, the data was separated for pre- and post-eruption as shown in Figure 1.2.4.

The pre-eruption data shows the prevailing wind as being east during the dry season and split between southwest, south and east during the wet season. The post-eruption data shows the prevailing wind as no longer easterly, but north-westerly, while south and southwesterly winds are prevalent during the wet season.

At present it can only be concluded that the wind data at Iba has a possibility of being influenced by local conditions and not be indicative of the greater climate condition of Zambales. A more indicative windrose was found to be that of Cubi Point in Figure 1.2.5, which shows wind directions more typical of Type I climate (i.e. south west monsoon winds during the wet season and north-east winds during the dry season).

(5) Tidal Condition

Tidal conditions were determined using "Tide and Current Tables" for 2002. The station for Iba (15° 19'N, 19° 58'E) and San Antonio (14° 55'N, 120° 04'E) were closest to the study area. The annual mean tide for Iba is 0.45 m and San Antonio is 0.44 m above mean sea level. The maximum tide was also determined using linear interpolation between these two stations. The maximum predicted tide in 2002 for Bucao, Maloma and Sto. Tomas River was found to be 1.44 m, 1.40 m and 1.38 m respectively, occurring on August 9 and 10, 2002.

1.3 Hydrology

During the wet season, the combination of steep upper slopes and typhoon-induced rainstorms in the study area result in rapid runoff with frequent fluctuation of the riverbed. Riverbed is to be aggravated by the additional flow and deposits of lahar.

The annual runoff characteristics in the three river basins are similar to those of other basins draining from Mount Pinatubo. Historical data indicate that coefficient of annual runoff is 54% to 58% for the basins, while the Sacobia River basin, one of the other basins of Mount Pinatubo, has reported 62%.

In addition to the pre- and post-eruption natural features of the basin, a number of structures lie within the basins which also influence the hydrology. Most notably, each basin is lined with protection dikes of various length, height, durability and material. They were constructed mainly as part of the post-eruption rehabilitation works. Catchment areas are thus, reduced to the area enclosed by the dikes.

Another structure is the artificial channel draining from Mapanuepe Lake in the Sto. Tomas River basin. This channel, constructed by blasting, allows the lake water to freely drain to the downstream. Study has also been made on the use of this channel as an irrigation inlet for downstream fields. Prior to eruption, similar irrigation intakes were said to have taken place.

1.4 Availability of Data

No one single agency was relied upon to obtain the relevant data required for flood analysis. For instance, though the Philippine Atmospheric Geographical and Astronomical Services Administration (PAGASA) has most of the precipitation data, other institutions were checked as well.

(1) Rainfall Data

The Climate Data Section of PAGASA is responsible for the meteorological data from their synoptic station network and thus, was the source of the data. In addition, daily rainfall data from past and present rainfall stations were available. Hourly rainfall data for Iba synoptic station for a limited time period was found in the PAGASA Flood Forecasting Center. For reference, annual typhoon summaries indicating date, path and brief description were retained. In addition to the PAGASA rainfall data, a limited amount of rainfall data from the Philippine Institute of Volcanology and Seismology (PHIVOLCS) in The University of the Philippines was also available. The availability of rainfall data is shown in Figure 1.4.1.

(2) Discharge Data

Hydrological data was limited to the discharge data at one location for each of the rivers, mostly during the 1960's, 70's and 80's. This data was found at the Bureau of Research and Standards (BRS) of DPWH. Post-eruption discharge data was unavailable, due to the fact that water level data was not collected, or if collected, remains unprocessed. The availability of discharge data is shown in Figure 1.4.2. Limited data on discharge rating curves and limited cross sectional data were available at BRS.

(3) Topographic Data

The National Mapping and Resource Information Authority (NAMRIA) had topographic maps at 1:50,000 scale. Unfortunately, these maps were published before the eruption (in 1977) and have not been updated. Where possible, the satellite photos taken in December 2001 were referenced. NAMRIA also publishes the aforementioned tide data.

Topographic data of post eruption was obtained from aerial photogrammetric survey conducted during the study. As well, cross section data were updated by additional cross sections survey through the study.

CHAPTER 2 RAINFALL ANALYSIS

2.1 Precipitation Data

The locations of the gauges adopted for rainfall analysis are shown in Figure 2.1.1. There are five present or former rainfall station of PAGASA and three former rainfall stations of PHIVOLCS situated on the western side of Mount Pinatubo. The PAGASA stations are situated along low-lying coastal areas, all no greater than 30 m in elevation, while those for PHIVOLCS were at higher elevation.

(1) PAGASA Rainfall Gauges

Most of the PAGASA stations collect daily rainfall data by a gauge keeper. For Iba Synoptic Station, hourly rainfall data is also collected using a tipping bucket and automatic wind-up logger. Unfortunately, it was discovered during the investigation that most of the rainfall charts past 1990 were unprocessed. In addition, their location was scattered in the offices of PAGASA, which severely affected the analysis. Annual maximum daily rainfall for the three gauges in the study area is shown in Table 2.1.1.

For comparison purposes, Becuran with its long duration of record was also selected. The data shows that the western gauges have an annual rainfall over 3,000 mm, except San Felipe and Palawig which are closer to 2,000 mm. Given the rainfall patterns experienced during the investigation by the study team, annual rainfall close to 2,000 mm is highly unlikely and was subject to further scrutiny.

(2) PHIVOLCS Rainfall Gauges

The PHIVOLCS stations had tipping bucket type with telemetry systems. The telemetered data was signaled in thirty-minute intervals however, examinations of the collected data reveal many missing periods. Furthermore, the values were reported as zero even when the system was not functioning properly. Nevertheless, the data was valuable in terms of establishing an elevation-depth relationship. Although the duration was limited and quite often fragmented, the rainfall in the mountainous area was further investigated.

(3) Other Rainfall Gauges

A flood warning system including two rainfall gauges, connected with telemetry system, was installed by JICA in 1993 with the cooperation of the RDCC (Regional Disaster Coordination Council). It was hoped that the data would be available for model development however, the system is presently not in operation. Furthermore, past records were not available when the RDCC office was visited.

2.2 Double Mass Curve Analysis and Areal Relationship

The daily rainfall data were screened for appropriateness by plotting double mass curves for the concerned rainfall stations. The PAGASA data for the station were first screened as shown in Figure 2.2.1. Results show that Palawig Station and San Felipe Stations have a crooked relationship further putting suspicion on the two stations, while those for Iba and Santa Rita are relatively straight.

A matrix of correlation coefficients is shown in Table 2.2.1. The correlation coefficient is an index of the degree of closeness of rainfall events between two different gauges. For the San Felipe and Palawig stations, the correlation coefficient is shown to be fairly low as compared to other stations. The proximity of the gauges would suggest that a close correlation is to be expected. However, due to this disparity, and in consideration of the questionable annual rainfall values above, the Palawig and San Felipe stations were removed from further analysis.

In addition, further study of rainfall between the western and eastern side of Mount Pinatubo and summit rainfall, were conducted as follows.

1) Rainfall on Eastern and Western Mount Pinatubo

Validity of using data on the eastern slope of Mount Pinatubo was examined for reference. The rainfall station of Becuran was adopted because of its long period of record. Examination of Figure 2.2.1 shows that Becuran has a close relationship with western coastal rainfall. Such data continues to support statements in past studies and in previous sections that Mount Pinatubo and the Zambales mountain range form a distinctive rain shadow over the eastern side.

2) Rainfall near the Summit

The data obtained by PHIVOCS was analyzed in order to determine the relationship between orographic rainfall and coastal rainfall. Six rainfall gauges in total were installed initially and another was installed subsequently in the years following the eruption. All monitoring of rainfall was ceased in 1997. Three of the gauges were situated within the study area and were checked for appropriateness, along with a fourth which had a relatively long duration of records. The data were initially screened to check for obvious irregularities in data.

A common problem encountered was that the data was very fragmentary so a continuous set of records was impossible. Next, double mass curves lead to a further realization that a number of zero values are actually non-recording values as indicated by long straight lines during, a rainy month. Removal of such data increased the accuracy of the results.

The curves after screening are shown in Figure 2.2.2. Results showed that of the gauges examined, gauge 204 was the only one found to have a noticeable correlation with the coastal stations. They showed that there is a distinct increase in rainfall between the western coastal area and western mountainous area, reaffirming the rainfall isohyetal pattern shown in Figure 1.2.3.

Based on the above, the 204 gauge only was adopted with a 20% increase to the Santa Rita Station. The correlation coefficient matrix between the PAGASA and PHIVOLCS rainfall data is shown in Table 2.2.2.

2.3 Point Rainfall

The point rainfall for the stations of Iba, Santa Rita, San Marcelino and Becuran were computed using statistical software. For the 1-, 2-, 3-, 4- and 5-day rainfall, the Log-Pearson and Gumbel distribution were computed and plotted on plotting paper. Results showed that the Log-Pearson distribution had a better fit and were adopted. The results are summarized in Table 2.3.1.

The only rainfall station with hourly data is Iba, but it is for short term. Rainfall intensity curves based on a thirty year data set were already available from DPWH for Iba Station, however for reasons already mentioned, data in the 1990's is yet to be processed. In order to coincide these results with the daily rainfall data set, the thirty year data set was adjusted to the forty year set by scaling the ratio of 24 hour values. These short-term rainfall values are also shown in Table 2.3.1.

2.4 Basin Mean Rainfall

Basin mean rainfall was computed for each of the three river basins. The Thiessen polygon method was adopted for calculating the basin mean rainfall. The stations used were PAGASA's, Iba, Santa Rita and San Marcelino stations, which are all located in the elevation of less than 30 m. Therefore, the PHIVOLCS' 204 station was also utilized to take into account of elevation effect in rainfall pattern. For the 204 station, it was assumed that the rainfall would be a 20% increase of the Santa Rita station. The Thiessen Polygon for the study area is shown in Figure 2.4.1. The weight distributions of the Thiessen polygon and basin mean rainfall are shown in Table 2.4.1.

Subsequently, annual maximum daily rainfall data of the four rainfall stations (Iba, Santa Rita, San Marcelino and No.204 gauges) for 18 years (1976-1995) after screening, was used for rainfall probability analysis.

Probable basin mean daily rainfall for the three river basins, Bucao, Maloma, and Sto. Tomas is tabulated in the following table.

Probable Basin Mean Rainfall in Bucao, Maloma, and Sto. Tomas River Basin

Unit (mm)

Basin	Return Period (Year)						
	2	5	10	20	30	50	100
Bucao	257	378	473	577	642	730	861
Maloma	203	309	399	502	570	665	811
Sto. Tomas	200	305	395	500	568	665	814

For estimation of the above probable rainfall, three theoretical probable distributions, Gumbel, Log-Pearson III and Iwai methods, were compared. Based on the comparison, it was judged that the Log-Pearson III is the best fit with the data as shown in Figure 2.4.2, and applied to the three basins.

2.5 Design Storm Duration and Temporal Pattern

A model hyetograph for the basin mean rainfall was developed taking into account the duration period of 10 largest recorded storms from 1970 to 1980 with more than 100 mm at the Iba station, which is only available automatic raingauge with long-term recording period in the study area. Figure 2.5.1 presents the model hyetograph developed by the study team. Consequently, the entire duration of the model hyetograph for the basins was set at 24 hours based on the duration of recorded floods. The rainfall distribution of the model hyetograph was determined in the form of percentage of each hourly rainfall to the total amount of 24-hour rainfall.

CHAPTER 3 FLOOD ANALYSIS

3.1 Runoff Model

Probable flood discharge for each river is presented in the following sections. Development of a flood runoff model requires that good quality historical data be available for calibration to major events. Sufficient data from rainfall stations within or near-by the basin are mandatory. Similarly, continuous data from discharge monitoring stations are necessary. Due to the small scale of the three basins, the run off is expected to be quick. Thus the discharge data should be in short intervals. Only when satisfaction of the above requirements is attained that a reliable flood discharge model can be developed.

For the three basins, such rainfall and discharge data were not available, affecting the quality of calibration of the model. Rainfall data close to the summit was limited. Therefore an attempt to adopt the PHIVOLCS data was made. Discharge data for all three rivers were limited to data collected mainly prior to the 1990s and consisted of daily discharges only. A flood runoff model was prepared as explained in the following section.

3.1.1 Subbasin Division

GIS techniques were used to delineate the basins for the three rivers utilizing 1:50,000 scale topographical maps published by NAMRIA. The basin was further subdivided into subbasins to differentiate the various characteristics within each basin. All subbasins were divided at confluences of major rivers and major changes in topography. Effort was made to keep subbasins to a maximum of 50 km^2, however some exceptions were made such as the Balintawak subbasin in the Bucao basins, which was fairly homogeneous and it was not necessary to divide subbasins further.

The subbasins delineation for the three rivers is shown in Figure 3.1.1. Figure 3.1.2 shows the change in river course and subbasin division of the Bucao River before and after the eruption. It shows that the Maraunot River is no longer connected directly to the crater lake. Direct connection with the lake has shifted to the Lubao River.

3.1.2 Unit Hydrograph

Flood analysis was conducted for the three basins, Bucao, Maloma, and Sto. Tomas, using the U.S. Army Corps of Engineers' (USACE) Hydrologic Modeling System (HEC-HMS) model. HEC-HMS is one of the free software developed by USACE. The Unit Hydrograph Method was selected in this study because of the following reasons:

1) The Unit Hydrograph Method was applied for runoff analysis in the eight river basins surrounding Mount Pinatubo in the Recovery Action Plan conducted by USACE in 1994.
2) It was also used for runoff analysis in Porac-Gumain River basin and Pasig-Potrero River basin conducted after the study of USACE.
3) In addition, the Unit Hydrograph method with the free software would be appropriate for technology transfer, one of the most important scopes of this study, because the model can be transferred completely to counterparts.

In order to set the model parameters, it is ideal to have extensive information on the basin. In lieu of the limited data available, past reports were reviewed and referenced.

(1) Rainfall Loss

The rainfall loss is the loss of the rainfall from the time when it enters the basin to the time of discharge at the outlet. The initial loss constant – rate method was used, where the initial loss and the constant rate of loss are specified. Since the antecedent moisture condition in a severe event is most likely to be during a saturated condition, the initial loss was set to zero. The constant loss rate, based on the examination of other studies around Mount Pinatubo, was adopted as a rate of 2 mm/hr.

(2) Baseflow

Baseflow is the flow in the river prior to the storm event and is a separable quantity. Since the baseflow of all three streams was unknown due to insufficient data, the following empirical relationship developed by the USACE for Mount Pinatubo was applied.

$$Q_{baseflow} = A\left(\frac{R}{17{,}500} - 0.12\right)$$

Where: $Q_{baseflow}$ is typical flood season base flow (m^3/s)
A is basin area (km^2)
R is average annual rainfall input (mm/yr)

(3) Transform

The Clark synthetic unit hydrograph was used to transform rainfall to runoff. Two parameters, the time of concentration, t_c, and the storage coefficient, S, need to be defined. Time of concentration is the time between the center of mass of the excess rainfall to the time of inflection of the receding hydrograph. One method is suggested for estimating t_c by using the following equation.

$$t_c \equiv \left(11.9 \cdot \frac{L^3}{\Delta H}\right)^{0.385}$$

Where: t_c is the time of concentration (hours)
ΔH is the elevation change along the longest water course in the subbasin (ft)
L is the length of the longest water course from the edge of the subbasin to the outlet (mi)

The storage coefficient is a parameter to consider the storage capacity of the basin. Based on reports of earlier studies for the basins of Mount Pinatubo, a storage parameter of S= 20 t_c has been suggested and was used as an initial value. This parameter was subject to calibration, which is discussed in the calibration section.

(4) Channel Routing

Channel routing is the attenuation effect of the flood wave as it passes through reaches in the basin. The Muskingum method was used for channel routing. This method requires two parameters, the X parameter defining the weight of the input, and the K parameter defining the travel time of the flood wave. To determine X, sufficient flow data of the reaches under consideration is necessary. For the model, an average value of 0.2, as is recommended in literature, was adopted for all reaches. The K-parameter was calculated by dividing the length of the reach by the wave speed of the flood.

$$K = \frac{L_{reach}}{c}$$

Where: L_{reach} is the length of reach (m),
c is the wave speed (m/s)

The wave speed adopted was 2.5 m/s based on the observation during storms in July 2002.

3.1.3 Calibration of Model Parameters

(1) Subbasin and Channel Routing

The adopted values for all parameters for the three basins are shown in Table 3.1.1. Ideally, information on major storm events is desired for calibration. Due to the unavailability of hourly discharge data required to calibrate the model parameters, calibration of model parameters was limited to use of daily average discharge data. In addition, examination of daily flow data for the three rivers revealed that discharge data for the Bucao River was the only one with a relatively long period of reliable data, except for the1970's where monitoring activity was stopped and the 1990's where the data is yet to be processed. In terms of hourly rainfall data required for input into the model, data for Iba was available for the 1970's and 1980's but not processed for the 1990's. Given these constraints, two storms in the 1980's were identified for calibration: Typhoon Diding in August 1983 for ten days and Typhoon Huaning in July of 1988 for six days. The model was run using the assumed parameters, with adjustment for baseflow.

Initial runs of the calibration with $S=20t_c$ showed that peaks were much lower and more delayed when compared to the daily average observed values. It was found that this was caused by the large amount of storage, as represented by the storage parameter, R. Although the value of this parameter worked well for the other basins, the storage is much too conservative for the Bucao River basin. This can be attributed to the steeper slopes of the western side and relatively shorter reaches.

Based on the above, the storage parameter was changed and a value of $S=10t_c$ was found to be appropriate. The calibration results for the two storms are summarized in Table 3.1.2 and Figure 3.1.3. Comparing average daily peaks, the simulated value is 5% higher for the storm in 1983 while it was 13% lower for the storm in 1988. The runoff coefficient for both storms is similar, after removing the contribution of baseflow. Improvement of the model would be difficult without hourly discharge data.

(2) Storage Effect of Mapanuepe Lake

Mapanuepe Lake was formed as a result of lahar movement which effectively "dammed" Mapanuepe River in the years following the eruption. As considerable storage is encountered due to its presence, a simple equation using the weir function for dams was used to model the storage effect of Mapanuepe Lake. The outflow adopted is as follows:

$$Q_{out} = Cbh^{3/2}$$

Where: C is the weir constant
b is the width of the outlet (m)
h is the head overflowing from the outlet (m)

The value of C was assumed at 1.80, which is generally used when the shape of weir is not clearly identified. The value of b was set to 12.5 m as the average width of the outlet.

The storage model of Mapanuepe Lake was calibrated with the elevation of lake surface because of the nonexistence of discharge data at Mapanuepe Lake outlet. The initial elevation of the surface was set to 123.0 m with h = 0 m. The value of h was estimated as the inflow volume at each time step divided by the initial surface area, namely 6.9 km^2.

Figure 3.1.4 shows the results of the runoff simulation in the area of Mapanuepe Lake for the flood in early July 2002. Hourly rainfall data in July 2002 was collected from a rainfall gauge station installed near Mapanuepe Lake by the study team is also shown. The elevation of the surface was observed to be 127.0 m at 11:00 a.m. on July 8, 2002. The figure shows that the line of simulated surface elevation passes close to the point of the observed elevation.

It is noted that the presence of the old mining dam, the Dizon Tailing Dam upstream of Mapanuepe Lake, also creates a storage effect. However, the reservoir was assumed to be at capacity during the rainy season resulting in no storage effect in an event of flood.

3.2 Probable Floods

3.2.1 Probable Peak Discharge and Hydrograph

With the parameters set, the model was run using the design storm mentioned in the previous sections to estimate the probable flood. Model diagrams for the Bucao, Maloma, and Sto. Tomas Rivers are shown in Figure 3.2.1. The design floods for the 1 day storm for return periods between 2 to 50 years were computed using the HEC-HMS software. Due to the small size of the basins and the relatively large range of coverage of rain clouds during typical monsoon rainstorms, no areal reduction factor was applied.

It is noted that based on U.S. Weather Bureau Technical Paper 38 and 49 concerning depth area relationships, a 24 hour storm will only be reduced to 85% of its point rainfall for distances of 15 km and beyond. Given that this only slightly reduces the depth, the more severe situation was assumed. Computed hydrographs for 1 day rainfall duration are shown in Figure 3.2.2 for the Bucao, Maloma and Sto. Tomas Rivers. The flow distribution diagrams throughout each basin are shown in Figure 3.2.3, 3.2.4 and 3.2.5.

In addition, Figure 3.2.6 shows the water level change of Mapanuepe Lake during probable floods. It shows that the 100-year flood would not overflow in the Marella River.

3.2.2 Verification of Obtained Peak Discharge

In order to verify if the magnitudes of the discharge estimates are reliable, the 20-year and 50-year specific discharge was computed for each river. Then, they are compared to those of other rivers which drain Mount Pinatubo. The values are shown in Figure 3.2.7. The specific discharge in the Bucao River basin is the highest, followed by the Maloma River basin. The specific discharge in the Sto. Tomas River basin has the smallest specific discharge in the three river basins due to the storage effect of Mapanuepe Lake. When compared to the other rivers, it is shown that the specific discharges in the study area are comparable to those of the Sacobia-Bamban and Abacan Rivers.

Another parameter, Creager's C value, which is normally used for extreme events, was also calculated for the 20- and 50-year events and is also shown in Figure 3.2.7. The value shows an empirical relationship relating the basin area and discharge. It indicates that the Bucao River has higher values than that of the Sacobia-Bamban and Abacan Rivers. This is likely due to the rainfall pattern difference between the western and east slope.

Based on the above, it is concluded that the estimated probable flood peak discharges are reasonable. This verifies that the estimated parameters and model are acceptable for the study area.

Next, historical maximum specific discharges were taken for streams of various basin areas in the Philippines and plotted as the unit maximum discharge against area. While the maximum gives no indication of return interval, some of the basins are those with data with periods of up to more than twenty years. These plots, together with those of the three rivers are shown in Figure 3.2.7. They show that for all 20-year and 50-year floods, the unit discharge falls within an acceptable range.

CHAPTER 4 STREAM FLOW ANALYSIS

4.1 Water Balance Analysis

Over the long periods, the validity of the daily discharge data for long period was checked by a water balance analysis using annual rainfall and annual evapo-transpiration.

The reliability of the daily discharge data can be judged by annual loss. By dividing the total annual discharge volume by the catchment area, the annual run-off height is calculated. Rainfall changes into run-off, and the difference between annual rainfall and annual run-off is called annual loss. Annual loss corresponds to evapo-transpiration from the land surface. In general, evapo-transpiration is equal to 50 to 90% (average 70%) of pan evaporation. Consequently, a reasonable annual loss must be in the range of 900 to 1,600 mm/yr, as follows:

Pan Evaporation = 1,736 mm/yr (Floridablanca in Pampanga, 1985-1987)

Annual Loss = 1,736 * (0.5 to 0.9) = 900 to 1,600 mm/yr

A complete daily discharge record without missing data is available over years for the Bucao River as shown in Table 4.1.1, and three years for the Sto.Tomas River as shown in Table 4.1.2. The water balance in the Bucao and Sto.Tomas River basins are examined in those tables. It is clear that the data in 1963 and 1984 for the Bucao River is reasonable, but the other data is determined to be unusable.

The monthly rainfall and discharge data in 1963 and 1984 are graphed in Figure 4.1.1, and seems to be acceptable based on the relationship between discharge and rainfall.

4.2 Flow Duration Curve

Representation of the daily discharge in a year in decreasing order gives the daily flow duration curve. Table 4.2.1 shows the detailed daily discharge data for 1963 and 1984. The average data of two years is adopted. Figure 4.2.1 shows a comparison between the Bucao River and the flow duration curve for the Porac River (from JICA Report in 1996). The Bucao River has a tendency for more high flow days and less low flow days compared with the Porac River.

CHAPTER 5 DISCHARGE MEASUREMENTS AND ACTUAL FLOODS

5.1 Present Discharge Measurement Activities

The Bureau of Research and Standards (BRS) in DPWH conducts discharge measurements in selected rivers throughout the ROP. For 21 rivers in Region 3, the DPWH Region 3 Office - Materials, Quality Control and Hydrology Division in San Fernando City is designated as the responsible organization for the discharge measurements, although the Mount Pinatubo Rehabilitation Project (MPR) was also entrusted with discharge measurements in the early 90's after the eruption. Of the 21 rivers, two are the Bucao River and the Maloma River. Due to excessive lahar accumulation and constant riverbed change in the Sto. Tomas River, discharge measurements have been discontinued as of 1997.

Measurements are presently conducted monthly at one location along the Bucao River (at the Bucao Bridge) and one location along the Maloma River (at the Maloma Bridge). The discharge measurement is conducted by using a price current meter to measure the velocity and a wading rod to measure the depth. A gauge keeper is retained to make staff gauge readings twice a day. Once an adequate rating is obtained using the discharge data, the results are be forwarded to BRS in Quezon City for approval and comment.

5.2 Discharge Measurement Records

Tables 5.2.1, 5.2.2 and 5.2.3 are the collected discharge measurement records for the Bucao, Maloma and Sto. Tomas Rivers, respectively. There are 119 measurements for the Bucao River, 56 of which were made after the 1991 eruption. 93 measurements were carried out for the Maloma River, 51 of which were made after the 1991 eruption. All 23 measurements in the Sto. Tomas River were attempted after the eruption.

It is obvious that discharges for a wider distribution of gauge heights were required. The reasons for not being able to measure the discharge at these heights are considered to be as follows:

- quick runoff of the basins resulting in missed peak flows
- difficulty of staff to mobilize during a peak flow situation (due to distance, slow traffic, road blockages)
- limitations inherent in using the present price water meter for measuring the velocity of floods

5.3 Floods in July 2002

5.3.1 Overview

Due to the stagnation of low pressure stimulated by series of typhoons "Gloria", "Hambalos" and "Inday" at off-shore of Zambales Province, heavy rainfall in the study area was observed for 12 days from July 4 up to July 15, 2002. Accumulated rainfall for those 12 days was recorded approximately 1,500 mm at the Baquilan raingauge station (newly installed by JICA) in the Bucao River basin.

At the Bucao River, lahar flow was observed at 8:30 a.m. on July 10. Local people reported that the height of the lahar wave was more or less 3 m, by which the flood water level was risen up suddenly. Two people and 5 carabaos were swept down when they crossed the Bucao River at Barangay Baquilan. They were flown down by lahar flow to the Bucao Bridge, 7 km downstream from the portion, and were rescued at the bridge. But the 5 carabaos were flown down to the river mouth. The study team member visited the bridge site at 11:00 a.m., when the floodwater level was El. 2.1 m, approximately 70 cm higher than 1 day before as shown in Figure 5.3.1.

Inundation was observed in the villages near the Maloma Bridge on July 7 and July 14. The floodwater overflowed across National Highway flowing down as shown in Figure 5.3.1. On the right side of the Maloma River, floodwater overtopped at the just upstream of the Maloma Bridge along the highway in the afternoon of July 7. The backfill material of the revetment was partially scoured.

The riverbed aggradation at the Maculcol Bridge of the Sto. Tomas River was remarkable on 7 July 2002, the flood water hit the girder of the bridge as shown in Figure 5.3.1. It was observed that the floodwater reached the bridge girder many times during the flood. The splash sometimes reached the slab of the bridge. The clearance between the bridge girder and the riverbed became more or less 1 m for the whole section. The course of the flood under the bridge was always changed from left to right. Sand bars were formed and washed away frequently nearby the bridge section at different locations.

5.3.2 Rainfall Observation

The daily rainfall record in and around the Study Area during the series of typhoons are as follows:

Daily Rainfall Record from 4 July to 15 July (Unit: mm)

Sta. Name	Iba	Baquilan	San Felipe	Mapanuepe	San Fernando	Apalit
Province	Zambales	Zambales	Zambales	Zambales	Pampanga	Pampanga
River		Bucao	Maloma	Sto. Tomas	Pasig-Potorero	Pampanga
Owner	PAGASA	JICA	JICA	JICA	JICA	Nippon Koei
7/4	38.4	91.7	104.1	86.4	12.19	3.2
7/5	164.2	115.3	178.1	199.6	24.38	52.0
7/6	204.0	129.0	205.8	177.5	80.27	157.0
7/7	231.4	404.4	385.3	369.1	257.31	170.4
7/8	13.7	41.9	90.2	33.8	104.64	39.0
7/9	68.7	60.2	64.7	15.7	71.37	9.4
7/10	121.4	181.6	81.5	10.4	61.46	17.6
7/11	-	54.4	102.6	4.5	91.43	-
7/12	-	143.8	113.5	127.3	34.29	-
7/13	-	189.0	146.0	186.4	142.49	-
7/14	-	13.7	56.6	43.4	31.23	-
7/15	-	72.6	70.4	66.8	4.29	-

Note: "-" indicates no available data

The cumulative rainfall for Mapanuepe Lake, Baquilan and San Fernando are shown in Figure 1.2.2.

Based on the recorded rainfall above, the followings are obtained:

(1) Return period of rainfall for 3-day and 4-day in Iba was between 5- and 10-year. At Apalit in Pampanga, the eastern Pinatubo, rainfall was also recorded at the same return period of 5- to 10-year.
(2) Rainfall in the western side showed much bigger than the eastern side. 5-day rainfall at Mapanuepe, the Sto. Tomas River basin was 68% bigger than the recorded rainfall in San Fernando, Pampanga.
(3) Triple peak of rainfall pattern was observed on July 7, July 10, and July 13. These were directly affected by the south-west monsoon clouds stimulated by the series of typhoons, "Gloria" on July 7, "Hambalos" on July 10 and "Inday" on July 13.

5.3.3 Discharge Measurements

During the 2002 wet season, attempts were made to measure the peak flows by use of floats in order to refine the h-Q rating curve. It is also mandatory to continue shallow water discharge measurements by the present procedure. Surface floats were used to measure the discharge at the Bucao Bridge, Maloma

Bridge and Sto. Tomas Bridge

The sequence of the float measurement was as follows:

1) Cross sectional area was determined in the following manner. Two measuring points along the riverbank were selected along the river. For practical reasons, namely float throwing location, the points were selected downstream of the bridges. The distance was measured between the two points and marked with paint and a nail marker. The distance between the points was set at either 30m or 50m. Flags or permanent identification markers were set on the opposite bank. Next, the cross section at the midpoint of the two points was surveyed and used as the average cross section. The method of survey was by a laser range finder mounted on a tripod and fitted with an inclinometer. Distance and depth was recorded by placing a staff rod at designated locations in the river. The zero relationship between the permanent staff gauge was also surveyed.
2) Flow velocity was determined by throwing floats at designated locations from the bridge. The time required for the float to run from the upstream point to the downstream point was measured using a stopwatch. One person at the first observation point signaled the float thrower and started the stopwatch as it passed the first point. The stopwatch was stopped once the float passed the second point as indicated by a third person standing at the second point.
3) This process was repeated for the number of floats to be used.
4) The discharge was calculated by the following equation:

$$Q = f \;\Sigma A_1 \text{ x } V_m$$

Where, Q : Discharge (m^3/sec)
AI : Representative sectional area (m2)
Vm : Average traveling time of the floats between the upstream and the downstream section (m/s)
f : Correction factor of float used

The velocity measured with floats is multiplied by a correction factor, f, to account for the vertical and longitudinal velocity profile. The types of floats and correction coefficient for the floats are shown below:

Types of Floats and Correlation Coefficient Factor

Float No.	Water Depth (m)	Stem of float (m)	Correction Factor, f
1	Shallower than 0.7	Surface float	0.85
2	0.7 to 1.3	0.5	0.88
3	1.3 to 2.6	1.0	0.91
4	2.6 to 5.2	2.0	0.94
5	over 5.2	4.0	0.96

For the monitoring of the three rivers, only Float No. 1-surface float was used.

Table 5.3.1 shows the results of discharge measurements from 4 July to 8 July 2002. The cross sectional survey at the Bucao Bridge on July 3 and at the Maloma Bridge on June 20 was used as representative sectional area in the calculation. It was impossible to estimate discharge at the downstream of the Maculcol Bridge after July 7 because the water level was already over the height of girder.

5.3.4 Discharge Rating Curve

(1) Cross Sectional Survey

Before the flood in July, cross sectional survey was carried out at the downstream of the Bucao, Maloma and Maculcol Bridge on July 3, June 20, and June 25, respectively.

Another cross sectional survey was conducted from 25 August to 27 August 2002 at the three bridges to examine the change of riverbed elevation. The results of cross sectional survey in the Bucao, Maloma, and Sto. Tomas River are shown in Figure 5.3.2.

Comparing the results of cross sectional survey in June, July, and August, there is a similar trend in the Bucao and Maloma Rivers that riverbed degradation is predominant in the low water channel. On the other hand, riverbed aggradation was observed in the high water channel. Riverbed aggradation was remarkable at the downstream of the Maculcol Bridge with rise of more than 2 m averagely.

(2) Rating Curves

Figure 5.3.3 shows the rating curves in the Bucao and Maloma Rivers. The relationship of water level and discharge (H-Q) is plotted based on the entire series of discharge measurements at the downstream of the Bucao and Maloma Bridge during the flood in July 2002. The rating curves are shown as regression curves for each plot. Estimated discharges using the results of velocity measurements during the flood in July with the cross sectional areas in August are also plotted as a reference.

It is found that a single rating curve cannot be adapted to any river in the study area. That is because the three rivers in the study area indicate significant changes on cross section during rainy season due to dynamic riverbed aggradation and degradation caused by floods with high concentration of sediment.

5.3.5 Runoff Coefficient

Observed discharge during the flood in July 2002 was compared to the discharge simulated with the HEC-HMS established for this study area. The observed discharge and simulated discharge are shown in Figure 5.3.4. Runoff coefficient was calculated for both kinds of discharges in the Bucao River basin to verify the validity of observed and simulated discharges. As a result, the simulated discharge indicates large coefficient of runoff (80%). The observed discharge shows significantly small coefficient of runoff (40%). This is too small to verify the characteristic of high runoff in the study area due to heavy rain. It is estimated that the abnormal runoff coefficient in the observed discharges was caused by the following reasons:

(1) Riverbed Degradation during Flood

The results of cross sectional survey indicate that the flood in July 2002 caused riverbed degradation in the low water channel. It implies that the riverbed scouring would be greater during the flood. Without riverbed degradation, it is possible that higher water level would have been observed during the flood resulting in greater discharge.

(2) Storage Effect of Lahar Deposits

It is found that a huge amount of lahar deposits exists along reaches in the study area, especially in the Bucao and the Sto. Tomas Rivers. There should be large amount of seepage into such lahar deposits during floods if the deposits are dried before floods. Such storage effect in lahar deposits contributes to the loss of runoff resulting in small coefficient of runoff observed during the flood in July. The presumed phenomenon of storage effect of lahar deposits is shown in Figure 5.3.5.

Considering the seepage phenomenon, discharge data since 1990 would not be applied because of big storage effect in lahar deposits. It is recommended to study further about the storage effect of lahar deposits to estimate more accurate discharge in the Bucao and Sto. Tomas Rivers.

5.4 Floods in May 2003

5.4.1 Overview

The stud area suffered from heavy rain at the end of May 2003 because of the typhoon Linfa (or Chedeng in the Philippines) which occurred from 24 May to 2 June 2003. The typhoon did not cause breach of the existing dike in the three rives, Bucao, Maloma, and Sto. Tomas Rivers, or overflow of floods over the dike but inundation in the plain lowland area along the National Highway No.7.

In particular, there was severe inundation along the Maloma River from the confluence with the Gorongoro River to the small creak at 4.0 km upstream of the Maloma Bridge because the breach portions along the existing dike had not been repaired since the flood in July 2002.

5.4.2 Rainfall Observation

Rainfall data during the occurrence of the typhoon was collected from four rainfall gauge stations: one from PAGASA at Iba with six hour rainfall and three hourly data from the installed one by the study team at Baquilan, Paete and Mapanuepe. The recorded rainfall is shown in the following table.

Daily Rainfall Record during the Typhoon in May 2003 (Unit: mm)

Date	Iba	Baquilan	Paete	Mapanuepe
	PAGASA	Study Team	Study Team	Study Team
5/24	67.1	-	-	-
5/25	51.8	-	-	-
5/26	153.2	-	-	-
5/27	-	216.1	155.2	125.5
5/28	-	75.9	192.0	205.2
5/29	-	127.8	24.1	10.4
5/30	-	178.0	121.2	127.2
5/31	-	67.6	42.7	69.6
6/1	-	105.9	27.4	48.0
6/2	-	59.7	49.5	127.3
Accumulated	272.1	831.1	612.2	713.2
Max. Daily	153.2	216.1	192.0	205.2
Max. 2 days		305.8	347.2	330.7
Max. 3 days		419.8	371.4	342.8
Max. 4 days		597.9	492.5	468.3
Max. 5 days		665.4	535.2	537.9

Note: "-" indicates no available data

Comparing the point rainfall record with the probable rainfall in Iba shown in Table 2.3.1, it was estimated that probability of rainfall due to the typhoon Linfa was 2 to 5 year.

5.4.3 Water Level Observation

Water level was observed every hour during the storm and three times a day without the storm at three bridges, Bucao, Maloma and Maculcol Bridges by the gauge keepers employed by the study team. Records of water level at the bridges are shown in Figure 5.4.1 with hyetograph of the nearest rain-gauge station.

Results indicate that the peak of water level was observed on 27 May at the Bucao Bridge due to the heavy rainfall on the same day. At the Maloma Bridge, two peaks were recorded on 27 and 28 May with similar levels each other. It is noted that surface water in the Sto. Tomas River had not been observed until 6:00 a.m. on 28 May, 2003, which was 4 days after the occurrence of the typhoon. It implies that accumulated rainfall from 24 to 27 May can be regarded as initial loss for the flood.

5.4.4 Cross Section Survey

To monitor riverbed change by the flood in May 2003, cross section survey was conducted after the flood at the immediate downstream of the Bucao and Maculcol Bridges by the study team. The results are shown in Figure 5.3.2.

It is shown that the riverbed at the both bridges was scoured down to the same elevation as the original in June 2002. As a result, it is assumed that riverbed elevation would fluctuate above the existing level as of June 2003 with the range of approximately 2 m at the Bucao and Maculcol Bridges.

5.5 Recommendation on Future Discharge Measurement

As is explained in the section 5.3.5, there was considerable difference between observed discharge by the study team and simulated discharge with the flood runoff model developed in the study. Therefore, the runoff model should be calibrated and updated through continuous discharge measurements in future. The purpose of future discharge measurement is to provide necessary data for calibration of the runoff model and revise the design probable flood if necessary.

5.5.1 Bucao River

Continuous discharge measurement during floods is strongly recommended in the Bucao River to improve the rating curve of relationship between water depth and discharge (H-Q). Regular water level observation is also recommended at the Bucao Bridge. Accumulation of these data is necessary to improve the runoff model.

However, it is noted that relatively small peak discharge in terms of surface water is likely to be observed at the immediate downstream of the Bucao Bridge as mentioned in the section 5.3.5. It is assumed that riverbed scouring during flood at the measurement section is one of the major reasons for the small peak discharge because riverbed scouring prevents water level from increasing. If the riverbed scouring during the peak of flood is measured, flow area can be estimated more accurately resulting in more reliable peak discharge data. Probable peak discharge is related to design of structures. Therefore, it is important to measure peak discharge during flood.

Figure 5.5.1 shows proposed measurement system for riverbed scouring during flood at bridge. In the system, range of riverbed scouring can be measured with the movement of steel bar inside a transparent pipe attached to the pier. Each installed steel bar stays on the riverbed before flood. During flood, the steel bar will descend as riverbed is scoured by the water flow with large velocity. At the end, riverbed will be elevated with sediment deposits. On the other hand, the lower portion of steel bar will stay under the riverbed. Finally, range of riverbed scouring will be measured with difference in the elevation of the top of the steel bar before and after flood.

Based on the measured riverbed scouring, flow area during flood will be determined more accurately. Using the obtained flow area, discharge is calculated with water level and velocity through discharge measurement. It is assumed the measured discharge with the proposed system would show greater peak discharge than without case. The improved peak discharge should be applied for calibration of the runoff model with rainfall data.

5.5.2 Maloma River

As well as the Bucao River, continuous water level observation and regular discharge measurement are recommended at the Maloma Bridge. Accumulated discharge and water level data are useful to improve the rating curve of relationship between water depth and discharge (H-Q) and the runoff model.

It is estimated that sediment deposition is not serious in the Maloma River channel. Riverbed scouring would not be predominant at the discharge measurement section at the downstream of the Maloma Bridge. Therefore, the proposed measurement system for riverbed scouring will not be necessary for the discharge measurement in the Maloma River.

5.5.3 Sto. Tomas River

It seems impossible to measure accurate discharge during flood and water level at the Maculcol Bridge because the clearance between riverbed and the bridge is so small that water level at the immediate downstream of the bridge is constant resulting from clogging of water flow. Such condition with small clearance would continue for the next 20 years as riverbed near the Maculcol Bridge has tendency of aggradation based on the riverbed movement analysis in the appendix IV.

It is not recommended to conduct water level observation and discharge measurement in the near future unless the present condition is changed significantly. However, discharge measurement would be possible when the clearance at the bridge becomes enough by reconstruction of the bridge.

Because of the difficulty in discharge measurement, the runoff model for flood in the Sto. Tomas River might not be improved. Similar parameter in the runoff model for the Bucao and Maloma Rivers can be applied to the Sto. Tomas River if appropriate calibration data is not available in the Sto. Tomas River.

CHAPTER 6 WATER QUALITY

6.1 Water Quality Monitoring Activity

The Bureau of Research and Standards (BRS) in DPWH conduct water quality monitoring in selected rivers throughout the Philippines. For rivers in Region III, Materials, Quality Control and Hydrology Division the DPWH Region III Office in San Fernando City is designated as the responsible organization for collecting water samples under the National Water Collection Program. Water samples are collected on a quarterly basis at present.

For the Bucao and Maloma Rivers water quality data for basic parameters over seventeen years were found and are shown in Tables 6.1.1 and 6.1.2, respectively. Monitoring for the Sto. Tomas River is presently ceased, however, some limited water quality data from the past was also available and is shown in Table 6.1.3. All samples are taken at the respective bridges along the No.7 national highway. Through interview, it was found that the missing data in the tables are most often attributed to broken monitoring equipment, lack of monitoring materials or misplaced data.

Upon inspection of the reported results, some values can be regarded as questionable, such as a sudden twenty-fold increase in chloride value of 1400 mg/l for the Bucao River on March 16, 1990. Reasons for such errors can be due to a number of factors such as erroneous sampling location, erroneous meter reading, erroneous data transfer and mis-calibration of equipment. Nevertheless, the data provides an excellent snapshot of the state of the rivers for both pre- and post-eruption as discussed below.

The most obvious conclusion from the historical water quality results is the significant increase in mineral load after the June 1991 eruption for both the Bucao and Maloma Rivers. The pre-eruption characteristics for both rivers were that of relatively neutral water, with some hardness and some mineral content, all comparable to other rivers draining from Mount Pinatubo. The post-eruption characteristic was that showing a two to three fold rise in electric conductivity, hardness, chlorides, while alkalinity increase was less significant. Most of the alkalinity was in the form of the bicarbonate ion, coinciding with the pH results.

The significant increase in hardness, coupled with the relatively insignificant rise in alkalinity implies that non-carbonate hardness (such as calcium sulfate and magnesium sulfate) is the major contributor to the increase in hardness after the eruption. Therefore, it can be inferred that the ash fall and pyroclastic material contains high calcium, magnesium and sulfate.

Further inspection of the most recent data shows that the values are gradually resuming their pre-eruption levels. Therefore, it can be concluded that the sudden 'jack' in concentration was probably due to ash fall and pyroclastic deposits that washed into the rivers, either through direct mixing or leaching.

The two rivers themselves show a contrasting degree of severity for pre- and post-eruption. While the Maloma River tended to double in concentration after the eruption, it was common to see values tripled in the Bucao River. This is most likely due to the more direct exposure of the Bucao/Balin-Baquero River system to the summit, together with the shadowing effect of Mt. Quimalogong (El. 947 m), Mt. Nagdayap (El. 942 m), Mt. Binawawan (El. 840 m) and Mt. Maquinang (El. 784 m) on the Maloma River. It is hypothesized that if samples were taken in upper reaches of the Maloma, values closer to those in Bucao would be expected. For the limited Sto.Tomas River results, a relatively high electric conductivity was found while other values were relatively normal.

Seasonal examination of the post-eruption water quality show some indication of a trend during the wet season, the levels had a tendency to decrease in concentration, mainly as a result of the 'washing-out' effect of the rain. On the other hand, during the end of the rainy season, the concentrations had a tendency to rise as washed out material began to deposit from the decreased stream flows. The complete set of water quality data, if it could be found from the archives, could validate this trend. Furthermore, given the duration of collected data, it may even be possible to extrapolate the number of years required for the water chemistry to return to pre-eruption levels.

Table 6.1.4 shows water quality data reported in "Fire and Mud", 1996, for the Mount Pinatubo Crater Lake. They reported that the lake water increased from a slightly acidic level to a very acidic level within a year of eruption, together with an increase in chloride, sulfate and hardness level which is common in volcanic areas. Such increases in levels are attributed to not only the exposed crater geology, but also from the buffering effect of gases arising through cracks and fissures after the eruption. This is also true for the outer slopes as well via springs which also contribute to the increase in sulfate and chloride levels for the Bucao and Maloma Rivers.

Table 6.1.5 shows water quality data reported in "Mapanuepe River-Lake Irrigation Project, Feasibility Report", 1996, conducted by the National Irrigation Authority (NIA). The results show that electrical conductivity is lower than that historically obtained at the Sto. Tomas River in Table 6.1.3 and that furthermore, the levels would not cause damage to crops. The fact is that all alkalinity is in the form of bicarbonate conforms with the pH reading of 7.5. Also, a high concentration indicates that some of the hardness is non-carbonate hardness, a characteristic also found in the Bucao and Maloma Rivers as mentioned above.

6.2 Water Quality Monitoring

6.2.1 Water Quality Monitoring in 2002

Six locations throughout the study area were selected to conduct water quality monitoring to ascertain the present health of the water. The six locations are shown in Figure 6.2.1. Two rounds of testing were made, once in the dry season and once in the wet season, for the purpose of picking out any seasonal relationship. At all sampling locations, temperature, pH and electric conductivity measurements were conducted in the field. In addition, 24 other parameters were tested on laboratories in Manila.

The aim of the testing was to determine the state of water quality in the three rivers at present. The results for 26 parameters are shown in Table 6.2.1, along with relevant Philippine Criteria and WHO guidelines (Criteria and Guidelines). Note that Class AA standards refer to drinking water without treatment, Class C standards refer to fishery and Class D standards refer to irrigation use.

(1) Round 1 Results

The Bucao River results (sample 1 and 2) showed indications of urbanization where the downstream values for BOD, COD, nitrogen and iron increased while pH and DO decreased. This difference is believed to be attributed to addition of small quantities of waste water arising from Baquilan Resettlement Center and San Juan Barangay. Increases in other parameters are believed to be from non-artificial sources. In comparison to historical values in Table 6.1.1, chlorides, magnesium and calcium were in an appropriate range however, electric conductivity showed a considerably high value, rivaling values immediately after eruption. In comparison to the Criteria and Guidelines, there is some cause for concern for arsenic, phenols, copper and sulphate.

The Maloma River sample was taken at one location only which was the Maloma-Gorongorong River confluence (sample 3). Results showed levels comparable to that of the Bucao upstream, indicating low urban activity in the upstream of both rivers. Sulphate is again a concern, being the highest of the three rivers. In comparison to the historical values, chloride and hardness levels are close to or below pre-eruption levels.

The Mapanuepe Lake outlet (sample 4) shows signs of urban activity due to similar values to that of the Bucao downstream (sample 2) for BOD and COD. No signs of eutrophication are indicated, as organic load and nitrogen levels are low. Levels of copper were over standards for fishery however, is lower than near the copper mine source, indicating some lake dilution. Conductivity is in line with historical values and is considered acceptable for irrigation, as concluded in the NIA report. The only other cause for concern for fish growth would be iron, manganese and conductivity which are all in exceedance of allowable DENR levels.

The Marella River (sample 5) results showed higher values of calcium, chloride, conductivity, manganese, iron, sulphate and COD, indicating that characteristics of lahar related material continue to be flushed out in water. Meanwhile, the decrease in BOD and increase in DO justify the claim for urbanization (perhaps Aglau Barangay) at Mapanuepe.

The Crater Lake results (sample 6) show that the water is still abnormally high in conductivity, chloride, cyanide, sulphate and arsenic. At such concentration, exposure to skin could cause irritation and cause eyes to turn red. The initial acidic condition in 1991 and 1992 appears to have returned to a neutral state.

The Round 1 results showed that parameters which have been historically high continued to persist, however other parameters, such as heavy metals, were in minute quantities or non-detectable.

(2) Round 2 Results

Round 2 results show that some constituents increased and some decreased in water quality as a result of the wet season. In all cases, none of the water quality criteria were exceeded to a noticeable degree.

The Bucao River upstream showed slightly better water quality during the wet season than the downstream. The general trend was to see an increase in iron, manganese, zinc, copper due to flushing, while organic matter and dissolved oxygen from the small communities decreased.

The Maloma River showed similar trends. Lake Mapanuepe outlet water quality indicated that the wet season helps to dilute the water as indicated by the decrease in levels in many parameters. The same is true for the crater lake water quality.

The Marella River however, had a general increase in most parameters, indicating that flushing of naturally occurring constituents continues to exist.

6.2.2 Water Quality and Bottom Material Monitoring in 2003

(1) Sampling Locations and Items

Additional water quality and bottom material survey was conducted in January 2003. The locations of the samples are shown in Figure 6.2.2. The samples were collected at the Dizon Copper Mining Dam reservoir (one location) and Mapanuepe Lake (four locations) to determine the appropriateness of the Mapanuepe Lake water for irrigation, fish hatchery and recreation use.

At each location, two water quality samples (surface and mid-depth) and one bottom material sample was obtained. The analysis of samples was carried out in a laboratory in Manila. Water samples were analyzed for 28 parameters and the bottom material was analyzed for 16 parameters.

Based on site inspection, there are no large-scale municipal or industrial discharge sources around Mapanuepe Lake. The Dizon Copper Mining Company dam is located on the eastern side of Mapanuepe Lake. According to local authorities, the reservoir had been used for storage of mine tailings. Operations were ceased in 1997 and at present, the mine is not in operation.

(2) Comparison to Standards

Table 6.2.2 shows the water quality results with Philippine Class C standards for fishery and Class D standards for irrigation. Table 6.2.3 shows the bottom sediment results.

For the Dizon Dam reservoir, the water quality standards were exceeded for pH, mercury, lead, iron, manganese, fluoride and copper. For Mapanuepe Lake, standards were exceeded for mercury, lead, manganese, phenols and copper. Although values that exceed standards are very important, three of the results in particular are noteworthy.

First of all, mercury was detected in two samples. The values were approximately two orders of magnitude greater than the Philippine standards. Further, if compared to the more stringent Japanese environmental standard of 0.0005 mg/l, the values would be three orders of magnitude greater. Such levels would be even greater than normal industrial levels. At these levels, one can say that levels are abnormally high and that the Mapanuepe Lake water would be very harmful for fishery and for irrigation.

The second noteworthy value was for manganese. All samples were far greater than the Philippine standard for agriculture/irrigation with three orders of magnitude. The values are about 900 mg/l for the Dizon Dam reservoir and around 300 mg/l for the whole portion of Mapanuepe Lake though the Philippine standard for agriculture and irrigation was limited to 0.2 mg/l. It would be also harmful for fishery though there is no water quality standard for fishery, recreation and industry.

The third noteworthy value was for lead. All samples were greater than the Philippine standard for fishery. The Japanese environmental standard for rivers is 0.01 mg/l and the standard for freshwater fish is 0.001 mg/l. For fear of lead poisoning, the Mapanuepe Lake water should not be used for irrigation or fishery without prior treatment.

The fourth noteworthy value was for copper. The Philippine standard for fish is exceeded at seven of the ten values. Compared to the Japanese standard for rice growing, 0.02 mg/l[1], all values are exceeded. Due to the toxicity of copper to fish and to rice, again the Mapanuepe Lake water should not be used without prior treatment.

The pH levels at Mapanuepe Lake were between 6.02 and 6.65 which would be considered somewhat low. The Dizon Dam pH was measured to be 3-4 and would be considered abnormally low for natural waters. Commonly, a value below 5 would indicate that some external factor is influencing the pH. In this case, the dam tailings would be the major suspect, while the eruption material and natural geology may also has some effect but to a lesser degree. A low pH is significant because it could cause an increase in concentration of metals, as the water would ionize the metal solids contained in the bottom material. This may be part of the reason for the high concentrations of mercury, iron, manganese, zinc, lead and copper.

(3) Other Notable Results

Although not exceeded by the Philippine standards, some other notable comments are given below.

First, the values for zinc were high. In Japan, the standard for rice growing is 0.5 mg/l and for fish in freshwater is 0.001 mg/l. Zinc is particularly toxic to rice and therefore, should be closely monitored in the future.

Next, the organic content as indicated by BOD and COD were fairly low, indicating that organic

[1] ‘Mizu Syori Binran’ (Water Treatment Handbook, in Japanese) , Maruzen Publications.

pollution of Mapanuepe Lake was not a problem. One small exception was at location D., D/S near channel, where the values were higher than at the other locations and should be verified in future monitoring. Similar trends can also be seen for nitrates.

With regard to sulphate concentration, the value in the Dizon Dam was high although it did not exceed standards. Sulphate concentrations of rivers are usually less than 100 mg/l and therefore, should be cause for some concern.

(4) Inconsistencies and Deficiencies

Examination of the results also reveals a few inconsistencies and deficiencies, as noted below.

First, in Mapanuepe Lake, one location on the surface indicated mercury to be extremely high while those in the other three locations were under detection limits. The detected location is away from the dam reservoir and therefore, is a suspicious value. On the other hand, mercury were detected from all the bed materials sampled from the five locations, one from the Dizon dam reservoir, and four from the bottom of Mapanuepe Lake. It is stressed here again that the value itself, 0.42 mg/l, is abnormally high and further tests should be conducted.

Next, regarding the detection limit of mercury, 0.004 mg/l, it is noted that this is a limitation of the measuring equipment and does not imply that mercury is not present. This can be supported by the presence of mercury in bed sediment concentrations. Since it appears that mercury is present, equipment with lower detection limits should be used for further monitoring. The reason for using more sensitive equipment to detect mercury is that the possibility of adverse effects exists at concentrations below the 0.004 mg/l detection limit, based on experiences in Japan.

Next, in the presence of manganese, it is common that iron is also present. While this was the case for the Dizon Dam, this was not observed for the remaining results. On the other hand, high concentration of the iron was detected from the bed materials sampled from five locations. Nevertheless, the high values for manganese should be of some concern.

6.2.3 Conclusions and Recommendations

The laboratory results indicated that seven parameters exceeded the Philippine standards for fishery and irrigation at the Dizon Dam and four parameters were exceeded in Mapanuepe Lake. Of the exceeded results, the results for mercury, lead and copper showed cause for concern. Only two samples contained mercury but the values were abnormally high. All samples contained manganese, lead and most of the samples contained copper. Apart from the above three parameters, levels of zinc were found to be high.

Based on the discussion in the preceding sections, it can be said that the sampled area is not typical of that in natural river water, indicated by the relatively low overall value of pH. Since there are no municipal or industrial discharge sources in the area, it can be said that the high values are caused by a combination of the Dizon Copper Mining Dam tailings, the erupted material and the background geology. Based on the results, it is recommended that the Mapanuepe Lake water not be utilized for irrigation, fish hatchery or recreation. The detected results are extremely high for mercury, manganese, lead and copper.

Since the samples were taken only once, and since some inconsistency was noted in the results, it is recommended that additional sampling and laboratory analysis be conducted. It would be preferable to conduct sampling in short regular intervals, say monthly or even bi-weekly, in order to detect any seasonal trends. In addition, it would be desired if the laboratory acquire a measuring device that has a lower detection limit for mercury than that used during the survey.

Another recommendation is that the regular health check for the people resided surround Mapanuepe Lake shall be conducted. It is worried that heavy metal contained in the water might be accumulated to the human body through the food / water, which may be affected by the water quality. Also the regular examination of fishes and crops in and around the lake is recommendable.

If the results are verified, and if it is still desired to use the water for irrigation, fish hatchery or recreation, treatment prior to usage would be required. In such cases, chemical treatment such as flocculation or precipitation removal would be required. Such treatment processes are generally expensive and would not be economically justified. Under the financial conditions, it may be preferable to let the concentration values decrease over time.

CHAPTER 7 INSTALLATION OF HYDROLOGICAL MONITORING EQUIPMENT

To strengthen the monitoring network within the western Pinatubo area, four automatic rainfall gauges and three manual-read water level staff gauges were installed during the study period. Their locations are shown in Figure 7.1.1 and a location description is given in Table 7.1.1 and Table 7.1.2 for rainfall and staff gauges, respectively.

7.1 Rainfall Gauges

In order to grasp the rainfall pattern variation between the eastern and western side of Mount Pinatubo, one rainfall gauge was installed on the eastern side and three rainfall gauges were installed on the western side of Mount Pinatubo. To decide the location of each gauge, considerations for scientific usefulness (such as higher elevation and proximity to the summit) were balanced with practicality (such as accessibility and prevention of vandalism).

Each station has a 4 m x 4 m reinforced concrete slab floor. An opening in the middle of the slab was left to set the gauge. This opening was also necessary to set the ground cable. In order to provide stability to the gauge, permanently embedded steel stilts on both sides of the gauge were provided. The station was also equipped with a cyclone wire mesh fence with access door and lock for protection.

The raingauge itself is a tipping bucket type with automatic data logger. Rainfall is collected in a standard aluminum cylinder and rainfall amount is recorded by the logger according to the number of tips of the bucket. Data is retrieved by data logger to a laptop computer, via special serial connector cable. Computer software is also required for the interfacing. All four rainfall gauges were set for hourly rainfall observation but can be changed if necessary. For the three rainfall stations on the western side, three gauge keepers were retained for protection of the gauge. Another rainfall gauge in the eastern side is maintained by the DPWH Region III Office.

7.2 Water Level Gauges

The staff gauges were installed on the Bucao, Maloma and Maculcol Bridges in consideration of accessibility, stability and ease of obtaining data. Thirty pieces of one-meter staff gauges were procured locally for the installation.

Three staff gauge keepers for the three locations were retained to take water level recordings. Water level readings was taken three times a day (6:00 a.m., 12:00 p.m. and 6:00 p.m.) during normal condition and increased to an hourly basis during stormy conditions.

7.3 Required Operations and Maintenance

(1) Permits and Approvals

Prior to installation, consultation with the municipal staff and local authorities' barangay captains were conducted to ascertain the land ownership for the gauge sites. The status of ownership and the approvals obtained are explained as follows.

The Baquilan Resettlement Center rainfall gauge is situated on public property owned by the Municipality of Botolan. The municipality requires a work permit for any construction work and therefore, a permit was applied for and issued to the study team. No other agreements were necessary.

The Paete Elementary School rainfall gauge is situated within the Municipality of San Narciso on school property owned by the education ministry. A memorandum of agreement between the municipality and the team was signed.

The Mapanuepe Lake rainfall station is situated on public property owned by the Municipality of San Marcelino. A memorandum of agreement between the municipality and the team was signed.

The DPWH-Region III rainfall station is situated within the office compound and therefore, direct order from DPWH head office was given for its installation. The three water level gauges are set on bridges along National Highway No.7. Therefore, no agreements were necessary under the property of DPWH.

From the above, it will be necessary to re-sign a memorandum of agreement for the Paete Elementary School and Mapanuepe rainfall stations.

(2) Upkeep Activity

The rainfall gauges and water level gauges will require upkeep for continuous monitoring. The major activities are operation and maintenance/data retrieval, cross section measurement and discharge measurement.

1) Operation and Maintenance/Data Retrieval

Operation and maintenance is the regular checking of equipment to ensure they are working properly. At the same time, data retrieval is also required.

Operation and maintenance of the rain gauges consists of replacing a rechargeable 6-volt, 8 amp-hour lead acid battery for the logger. Prior to replacement, charging of each battery is required. The manufacturer recommends charging every two months however, given the rainfall amount in the study area, monthly replacement is recommended as battery is consumed when readings are made.

When reaching the station, the aluminum cylinder should first be checked for obstructive items and removed prior to accessing the logger inside. If rain is found in the cylinder, then the drainage holes in the gauge are clogged and require cleaning. The stored rainwater should be carefully placed in a bucket, the aluminum cylinder removed and cleaned, and then the rainwater should be passed through the gauge and recorded as a total amount. Hourly and daily data will be lost in this case, however monthly and annual totals can still be computed.

Data retrieval consists of connecting the logger to a laptop computer via serial port and uploading it in text format. Regular backup of data is recommended.

The water level gauges are installed on bridge piers and should be checked periodically for damage or wear. If debris covers the staff during a storm, it should be as soon as possible, considering safety. Data is recorded by the water level gauge keeper. The records are to be collected and new sheets of form to be filled out given during each visit.

2) Cross Section Survey

Cross section survey serves two purposes. First, the survey result will be used to calculate flow after discharge measurements are made. Second, it can provide some indication on how the riverbed changes over time.

For the three rivers, the only suitable location to set the staff gauges was on the bridges along National Highway No. 7. Because of the fact that the river bed continues to change during a flood, it is desirable to measure the cross section after each flood. This may be impractical due to resource or safety limitations. It is therefore proposed that one measurement at the minimum be taken during the year, after the rainy season is over. This measurement can be conducted in-house by DPWH staff, or it may be contracted to a local surveying firm.

3) Discharge Measurement

A rating curve was developed using historical DPWH discharge measurements as well as the study team results. However, refinements to the curve should be made from time to time and therefore, continued discharge measurements should be conducted. The measurement should be made by use of floats when heavy rains cause the water level rising. It is desirable to make three to five separate measurements for each river as the water level rises or decreases. Due to the nature of storms, two days should be allotted for discharge measurement.

Measurement will made by throwing floats into the river from predetermined areas on the bridge. The start and end time for floats to pass by a designated stretch of the river are recorded to determine the velocity. Finally, the water level during the measurement is recorded which can then be used to compute the discharge.

If the measurement crew will be Manila based, it will be difficult to make measurements when a specific water level for the rating curve is desired. It is recommended that close contact be made with the DPWH Region III Office as well as the weather forecasts before setting out.

4) Equipment

Suggested equipment for maintenance and data collection are as follows.

- off-road vehicle for accessing site(1 vehicle)
- laptop computer for rainfall data download (1 unit)
- special serial cable for rainfall data download (1 piece)
- rechargeable battery (4 units + 4 spare units)
- battery charger (1 unit)
- hammer, screwdriver and other basic tools (1 set)
- keys for rainfall gauge fence lock (4 sets)
- water level recording sheets (as required)
- paper towels and rag cloth (as required)
- bucket (1 piece)

Suggested equipment for cross section survey is as follows.

- range finder with bracket (1 unit)
- tripod (1 unit)
- staff rod with reflector (1 piece)
- signal flags (2 flags)
- spray paint and stakes (2 cans of different color)
- tools (1 set)
- raincoat and towels (as required)
- whistle and camera (Each 1 unit)

Suggested equipment for discharge measurement is as follows.

- floats (as required)
- signal flags (2 flags)
- stop watches (1 piece)
- spray paint and stakes (2 cans of different color)
- tools (1 set)
- raincoat and towels (as required)
- whistle
- camera (1 unit)

Tables

Table 1.2.1 Monthly Mean Rainfall, Temperature, Relative Humidity for Regional Synoptic Stations

Rainfall (mm)

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Iba	3.2	5.2	16.5	30.3	295.8	489.2	839.3	1019.3	514.4	272.7	78.1	15.0	3579.0
Manila Port	19.0	7.9	11.1	21.4	165.2	265.0	419.6	486.1	330.3	270.9	129.3	75.4	2201.2
Cabanatuan	8.4	9.8	17.3	29.6	179.1	250.4	368.4	381.9	307.3	207.2	104.2	40.6	1904.2
Dagupan	8.0	6.1	17.6	52.8	204.4	331.8	535.8	608.6	362.2	200.6	53.4	10.4	2391.7
Baguio	12.1	11.7	29.3	92.3	355.4	436.6	838.4	911.8	581.2	461.8	124.6	23.7	3878.9

Temperature (degrees Celcius)

Station		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Average
Iba	Max	30.8	31.3	31.9	33.1	32.7	31.4	30.4	29.9	30.5	31.3	31.4	31.1	31.3
	Min	20.4	20.7	21.6	23.2	23.5	23.3	22.9	22.7	22.8	23.1	22.5	21.5	22.4
	Mean	25.6	26.0	26.7	28.1	28.1	27.4	26.6	26.3	26.7	27.2	26.9	26.3	26.8
Manila Port	Max	29.5	30.5	32.1	33.5	33.2	32.2	31.1	30.6	30.9	30.9	30.7	29.7	31.2
	Min	23.5	23.8	24.9	26.2	26.7	26.2	25.8	25.5	25.5	25.5	24.9	23.9	25.2
	Mean	26.5	27.1	28.5	29.9	30.0	29.2	28.5	28.1	28.2	28.2	27.8	26.8	28.2
Cabanatuan	Max	31.4	32.2	33.3	35.0	35.1	33.7	32.5	31.7	32.2	32.3	32.3	31.5	32.8
	Min	20.3	20.8	21.5	23.1	23.9	23.9	23.6	23.5	23.4	23.0	22.2	21.2	22.5
	Mean	25.8	26.5	27.4	29.0	29.5	28.8	28.1	27.6	27.8	27.7	27.2	26.3	27.6
Dagupan	Max	30.9	31.9	33.4	35.1	34.3	33.2	32.0	31.3	31.8	32.0	31.8	31.0	32.4
	Min	20.9	21.4	22.6	24.4	24.8	24.6	24.3	24.2	24.2	23.9	23.0	21.6	23.3
	Mean	25.9	26.7	28.0	29.7	29.5	28.9	28.2	27.7	28.0	27.9	27.4	26.3	27.9
Baguio	Max	23.1	23.9	25.1	25.7	25.0	24.4	23.4	22.5	23.5	23.9	23.9	23.3	24.0
	Min	12.9	13.2	14.3	15.7	16.3	16.5	16.2	16.1	15.9	15.7	15.0	13.8	15.1
	Mean	18.0	18.6	19.7	20.7	20.7	20.5	19.8	19.3	19.7	19.8	19.5	18.6	19.6

Relative Humidity

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Average
Iba	74%	75%	74%	73%	77%	82%	85%	86%	86%	82%	78%	76%	79%
Manila Port	71%	68%	65%	65%	70%	76%	79%	81%	80%	78%	75%	74%	74%
Cabanatuan	76%	74%	74%	72%	76%	82%	86%	87%	86%	84%	81%	77%	80%
Dagupan	77%	76%	74%	74%	78%	82%	85%	87%	85%	82%	80%	78%	80%
Baguio	83%	81%	80%	82%	87%	88%	91%	93%	90%	87%	84%	82%	86%

Table 2.1.1 Annual Maximum Daily Rainfall in the Study Area

(mm/day)

Year	Station		
	Iba	Sta. Rita	San Marcelino
1976	543	610	363
1977	291	326	439
1978	196	341	222
1979	398	471	472
1980	281	249	131
1981	183	162	163
1982	321	258	188
1983	190	157	214
1984	263	137	156
1985	285	314	281
1986	218	334	217
1987	172	211	143
1988	191	197	135
1989	184	194	135
1990	175	207	200
1991	183	281	220
1992	325	109	190
1993	242	250	281
1994	168	212	112
1995	176	163	100

Table 2.2.1 - Correlation Coefficients for PAGASA Raingauges

(before screening)

	Iba	Palawig	Santa Rita	San Filipe	San Marcelino	Becuran
Iba		0.64	0.84	0.57	0.73	0.52
Palawig			0.63	0.39	0.63	0.51
Santa Rita				0.59	0.74	0.53
San Filipe					0.59	0.43
San Marcelino						0.57
Becuran						

Table 2.2.2 - Correlation Coefficients for PAGASA-PHIVOLCS Raingauges

(before screening)

	201 EL.980	202 EL.440	203 EL.550	204 EL.580
Iba EL.5.4	0.204	0.309	0.435	0.573
Santa Rita EL.22	0.291	0.350	0.496	0.672
San Marcelino EL.29.5	0.158	0.319	0.434	0.603
Becuran EL.17.5	0.199	0.268	0.506	0.540
201		0.583	0.153	0.418
202			0.619	0.536
203				0.646

Number of Days for Correlation Calculation
(before screening)

	201 EL.980	202 EL.440	203 EL.550	204 EL.580
Iba EL.5.4	923	846	780	384
Santa Rita EL.22	688	662	487	374
San Marcelino EL.29.5	923	847	780	384
Becuran EL.17.5	892	816	749	384
201		424	407	341
202			564	356
203				169

Rainfall IncreaseFactor
(before screening)

	201 EL.980	202 EL.440	203 EL.550	204 EL.580
Iba EL.5.4	0.7	1.1	0.6	1.3
Santa Rita EL.22	0.9	1.3	0.6	1.2
San Marcelino EL.29.5	0.8	1.4	0.8	1.6
Becuran EL.17.5	1.3	2.2	1.2	2.3
201		2.0	2.3	0.9
202			0.9	0.9
203				2.0

Correlation Coefficients for PAGASA-PHIVOLCS Raingages
(after screening)

	201 EL.980	202 EL.440	203 EL.550	204 EL.580
Iba EL.5.4	0.445	0.391	0.458	0.573
Santa Rita EL.22	0.462	0.370	0.526	0.672
San Marcelino EL.29.5	0.395	0.316	0.469	0.603
Becuran EL.17.5	0.331	0.296	0.555	0.540
201		0.660	0.203	0.477
202			0.675	0.584
203				0.646

Number of Days for Correlation Calculation
(after screening)

	201 EL.980	202 EL.440	203 EL.550	204 EL.580
Iba EL.5.4	516	356	739	384
Santa Rita EL.22	562	317	446	374
San Marcelino EL.29.5	682	633	739	384
Becuran EL.17.5	743	655	709	384
201		214	346	312
202			518	200
203				169

Rainfall Increase Factor
(after screening)

	201 EL.980	202 EL.440	203 EL.550	204 EL.580
Iba EL.5.4	1.8	1.6	0.7	1.3
Santa Rita EL.22	1.5	2.0	0.7	1.2
San Marcelino EL.29.5	2.1	1.4	0.9	1.6
Becuran EL.17.5	2.2	2.8	1.4	2.3
201		1.8	1.6	0.7
202			0.9	0.6
203				2.0

*-screening refers to data set after removal of questionable values
(eg.: no rain recorded for enitre rainy season month but recorded as "0")
[shaded] not changed

Table 2.3.1 Point Rainfall for Duration

1 Day Rainfall	**2 year**	**5 year**	**10 year**	**20 year**	**25 year**	**50 year**	**100 year**
Iba	229	305	359	413	432	489	548
Sta. Rita	231	336	414	495	522	610	705
San Marcelino	198	284	346	410	431	499	571
Becuran	125	197	250	304	322	379	440
2 Days Rainfall							
Iba	343	463	555	654	687	797	917
Sta. Rita	366	507	606	704	736	836	941
San Marcelino	316	435	517	599	626	709	795
Becuran	187	288	360	433	457	534	613
3 Days Rainfall							
Iba	420	557	663	778	817	947	1,089
Sta. Rita	448	612	727	844	882	1,004	1,130
San Marcelino	398	541	636	727	756	846	936
Becuran	222	336	418	501	528	614	702
4 Days Rainfall							
Iba	486	640	755	874	913	1,041	1,179
Sta. Rita	529	719	852	987	1,031	1,172	1,319
San Marcelino	449	612	724	834	869	980	1,093
Becuran	254	380	649	558	587	679	773
5 Days Rainfall							
Iba	547	711	828	947	987	1,112	1,244
Sta. Rita	602	813	955	1,093	1,138	1,276	1,415
San Marcelino	496	674	800	925	966	1,096	1,232
Becuran	282	413	505	596	625	717	812

*based on 40 years of records ('61-'00)

Short-term rainfall at Iba Station

	2 year	**5 year**	**10 year**	**20 year**	**25 year**	**50 year**	**100 year**
1hr	68.3	86.6	101.0	114.8	116.3	131.9	148.2
6hr	139.0	180.6	210.4	241.9	248.9	281.9	316.3
12hr	178.7	235.2	275.3	316.9	328.3	371.7	417.1

*based on 40 years of records ('61-'00) and inference from FCSEC data

Table 2.4.1 Basin Mean Rainfall

	Weights		
	Bucao	Maloma	Sto. Tomas
Iba	0.082	0.000	0.000
Santa Rita	0.232	0.222	0.000
San Marcelino	0.000	0.468	0.612
204 (PHIVOLCS)	0.686	0.310	0.388

	2 year	5 year	10 year	20 year	30 year	50 year	100 year
Bucao River Basin							
1 -day	256.7	377.9	473.4	576.9	642.2	730.1	860.8
2 -day	420.1	587.5	707.7	829.9	903.4	998.8	1,134.2
3 -day	512.4	704.3	840.9	979.1	1,061.9	1,169.1	1,320.6
4 -day	609.8	830.6	985.4	1,140.3	1,232.4	1,351.0	1,517.5
5 -day	699.9	937.7	1,095.2	1,246.3	1,333.7	1,443.5	1,593.1
Maloma River Basin							
1 -day	203.2	308.9	399.0	502.4	570.2	664.7	810.8
2 -day	341.3	486.6	597.5	715.1	788.0	885.1	1,027.0
3 -day	430.7	596.1	720.5	851.2	931.6	1,038.1	1,192.6
4 -day	488.4	663.6	797.6	939.9	1,028.2	1,145.8	1,317.7
5 -day	579.7	783.0	925.4	1,067.6	1,152.2	1,261.0	1,413.6
Sto. Tomas River Basin							
1 -day	200.1	305.0	395.3	499.6	568.4	664.5	813.9
2 -day	339.7	484.6	593.2	707.0	777.0	869.3	1,003.2
3 -day	430.3	598.0	723.9	855.9	937.1	1,044.5	1,200.3
4 -day	492.4	680.0	822.8	974.1	1,067.8	1,192.4	1,374.4
5 -day	564.2	768.8	917.2	1,069.2	1,161.2	1,281.2	1,452.4

Table 3.1.1 Model Parameters (1/3)

Parameter	Bucao River B1 Balinbaquero1	B2 Balinbaquero2	B3 Lubao	B4 Maraunot	B5 Bucao1	B6 Balintawak	B7 Balinbaquero3	B8 Bucao2	B9 Bucao3	B10 Baquilan	B11 Bucao4	reach1	reach2	reach3	reach4	reach5	reach6
Subbasin Characteristics																	
Area (km2)	68.4	20.0	50.5	12.0	142.1	154.0	64.9	13.0	35.1	60.9	33.9						
Losses																	
Initial Loss (mm) *	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-
Loss Rate (mm/hr) *	2	2	2	2	2	2	2	2	2	2	2	-	-	-	-	-	-
Runoff																	
Length of longest reach, L(km)	18.0	6.9	16.4	11.1	30.2	21.1	14.5	4.6	11.1	13.7	9.5	-	-	-	-	-	-
Change in elevation, H (km)	1.2	1.3	1.4	0.6	1.0	1.7	1.3	0.4	0.8	1.6	0.7	-	-	-	-	-	-
Average Slope	0.066	0.190	0.082	0.055	0.032	0.079	0.091	0.088	0.072	0.114	0.075						
Convert to imperial units:																	
Length of longest reach, L(mi)	11.2	4.3	10.2	6.9	18.7	13.1	9.0	2.8	6.9	8.5	5.9	-	-	-	-	-	-
Change in elevation, H (ft)	3,900	4,300	4,400	2,000	3,200	5,400	4,300	1,300	2,600	5,100	2,300	-	-	-	-	-	-
Time Concentration (hrs)	1.8	0.6	1.5	1.3	3.4	1.9	1.3	0.5	1.2	1.2	1.0	-	-	-	-	-	-
Lag time (hrs)	1.1	0.3	0.9	0.8	2.1	1.1	0.8	0.3	0.7	0.7	0.6	-	-	-	-	-	-
Clark Storage (hrs)	18	6	15	13	34	19	13	5	12	12	10	-	-	-	-	-	-
Baseflow (cms)	7.0	2.1	5.2	1.2	14.6	15.9	6.7	1.3	3.6	6.3	3.5	-	-	-	-	-	-
Recession Ratio	1	1	1	1	1	1	1	1	1	1	1	-	-	-	-	-	-
Flood Routing																	
Routing Length(m)	-	-	-	-	-	-	-	-	-	-		3,400	13,900	4,800	5,200	1,000	6,000
Wave Velocity, v (m/s)	-	-	-	-	-	-	-	-	-	-		2.5	2.5	2.5	2.5	2.5	2.5
Musk K	-	-	-	-	-	-	-	-	-	-		0.38	1.54	0.53	0.58	0.11	0.67
Musk X	-	-	-	-	-	-	-	-	-	-		0.20	0.20	0.20	0.20	0.20	0.20

* - USACE & Pinatubo Hazard Urgent Mitigation Project Phase II

Table 3.1.1 Model Parameters (2/3)

Parameter	Maloma River M1 Maloma1	M2 Maloma2	M3 Maloma3	M4 Kakilingar	M5 Maloma4	reach1	reach2	reach3
Subbasin Characteristics								
Area (km2)	42.6	39.4	17.4	42.1	10.4			
Losses								
Initial Loss (mm) *	0	0	0	0	0	-	-	-
Loss Rate (mm/hr) *	2	2	2	2	2	-	-	-
Runoff								
Length of longest reach, L(km)	16.3	13.0	8.1	20.1	5.0	-	-	-
Change in elevation, H (km)	0.61	0.97	0.70	0.71	0.31	-	-	-
Average Slope	0.038	0.074	0.086	0.035	0.061			
Convert to imperial units:								
Length of longest reach, L(mi)	10.1	8.1	5.0	12.5	3.1	-	-	-
Change in elevation, H (ft)	2,000	3,200	2,300	2,300	1,000	-	-	-
Time Concentration (hrs)	2.0	1.3	0.8	2.4	0.7	-	-	-
Lag time (hrs)	1.2	0.8	0.5	1.5	0.4	-	-	-
Clark Storage (hrs)	20	13	8	24	7	-	-	-
Baseflow (cms)	7.4	6.8	3.0	7.3	1.8	-	-	-
Recession Ratio	1	1	1	1	1	-	-	-
Flood Routing								
Routing Length(m)	-	-	-	-	-	9,200	6,200	5,000
Wave Velocity, v (m/s)	-	-	-	-	-	2.5	2.5	2.5
Musk K	-	-	-	-	-	1.0	0.7	0.6
Musk X	-	-	-	-	-	0.2	0.2	0.2

* - USACE & Pinatubo Hazard Urgent Mitigation Project Phase II

Table 3.1.1 Model Parameters (3/3)

	Sto. Tomas River														
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11				
Parameter	**Marella1**	**Marella2**	**Marella3**	**Dizon**	**Algau**	**SantaFe**	**StoTomas1**	**StoTomas2**	**StoTomas3**	**TailingsPit**	**Mapanuepe**	**reach2**	**reach3**	**reach4**	**reach5**
Subbasin Characteristics															
Area (km2)	54.4	22.2	13.9	18.8	39.0	42.1	29.1	6.8	6.1	9.3	20.7				
Losses															
Initial Loss (mm) *	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-
Loss Rate (mm/hr) *	2	2	2	2	2	2	2	2	2	2	2	-	-	-	-
Runoff															
Length of longest reach, L(km)	13.6	8.2	7.2	5.1	5.9	17.0	12.0	4.5	7.9	5.2	3.0	-	-	-	-
Change in elevation, H (km)	1.50	1.30	0.40	0.90	1.02	0.62	0.44	0.29	0.09	0.90	0.82	-	-	-	-
Average Slope	0.110	0.159	0.055	0.175	0.174	0.037	0.036	0.065	0.011	0.172	0.274				
Convert to imperial units:															
Length of longest reach, L(mi)	8.5	5.1	4.5	3.2	3.6	10.5	7.4	2.8	4.9	3.2	1.9	-	-	-	-
Change in elevation, H (ft)	4,900	4,300	1,300	2,900	3,300	2,000	1,400	1,000	300	2,900	2,700	-	-	-	-
Time Concentration (hrs)	1.2	0.7	0.9	0.5	0.5	2.1	1.6	0.6	1.8	0.5	0.3	-	-	-	-
Lag time (hrs)	0.7	0.4	0.6	0.3	0.3	1.3	1.0	0.4	1.1	0.3	0.2	-	-	-	-
Clark Storage (hrs)	12	7	9	5	5	21	16	6	18	5	3	-	-	-	-
Baseflow (cms)	4.6	1.9	1.2	1.6	3.3	3.6	2.5	0.6	0.5	0.8	1.8	-	-	-	-
Recession Ratio	1	1	1	1	1	1	1	1	1	1	1	-	-	-	-
Flood Routing															
Routing Length(m)	-	-	-	-	-	-	-	-	-	-	-	7,000	13,500	4,300	7,800
Wave Velocity, v (m/s)	-	-	-	-	-	-	-	-	-	-	-	2.5	2.5	2.5	2.5
Musk K	-	-	-	-	-	-	-	-	-	-	-	0.8	1.5	0.5	0.9
Musk X	-	-	-	-	-	-	-	-	-	-	-	0.2	0.2	0.2	0.2

* - USACE & Pinatubo Hazard Urgent Mitigation Project Phase II

Table 3.1.2 Calibration Summary

1. Typhoon Diding (1983)

Date	Basin Rainfall (mm)	Flow Observed (m^3/s)	Flow Simulated (m^3/s)	Baseflow Observed (m^3/s)	Baseflow Volume (m^3)	Baseflow Simulated (m^3/s)	Baseflow Volume (m^3)
8/10	59.4	23.5	76.3	16.0	1,382,400	67.0	5,788,800
8/11	64.7	220.0	206.3	16.0	1,382,400	67.0	5,788,800
8/12	79.1	499.2	344.6	16.0	1,382,400	67.0	5,788,800
8/13	77.9	423.2	274.9	16.0	1,382,400	67.0	5,788,800
8/14	146.1	698.1	397.9	16.0	1,382,400	67.0	5,788,800
8/15	141.8	983.0	657.9	16.0	1,382,400	67.0	5,788,800
8/16	179.4	1137.0	1,201.2	16.0	1,382,400	67.0	5,788,800
8/17	28.1	220.0	1,021.3	16.0	1,382,400	67.0	5,788,800
8/18	8.1	220.0	485.7	16.0	1,382,400	67.0	5,788,800
8/19	9.1	36.4	247.6	16.0	1,382,400	67.0	5,788,800

Runoff Estimation

	Total Volume (m^3)	Base Volume (m^3)	Runoff Volume (m^3)	Runoff (mm)	% Runoff
Vobs	385,378,560	13,824,000	371,554,560	574.6	72.4
Vsim	424,543,680	57,888,000	366,655,680	567.1	71.4
%diff			-1.3%		

2. Typhoon Huaning (1988)

Date	Basin Rainfall (mm)	Flow Observed (m^3/s)	Flow Simulated (m^3/s)	Qbase Flow (m^3/s)	Qbase Volume (m^3)	Baseflow Simulated (m^3/s)	Baseflow Volume (m^3)
7/26	86.9	913.7	672.4	621.1	53,663,040	620	53,568,000
7/27	64.6	1,029.2	746.6	621.1	53,663,040	620	53,568,000
7/28	149.1	1,291.0	1,354.3	621.1	53,663,040	620	53,568,000
7/29	215.8	1,545.1	1,412.0	621.1	53,663,040	620	53,568,000
7/30	95.2	1,691.4	1,479.2	621.1	53,663,040	620	53,568,000
7/31	31.2	959.9	1,115.1	621.1	53,663,040	620	53,568,000

Runoff Estimation

	Total Volume (m^3)	Base Volume (m^3)	Runoff Volume (m^3)	Runoff (mm)	% Runoff
Vobs	641,977,920	321,978,240	319,999,680	494.9	77.0
Vsim	653,553,440	321,408,000	332,145,440	513.7	79.9
%diff			3.8%		

Table 4.1.1 Water Balance Analysis in the Bucao River Basin

Year	Annual Run-off			Annual Rainfall			Annual Loss (6) = (5)-(2)	Remarks
	Observed Days N	Mean Discharge (1) m3/s	Runoff Height (2) mm	Iba (3) mm	Santa Rita (4) mm	Basin (5) mm	(6) mm	
1963	365	70.29	3,604	3,784		4,654	**1,050**	**Reasonable Balance**
1964	366	34.30	1,764	3,385		4,164	2,400	Unreasonable
1965	365	30.87	1,583	3,739		4,599	3,016	Unreasonable
1969	365	29.87	1,532	3,585		4,410	2,878	Unreasonable
1970	365	46.53	2,386	4,272		5,255	2,869	Unreasonable
1975	365	65.80	3,374	2,528		3,109	-265	Unreasonable
1976	366	58.86	3,026	4,374	4,888	5,516	2,490	Unreasonable
1978	365	31.57	1,619	5,227		6,429	4,810	Unreasonable
1984	366	67.58	3,303	4,107	4,276	4,848	**1,545**	**Reasonable Balance**
1986	365	40.95	1,996	4,024	4,930	5,531	3,535	Unreasonable
1989	365	143.00	6,970		4,133	4,670	-2,300	Unreasonable

Note : Catchment Area at Gauge Station A= 615 km^2(1963-1978), A= 647 km^2(1984-1989)

Runoff Height (2) = (1) * N * 86.4 / (615 or 647 km^2)

Basin Rainfall (5) = 0.082 * (3) + 1.055 * (4)

or (5) = 1.23 * (3), or (5) = 1.13 * (4)

Pan-Evaporation = 1,736 mm/year (at Floridablanca in Panpanga, 1985-1987, JICA Report in 1996)

Reasonable Annual Loss = (Pan-Evaporation) * (Ratio) = 1,736 * (0.5 to 0.9) = 900 to 1,600 mm/year

Negative value for annual loss (6) is unreasonale in view of hydrological balance.

Larger value for annual loss (6) than pan-evaporation is also unreasonable in view of hydrological balance.

Table 4.1.2 Water Balance Analysis in the Sto.Tomas River Basin

Year	Annual Run-off			Annual Rainfall			Annual Loss	Remarks
	Observed Days N	Mean Discharge (1) m3/s	Runoff Height (2) mm	Iba (3) mm	Santa Rita (4) mm	Basin (5) mm	(6) = (5)-(2) (6) mm	
1963	365	20.38	3,631	3,784		4,011	380	Suspicious Balance
1964	366	10.08	1,801	3,385		3,588	1,787	Unreasonable
1965	365	7.11	1,267	3,739		3,963	2,696	Unreasonable
Average								

Note : Catchment Area at Gauge Station A= 177 km^2

Runoff Height (2) = (1) * N * 86.4 / (177 km^2)

Basin Rainfall (5) = 1.06 * (3)

Pan-Evaporation = 1,736 mm/year (at Floridablanca in Panpanga, 1985-1987)

Reasonable Annual Loss = (Pan-Evaporation) * (Ratio) = 1,736 * (0.5 to 0.9) = 900 to 1,600 mm/year

Negative value for annual loss (6) is unreasonale in view of hydrological balance.

Larger value for annual loss (6) than pan-evaporation is also unreasonable in view of hydrological balance.

Table 4.2.1 Daily Flow Duration Data of the Bucao River

Days	%	Discharge (m3/s) 1963 A= 615 km²	1984 A= 647 km²	1984 (A=615 km²)	(1) = Average A= 615 km²	Normalization Rate (2) = (1) / Mean Q
1	0.3	782.0	875.2	831.9	807.0	11.99
10	2.7	372.2	598.0	568.4	470.3	6.99
20	5.5	263.3	332.5	316.1	289.7	4.31
30	8.2	180.4	205.9	195.7	188.1	2.80
40	11.0	144.0	125.5	119.3	131.6	1.96
50	13.7	122.0	107.5	102.2	112.1	1.67
60	16.4	118.0	89.5	85.1	101.5	1.51
70	19.2	108.0	59.9	56.9	82.5	1.23
80	21.9	98.0	52.5	49.9	74.0	1.10
90	24.7	86.0	50.2	47.7	66.9	0.99
100	27.4	82.0	50.2	47.7	64.9	0.96
110	30.1	82.0	47.9	45.5	63.8	0.95
120	32.9	71.2	47.9	45.5	58.4	0.87
130	35.6	67.6	45.6	43.3	55.5	0.82
140	38.4	59.2	41.0	39.0	49.1	0.73
150	41.1	56.0	34.1	32.4	44.2	0.66
160	43.8	52.5	29.5	28.0	40.3	0.60
170	46.6	46.6	28.5	27.1	36.8	0.55
180	49.3	34.0	22.5	21.4	27.7	0.41
190	52.1	28.0	19.5	18.5	23.3	0.35
200	54.8	23.0	11.3	10.7	16.9	0.25
210	57.5	20.0	11.1	10.6	15.3	0.23
220	60.3	15.6	11.1	10.6	13.1	0.19
230	63.0	15.6	11.1	10.6	13.1	0.19
240	65.8	14.8	10.9	10.4	12.6	0.19
250	68.5	14.0	9.5	9.0	11.5	0.17
260	71.2	14.0	9.5	9.0	11.5	0.17
270	74.0	13.4	9.3	8.8	11.1	0.17
280	76.7	13.4	9.1	8.6	11.0	0.16
290	79.5	12.8	9.1	8.6	10.7	0.16
300	82.2	12.8	9.1	8.6	10.7	0.16
310	84.9	12.8	9.1	8.6	10.7	0.16
320	87.7	11.0	9.1	8.6	9.8	0.15
330	90.4	11.0	9.1	8.6	9.8	0.15
340	93.2	11.0	9.1	8.6	9.8	0.15
350	95.9	10.5	9.1	8.6	9.6	0.14
360	98.6	10.5	8.5	8.1	9.3	0.14
365	100.0	10.0	8.5	8.1	9.0	0.13
Mean Q		70.3	67.6	64.3	67.3	1.00

Table 5.2.1 Bucao River Discharge Measurements

at Bucao Bridge

No.	Date	Gage Height (m)	Discharge (m^3/s)
1	04/17/83	0.26	12.0
2	04/21/83	0.25	11.9
3	05/27/83	0.24	7.1
4	08/17/83	1.10	555.3
5	09/21/83	0.32	13.2
6	10/20/83	0.40	41.8
7	12/09/83	0.22	22.2
8	01/16/84	0.20	16.5
9	03/16/84	0.18	12.7
10	05/22/84	0.26	21.0
11	07/17/84	0.59	36.3
12	08/29/84	0.92	253.0
13	11/16/84	0.66	49.2
14	01/30/85	0.54	19.6
15	03/11/85	0.46	14.2
16	05/12/85	0.52	11.0
17	08/01/85	1.78	57.8
18	09/03/85	2.60	484.1
19	10/16/85	2.00	28.5
20	11/23/85	2.00	25.3
21	12/12/85	1.40	28.6
22	01/21/86	1.86	12.4
23	02/17/86	1.85	10.8
24	03/15/86	1.85	10.6
25	04/25/86	1.80	9.8
26	06/08/86	1.98	29.3
27	07/14/86	2.90	112.4
28	08/19/86	1.70	96.1
29	09/17/86	0.98	42.8
30	10/18/86	1.90	94.3
31	11/24/86	1.57	20.3
32	02/09/87	1.30	15.6
33	03/19/87	1.36	14.3
34	04/08/87	1.35	11.2
35	05/27/87	1.37	14.8
36	07/07/87	1.63	27.2
37	08/11/87	1.59	34.7
38	09/08/87	2.98	442.8
39	10/13/87	1.71	30.3
40	11/18/87	1.61	21.3
41	03/15/88	0.35	7.3
42	04/22/88	0.37	8.5
43	05/26/88	0.36	9.1
44	02/14/89	0.38	11.0
45	03/21/89	0.39	12.1
46	04/20/89	0.34	8.4
47	05/26/89	0.49	18.1
48	06/22/89	0.47	18.4
49	07/19/89	1.36	202.4
50	08/18/89	0.82	179.4
51	09/24/89	0.86	86.8
52	11/17/89	0.68	33.7
53	12/15/89	0.55	23.1
54	02/07/90	0.52	11.4
55	03/16/90	0.46	8.8
56	04/26/90	0.45	7.6
57	05/23/90	0.45	8.9
58	06/26/90	2.30	204.8
59	07/19/90	0.68	54.8
60	08/21/90	2.75	431.8
61	09/19/90	1.95	55.6
62	10/10/90	1.95	45.4
63	11/20/90	2.66	41.7
64	01/09/92	2.08	19.1
65	02/26/92	2.58	25.4
66	04/24/92	2.78	81.0
67	06/03/92	2.68	55.6
68	09/17/92	3.09	120.4
69	11/16/92	0.64	18.1
70	05/28/93	1.80	3.9
71	06/17/93	1.98	8.5
72	09/08/93	0.95	290.0
73	10/22/93	0.11	52.8
74	12/23/93	0.13	36.7
75	01/27/94	0.38	11.0
76	02/22/94	0.29	8.9
77	03/28/94	0.29	9.1
78	04/21/94	0.38	11.6
79	06/10/94	0.39	14.0
80	06/29/94	0.48	44.3
81	08/17/94	1.65	44.3
82	08/24/94	0.68	75.1
83	08/29/94	0.66	63.5
84	09/29/94	1.04	48.8
85	10/13/94	0.80	62.6
86	10/14/94	0.86	59.5
87	12/19/94	0.80	12.4
88	01/25/95	0.89	4.4
89	01/27/95	0.88	2.2
90	03/01/95	0.80	5.6
91	03/30/95	0.80	6.1
92	05/17/95	0.90	21.8
93	06/14/95	0.80	14.0
94	08/16/95	0.94	44.3
95	09/25/95	1.08	94.0
96	10/17/95	0.90	57.7
97	12/03/96	1.03	26.3
98	09/30/97	1.22	91.3
99	10/15/99	1.39	104.7
100	01/14/00	1.36	14.6
101	02/08/00	0.70	119.1
102	07/05/00	1.42	186.2
103	08/18/00	1.28	83.2
104	09/12/00	1.40	161.4
105	11/07/00	1.30	126.0
106	12/15/00	1.39	29.1
107	01/10/01	1.35	23.2
108	02/08/01	1.40	14.1
109	05/22/01	1.30	10.4
110	06/14/01	1.45	27.4
111	07/10/01	1.42	138.7
112	08/23/01	1.72	387.3
113	09/18/01	1.72	121.3
114	10/17/01	1.43	68.9
115	11/14/01	1.50	18.1
116	12/13/01	1.49	19.0
117	01/29/02	1.39	10.3
118	02/07/02	1.42	14.9
119	03/19/02	1.18	10.9

Source: BRS, DPWH

Table 5.2.2 Maloma River Discharge Measurements

at Maloma Bridge

No.	Date	Gage Height (m)	Discharge (m^3/s)
1	01/20/84	1.10	0.8
2	01/23/84	1.08	0.8
3	03/18/84	1.09	0.6
4	05/22/84	1.40	2.3
5	07/17/84	1.94	9.3
6	07/29/85	1.53	8.3
7	09/03/85	2.07	56.2
8	10/16/85	1.34	2.7
9	11/23/85	1.26	2.5
10	12/12/85	1.15	1.6
11	01/20/86	1.08	1.7
12	02/17/86	1.06	1.0
13	03/15/86	1.02	0.7
14	04/25/86	1.20	0.3
15	07/14/86	2.37	31.7
16	08/19/86	1.80	29.9
17	09/17/86	1.75	26.5
18	11/24/86	1.21	21.8
19	02/09/87	0.80	0.7
20	03/18/87	0.93	0.6
21	04/08/87	0.94	0.6
22	05/27/87	1.00	0.3
23	07/07/87	1.34	8.1
24	08/11/87	1.41	7.5
25	09/08/87	2.42	122.0
26	10/13/87	1.25	5.8
27	11/18/87	1.15	2.5
28	03/15/88	1.00	0.6
29	04/22/88	1.01	0.8
30	02/14/89	1.20	0.9
31	05/26/89	1.36	2.3
32	06/22/89	1.38	2.4
33	07/19/89	2.38	108.6
34	09/29/89	2.06	48.6
35	11/17/89	1.10	2.7
36	12/15/89	0.95	1.8
37	02/07/90	1.15	0.8
38	06/26/90	2.30	69.7
39	07/19/90	1.60	12.0
40	08/12/90	2.38	79.1
41	09/19/90	1.60	18.5
42	10/10/90	1.40	1.3
43	11/20/91	3.20	3.2
44	01/09/92	3.17	2.7
45	02/26/92	3.00	1.5
46	04/24/92	2.85	1.3
47	06/03/92	2.84	1.3
48	09/17/92	3.15	2.3
49	11/06/92	0.51	4.1
50	09/08/93	0.97	116.1
51	10/22/93	0.29	10.4
52	11/25/93	0.29	13.8
53	12/23/93	0.21	7.8
54	1/27/94	0.20	7.6
55	2/28/94	0.31	0.3
56	3/28/94	0.26	0.3
57	4/21/94	0.27	0.3
58	6/10/94	0.25	0.3
59	6/15/94	0.29	1.3
60	8/24/94	0.50	8.8
61	8/29/94	0.78	9.4
62	9/29/94	0.95	9.5
63	10/13/94	0.87	16.9
64	10/14/94	0.85	0.5
65	12/19/94	0.74	0.6
66	01/25/95	0.73	0.2
67	02/27/95	0.74	0.4
68	03/01/95	0.70	0.3
69	05/14/95	0.78	7.6
70	06/14/95	0.74	6.1
71	08/16/95	1.00	17.2
72	09/25/95	0.90	30.2
73	10/17/95	0.82	5.7
74	12/03/96	0.89	5.4
75	09/30/98	0.70	20.3
76	01/20/99	0.10	1.0
77	01/21/99	1.50	11.1
78	10/15/99	0.50	10.0
79	01/14/00	0.20	1.7
80	02/08/00	0.20	0.8
81	07/25/00	1.00	44.8
82	08/18/00	0.60	7.0
83	09/12/00	1.19	67.1
84	11/07/00	0.72	33.8
85	12/15/00	0.21	2.0
86	01/10/01	0.15	1.5
87	02/08/01	0.13	1.3
88	05/22/01	0.11	1.1
89	06/14/01	0.33	2.6
90	07/10/01	0.69	23.9
91	08/23/01	1.00	101.5
92	09/18/01	0.50	7.7
93	10/17/01	0.35	4.6
94	11/14/01	0.31	2.8

Source: BRS, DPWH

Table 5.2.3 Sto. Tomas River Discharge Measurements

at Maculcol Bridge

No.	Date	Gage Height (m)	Discharge (m^3/s)
1	11/05/92	1.72	0.6
2	09/18/93	1.80	40.2
3	10/22/93	1.92	6.0
4	11/25/93	1.93	5.7
5	01/27/94	1.55	0.2
6	02/22/94	1.67	0.2
7	03/28/94	1.58	0.1
8	04/21/94	1.56	0.1
9	06/10/94	1.57	0.2
10	08/16/94	2.10	3.6
11	08/17/94	2.00	4.1
12	08/24/94	1.74	13.0
13	08/29/94	2.00	23.7
14	09/29/94	2.02	17.1
15	10/13/94	2.08	3.9
16	10/14/94	2.10	5.9
17	12/19/94	no water	no water
18	01/25/95	1.80	0.2
19	01/27/95	no water	no water
20	03/01/95	no water	no water
21	05/17/95	0.60	12.5
22	06/14/95	no value	no value
23	09/25/95	2.05	7.8
24	10/17/95	2.20	13.4
25	12/03/96	2.70	12.6
26	09/30/97	2.98	13.5
27	10/15/97	2.80	28.7

Source: BRS, DPWH

Table 5.3.1 Summary of Discharge Measurements during Flood in July 2002

Bucao River

Date	Approximate Time	Gauge Height (m)	Measured Discharge (m^3/s)
7/4	12:55	1.7	94
7/5	15:00	1.8	155
7/6	17:45	1.7	123
7/7	09:20	2.8	1,366
7/7	16:45	2.2	723
7/8	11:45	1.6	

Maloma River

Date	Approximate Time	Gauge Height (m)	Measured Discharge (m^3/s)
7/4	13:30	0.9	25
7/5	12:30	1.1	33
7/5	14:20	1.2	47
7/6	15:10	1.6	93
7/6	16:45	1.6	91
7/7	10:20	2.2	231
7/7	15:45	2.5	302
7/8	11:50	1.4	61

Sto. Tomas River

Date	Approximate Time	Gauge Height (m)	Measured Discharge (m^3/s)
7/5	14:00	2.5	21
7/6	16:20	3.0	172
7/7	12:10	top girder	-
7/8	12:50	bottom girder	-

Table 6.1.1 - Quality Test Results for the Bucao River

Date	pH	Electric Conducticivity (uS/cm)	TDS (mgl/)	Chlorides (mg/l)	Ca (mg/l)	Mg (mg/l)	Hardness Total* (mg/l)	Hardness Total* (meq/l as $CaCO_3$)	OH (mg/l)	CO_3 (mg/l)	HCO_3 (mg/l)	Alkalinity (meq/l as $CaCO_3$)
5/26/84	-	350	224	11.0	23.8	0.00	22.5	59.4	-	20.13	0.00	33.6
7/17/84	-	240	154	-	-	0.00	-	-	-	-	-	-
6/5/86	-	-	0	-	-	0.00	-	-	-	0.00	158.6	130.0
4/8/87	7.50	325	208	40.0	80.0	2.43	90	210.0	-	0.00	170.8	140.0
7/7/87	7.51	350	224	55.0	55.0	23.09	150	232.1	-	0.00	164.70	135.0
10/13/87	6.52	375	240	20.0	40.0	14.58	100	159.8	-	0.00	134.20	110.0
11/18/87	6.10	270	173	15.0	40.0	17.01	110	169.7	-	0.00	122.00	100.0
11/24/87	7.47	-	0	4.5	4.0	0.49	6.00	12.0	-	0.00	14.03	11.5
2/9/87	7.65	325	209	45.0	50.0	12.15	100	174.8	-	0.00	140.3	115.0
6/89	7.59	350	224	80.0	105.0	0.00	55	262.5	-	-	-	-
7/19/89	7.60	320	205	20.0	60.0	12.15	110	199.8	-	-	-	-
8/18/89	7.80	-	-	50.0	110.0	12.15	160	324.8	-	-	-	-
9/26/89	7.94	-	-	25.0	-	-	-	-	-	-	-	-
11/17/89	7.55	-	-	60.0	-	-	-	-	-	-	-	-
12/15/89	6.92	-	-	60.0	-	-	-	-	-	-	-	-
3/16/90	7.94	-	-	1,400.0	10.0	4.37	28	42.9	-	-	-	-
4/26/90	7.83	232	162	-	-	-	-	-	-	20.52	102.60	118.5
6/26/90	7.47	200	140	-	-	-	-	-	-	4.56	101.99	92.9
7/19/90	7.61	215	-	-	-	-	-	-	-	2.28	108.95	93.1
8/21/90	7.64	620	-	-	-	-	-	-	-	0.00	307.81	252.3
9/19/90	7.40	135	95	8.3	-	-	-	-	-	0.00	80.52	66.0
10/10/90	7.58	160	112	11.1	-	-	-	-	-	2.40	80.52	70.0
11/21/91	6.00	1,004	502	160.0	420.0	26.73	530	1,159.6	-	0.00	109.80	90.0
1/9/92	6.40	1,460	710	80.0	660.0	0.00	530	1,650.0	-	0.00	207.40	170.0
2/26/92	6.00	1,396	699	100.0	590.0	48.60	790	1,674.3	-	0.00	134.20	110.0
4/24/92	7.60	1,396	698	150.0	1,150.0	0.00	710	2,875.0	-	0.00	524.60	430.0
6/3/92	6.00	1,410	710	80.0	450.0	46.17	640	1,314.3	-	0.00	158.60	130.0
11/6/92	-	870	430	160.0	250.0	53.46	470	844.2	-	0.00	439.20	360.0
5/28/93	-	280	657	100.0	290.0	140.94	870	1,302.9	-	0.00	146.40	120.0
9/8/93	6.00	840	840	100.0	360.0	31.59	490	1,029.5	-	0.00	207.40	170.0
10/22/93	-	1,200	605	120.0	360.0	2.43	370	910.0	-	0.00	195.26	160.0
11/25/93	-	1,510	760	50.0	120.0	43.74	300	479.3	-	0.00	134.20	110.0
12/23/93	-	1,502	752	100.0	510.0	0.00	500	1,275.0	-	0.00	109.80	90.0
1/94	-	1,614	810	38.3	-	-	-	-	0.00	9.12	141.40	131.1
2/94	-	1,330	680	-	-	-	-	-	0.00	0.00	146.00	119.7
4/94	-	1,420	730	72.8	-	-	-	-	0.00	18.20	129.80	136.8
8/29/94	-	200	100	57.4	-	-	-	-	0.00	6.24	105.53	96.9
9/29/94	-	980	490	126.4	-	-	-	-	0.00	22.80	39.41	70.3
1/27/95	8.51	720	360	34.5	280.0	41.31	450	869.4	0.00	30.50	86.59	121.9
10/15/99	7.77	820	410	-	-	-	-	-	0.00	0.00	96.62	79.2
11/7/00	-	910	460	-	-	-	-	-	0.00	0.00	111.79	91.6
8/31/01	-	490	-	-	-	-	-	-	0.00	0.00	77.30	63.4
9/28/01	-	470	-	-	-	-	-	-	0.00	4.08	97.48	86.7
10/26/01	-	490	-	-	-	-	-	-	0.00	0.00	118.22	96.9
12/5/01	-	590	-	-	-	-	-	-	0.00	4.73	136.99	120.2
1/22/02	-	680	-	-	-	-	-	-	0.00	0.00	185.06	151.7
2/5/02	-	310	-	-	-	-	-	-	0.00	0.00	221.11	181.2
Pre-eruption mean	7.45	298	158	119.1	52.5	7.57	84.7	168.0	-	3.6	120.5	104.9
Post-eruption mean	6.79	956	600	95.6	453.3	36.25	554.2	1,281.9	-	3.8	162.4	139.5

Source: DPWH - BRS "Test Report on Chemical Analysis"
* - hardness as reported
** - hardness as calculated in miliquivalents per liter
\- no value reported

Table 6.1.2 - Quality Test Results for the Maloma River

Date	pH	Electric Conducticivity (uS/cm)	TDS (mgl/)	Chlorides (mg/l)	Ca (mg/l)	Mg (mg/l)	Hardness Total (mg/l)	Hardness Total* (meq/l as $CaCO_3$)	OH (mg/l)	CO_3 (mg/l)	HCO_3 (mg/l)	Alkalinity (meq/l as $CaCO_3$)
07/17/84	-	168	108	-	-	-	-	-	-	-	-	-
04/08/87	7.61	400	256	40.0	70	12.2	120	224.8	-	0.0	231.38	190.00
07/07/87	7.74	350	224	55.0	55	20.7	140	222.2	-	0.0	152.50	125.00
11/24/86	7.86	-	-	4.5	7	2.3	16	27.0	-	0.0	19.52	16.00
10/13/87	6.40	350	224	20.0	50	17.0	120	194.7	-	0.0	122.00	100.00
11/18/87	6.22	275	176	20.0	30	19.4	112	154.7	-	0.0	183.00	150.00
06/05/86	-	-	-	-	28	17.6	152	141.0	-	0.0	170.80	140.00
6/89	7.83	350	224	25.0	180	0.0	165	450.0	-	-	-	-
07/19/89	6.85	200	128	30.0	20	31.6	150	179.5	-	-	-	-
08/18/89	7.09	-	-	80.0	110	17.0	180	344.7	-	-	-	-
09/29/89	7.72	-	-	80.0	-	-	-	-	-	-	-	-
11/17/89	7.99	-	-	30.0	-	-	-	-	-	-	-	-
12/15/89	7.71	-	-	50.0	-	-	-	-	-	-	-	-
06/26/90	7.06	170	119	-	-	-	-	-	-	4.56	92.72	83.60
07/19/90	7.60	225	-	-	-	-	-	-	-	4.56	118.22	104.50
08/21/90	6.31	165	-	-	-	-	-	-	-	0.00	148.80	121.80
09/19/90	7.43	210	147	9.2	-	-	-	-	-	3.60	101.26	89.00
10/10/90	7.60	200	140	10.1	-	-	-	-	-	9.60	92.72	92.00
11/20/91	7.00	673	336	80.0	210	48.6	410	724.3	-	0.00	256.20	210.00
01/09/92	6.80	802	402	60.0	270	38.9	430	834.4	-	0.00	231.80	190.00
02/26/92	6.80	833	417	50.0	90	75.3	400	533.9	-	0.00	292.80	240.00
04/24/92	6.00	946	473	90.0	210	155.5	850	1,162.6	-	0.00	292.80	240.00
06/03/92	7.00	940	470	100.0	210	72.9	510	823.9	-	0.00	280.60	230.00
11/06/92	-	483	240	80.0	210	26.7	320	634.6	-	0.00	256.20	210.00
06/17/93	-	650	323	50.0	170	58.3	410	664.1	-	0.00	231.80	190.00
09/08/93	6.00	231	231	60.0	100	12.1	150	299.7	-	0.00	134.20	110.00
10/22/93	-	431	213	80.0	210	36.5	360	674.4	-	0.00	280.60	230.00
11/25/93	-	470	240	50.0	70	21.9	160	264.7	-	0.00	85.40	70.00
12/23/93	-	468	231	40.0	110	14.6	170	334.8	-	0.00	73.20	60.00
2/94	-	510	250	19.2	-	-	-	-	0.00	0.00	187.80	153.90
4/94	-	740	370	49.8	-	-	-	-	0.00	18.20	169.20	169.10
08/29/94	-	200	100	57.4	-	-	-	-	0.00	6.84	115.90	106.40
01/27/95	8.26	470	240	34.5	90	72.9	390	523.9	0.00	32.76	119.90	152.88
10/15/99	8.31	260	130	-	-	-	-	-	0.00	13.20	112.73	114.40
11/07/00	-	240	120	-	-	-	-	-	0.00	0.00	143.73	117.81
08/31/01	-	170	-	-	-	-	-	-	0.00	0.00	94.87	77.76
09/28/01	-	230	-	-	-	-	-	-	0.00	0.00	82.96	68.00
10/26/01	-	240	-	-	-	-	-	-	0.00	4.08	109.92	96.90
12/05/01	-	260	-	-	-	-	-	-	0.00	4.73	100.94	90.62
01/22/02	-	290	-	-	-	-	-	-	0.00	0.00	194.68	159.57
02/05/02	-	190	-	-	-	-	-	-	0.00	0.00	91.33	74.86
Pre-eruption mean	7.31	255	175	34.9	61	15.3	128	215.4	-	2.0	130.3	110.17
Post-eruption mean	7.02	466	282	60.1	163	52.9	380	622.9	-	3.5	171.3	146.18

Source: DPWH - BRS "Test Report on Chemical Analysis"
* - hardness as reported
** - hardness as calculated in miliquivalents per liter

Table 6.1.3 - Quality Test Results for the Sto. Tomas River

Date	pH	Electric Conducticivity (uS/cm)	TDS (mgl/)	Chlorides (mg/l)	Ca (mg/l)	Mg (mg/l)	Hardness Total (mg/l)	Hardness Total* (meq/l as $CaCO_3$)	OH (mg/l)	CO_3 (mg/l)	HCO_3 (mg/l)	Alkalinity (meq/l as $CaCO_3$)
11/93	-	2,116	1050	50.0	420	0.0	210	1,050.0	0.00	0.00	158.6	130.00
2/94	-	1,170	590	30.6	-	-	-	-	0.00	0.00	150.7	123.50
4/94	-	1,370	690	80.4	-	-	-	-	0.00	20.5	215.6	210.90
08/29/94	-	360	180	76.6	-	-	-	-	0.00	3.84	66.37	60.80
10/15/99	7.86	1,060	530	-	-	-	-	-	0.00	0.00	107.36	88.00

Source: DPWH - BRS "Test Report on Chemical Analysis"
* - hardness as reported
** - hardness as calculated in miliquivalents per liter

Table 6.1.4 - Quality Test Results for Crater Lake

Date	pH	NO_3	NH_4	Cl	SO_4	Fe	Mn	As	F	Ca	Mg
	-	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Aug. 8. 1991	4.79	<0.05	0.02	1,029	1,727	<0.1	13.80	0.28	0.13	598.00	95.50
Nov. 19, 1991	5.21	-	-	742	1,689	2.39	-	-	0.36	597.00	84.10
Feb. 18, 1992	2.74	-	-	500	1,288	16.10	-	-	0.75	400.00	72.10
Dec. 4, 1992	1.90	-	-	849	1,364	15.00	-	-	1.68	419.00	121.00

Source: Fire and Mud, "Evolution of a Small Lake at Mount Pinatubo", 1996.
- not tested

Table 6.1.5 - Quality Test Results for Mapanuepe Lake

Date	Mapanuepe Lake Area (meq/l unless otherwise stated)									
	pH (-)	EC (uS/cm)	Na^+	K^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}	Cl^-	CO_3^{2-}	HCO_3^{-3}
17-5-1993	7.5	1,000	0.9	0.0	4.8	4.0	9.3	0.2	-	0.50
22-2-1994	7.35	60	0.2	0.0	3.9	1.9	4.9	0.1	-	0.80

Source: NIA '"Mapanuepe River - Lake Irrigation Project", March 1996
- nil value

Table 6.2.1 - Water Quality Analysis Results

	Parameter	Unit	STANDARD				Sample 1		Sample 2		Sample 3		Sample 4		Sample 5		Sample 6	
			DENR Class AA Drinking	DENR Class C Fishery	DENR Class D Irrigation	WHO (1993)	26-May	18-Jul	26-May	18-Jul	26-May	18-Jul	26-May	18-Jul	26-May	18-Jul	02-Jun	18-Jul
	Temperature	deg C	-	-	-	-	25	27	25	30	25	29	26	25	25.5	28.5	24	27.6
1	pH	-	6.5-8.5	6.5-8.5	6.0-9.0	6.5-8.5**	6.92	7.3	6.88	7.2	7.18	7.16	6.9	6.5	6.8	6.9	7.15	6.6
2	BOD_5	mg/l	1.0	7.0	10.0	-	14	5	35	10	16	6	33	10	17	8	11	6
3	COD	mg/l	-	-	-	-	31	21	51	49	38	63	51	21	58	53	77	21
4	Dissolved Oxygen	mg/l	5.0	5.0	3.0	-	7.4	7.8	6.9	8.0	5.9	8.3	7.6	9.2	8.6	6.9	6.9	7.5
5	Colour	PCU	15	not abnml	not abnml	15	50	15	20	50	50	15	5	5	50	50	10	5
6	Nitrite-N (NO_2^-)	mg/l	-			3	0.029	<0.018	0.082	0.03	<0.018	0.029	<0.018	0.039	0.176	<0.018	<0.018	0.018
7	Nitrate - N (NO_3^-)	mg/l	1.0	10	-	50	0.37	3.2	1.33	21.9	<0.09	5.2	<0.09	0.27	1.9	16.5	<0.09	10.4
8	Anmonia - N (NH_4^-)	mg/l	-	-	-	1.5**	0.26		0.3		<0.008		0.032		0.15		0.39	
9	Chloride (Cl)	mg/l	250.0	350.0	-	250**	13.6	14.4	43.4	119.0	1.1	1.9	3.9	4.8	68.2	90.4	1,582.0	1,532.0
10	Cyanide (CN)	ug/l	50	50	-	70	10	<1	20	<1	10	<1	5	0.021	10	0.03	70	<0.01
11	Mercury (Hg)	ug/l	2	2	2	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
12	Phosphorus (Ph)	mg/l	nil	-	-	-	13.6	11.1	11.3	11.7	8.6	11.5	4.5	8.7	15.2	13.3	11.7	15.2
13	Sulphate (SO_4)	mg/l	-	-	-	250**	131	20.9	262	153	357	15.8	121	74	246	267	746	121
14	Iron (Fe)	mg/l	-	-	-	0.3**	0.83	3.6	1.71	4.8	0.52	2.3	0.09	0.13	19.4	26.1	0.55	1
15	Manganese (Mn)	mg/l	-	-	-	0.5	0.3	0.36	0.09	0.67	0.34	0.02	4.02	2.1	2.1	1.05	1.32	1.35
16	Zinc (Zn)	mg/l	-	-	-	3**	<0.02	0.04	0.05	0.06	<0.02	<0.02	0.46	0.28	0.08	0.17	0.05	<0.02
17	Lead (Pb)	ug/l	50	50	500	10	<5	<5	<5	12	<5	<5	<5	<5	<5	25	<5	<5
18	Chronium (Cr-VI)	ug/l	50	50	100	50	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
19	Cadmium (Cd)	ug/l	10	10	50	3	<2	<2	<2	<2	<2	<2	2.6	<2	<2	<2	<2	<2
20	Arsenic (As)	ug/l	50	50	100	10	4.6	9.7	11	33	1.1	2.7	0.95	0.55	12	34	320	0.39
21	Flouride (F)	mg/l	-	-	-	1.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.91	<0.5	1.08	1.13	1.2
22	Phenols	ug/l	nil	20	-	0.1-0.3	30	20	0.11	0.27	0.05	<0.02	<0.02	<0.02	0.18	0.45	0.10	0.08
23	Calcium (Ca)	mg/l	-	-	-	75	160.6	52	178	128.7	12.3	12.7	113	60	272.1	302	137	109
24	Magnesium (Mg)	mg/l	-	-	-	50	46.7	5.7	43.8	12.6	24.7	4.8	25.5	13.5	40.4	13	40.3	28.2
25	Copper (Cu)	mg/l	1.0	0.05	-	2	<0.04	0.24	0.07	0.21	<0.04	0.16	0.45	0.72	0.17	0.67	<0.04	<0.04
26	Elec. Conductivity	uS/cm	-	-	-	1,500	1,476	500	1,800	1,500	300	200	1,000	600	2,400	2,500	6,667	6,500

* - Drinking water limit in the UK

** - levels which may cause discomfort if exceeded

Sample 1 - Bucao River at Malumboy
Sample 2 - Bucao River at Bucao Bridge
Sample 3 - Maloma River at Maloma/Kalkilengar River confluence
Sample 4 - Mapanuepe Lake outlet
Sample 5 - Marella River
Sample 6 - Crater lake near notch

Table 6.2.2 Results of Water Quality Survey at Mapanuepe Lake and the Reservoir of Dizon Mine Tailing Dam

ITEM NO.	*LABORATORY TEST ITEM*	*UNIT*	*METHODS OF ANALYSIS*	*Sampling Location/Results*										Standards	
				Dizon Mining Dam		Mapanuepe Lake									
				A. Reservoir Area		B. U/S near dam		C. Central area		D. D/S near channel		E. Inlet area			
				Surface	Mid-depth	Surface	Mid-depth	Surface	Mid-depth	Surface	Mid-depth	Surface	Mid-depth		
Total Water Depth during sampling				*14.9 meters*		*11.0 meters*		*14.0 meters*		*4.0 meters*		*13.0 meters*		Class C	Class D
1	PH	-	PH meter (determined on-site)	3.57	4.19	6.3	6.16	6.02	6.26	6.36	6.65	6.23	6.56	6.5-8.5	6.0-9.0
2	BOD_5	mg/l	Azide Modification (5-day@20 C)	1.0	1.0	3.0	2.0	1.0	1.0	6.0	1.0	3.0	2.0	7	10
3	COD	mg/l	Open reflux Dichromate	9	9.0	9.0	9.0	12	8.0	16.0	16.0	12.0	16.0	100	200
4	Dissolve Oxygen	mg/l	Azide modification	8.4	8.3	8.2	7.7	8.4	8.1	8.0	7.3	7.3	8.1	5.0(min)	3.0 (min)
5	Colour	PCU	Visual Comparison	15.0	25.0	20.0	25.0	25.0	15.0	25.0	25.0	20.0	15.0	150	None
6	NO_2^- N	mg/l	Colorimetric	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	None	None
7	NO_3^- - N	mg/l	Colorimetric	7.6	7.9	1.6	1.4	0.96	1.0	0.46	0.66	<0.40	<0.40	10	None
8	NH_4^- - N	mg/l	Titrimetric	0.12	0.08	<0.01	0.04	0.01	0.01	0.05	<0.01	<0.01	0.01	None	None
9	Chlorides (Cl)	mg/l	Titrimetric	1.4	1.4	6.1	6.8	6.8	6.4	7.0	7.0	6.2	6.4	350	350*
10	Cyanide (Cn)	mg/l	Ion-Selective	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	None
11	Mercury (Hg)	mg/l	AAS, ColdVapor Technique	0.26	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	0.42	<0.0004	<0.0004	<0.0004	0.002	0.002
12	Phosphorous (P)	mg/l	Colorimetric	0.16	0.19	<0.16	0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	0.4	None
13	Sulfate (SO4)	mg/l	Colorimetric	130.0	138.0	80.0	75.0	80.0	81.0	92.0	96.0	74.0	79.0	None	None
14	Iron (Fe)	mg/l	AAS	579.9	617.0	0.14	0.32	0.16	0.10	0.11	0.13	0.09	0.05	None	5.0*
15	Manganese (Mn)	mg/l	AAS	880.0	880.0	361.0	341.0	331.0	310.0	310.0	320.0	268.0	259.0	None	0.2*
16	Zinc (Zn)	mg/l	AAS	1.7	1.7	0.31	0.32	0.32	0.45	0.28	0.30	0.30	0.32	None	2.0*
17	Lead (Pb)	mg/l	ASV	0.06	0.06	0.11	0.07	0.10	0.14	0.14	0.12	0.15	0.15	0.05	5.0*
18	Chromium (Cr (VI))	mg/l	Colorimetric	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.05	0.01
19	Cadmium (Cd)	mg/l	ASV	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.01	0.05
20	Arsenic (As)	mg/l	AAS, Hydrite generation	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.01
21	Fluoride (Fl)	mg/l	Colorimetric	0.95	1.0	0.60	0.54	0.52	0.72	0.80	0.50	0.53	0.50	None	1.0
22	Phenols	mg/l	Colorimetric	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.03	0.03	0.02	None
23	Calcium (Ca)	mg/l	AAS, Flame	64.2	61.2	63.8	63.4	63.0	63.8	87.0	84.0	62.0	62.0	None	None
24	Magnesium (Mg)	mg/ml	AAS, Flame	40.8	49.0	32.0	38.0	38.0	38.0	43.0	46.0	41.0	49.0	None	None
25	Copper(Cu)	mg/l	AAS, Flame	391.4	407.0	0.54	0.50	0.53	0.53	0.04	0.19	<0.04	<0.04	0.05	0.2*
26	EC	µ S/cm	EC meter (determined on-site)	1120.0	1110.0	610.0	590.0	630.0	610.0	680.0	700.0	610.0	580.0	None	300*
27	Water Temperature	^0C	Thermometer (determined on-site)	26	26	21.5	21.5	26.0	22.0	27.0	27.0	26.5	26.0	-	-
28	Air Temperature	^0C	Thermometer (determined on-site)	31	31	31	31	29.0	29.0	31.0	31.0	31.0	31.0	-	-

NOTE: Standards are based on DENR Administrative Order # 34 (Class C – intended uses are for Fishery, Recreation and Industrial ; Class D – for Agriculture/Irrigation)
* - Based on Guidelines for Interpretation of water quality for irrigation, Wastewater Engineering

Table 6.2.3 Results of Bed Material Quality Survey for Mapanuepe Lake and Reservoir of Dizon Mine Tailing Dam

ITEM NO.	*LABORATORY TEST ITEM*	*UNIT*	*METHODS OF ANALYSIS*	*Sampling Location/Results*				
				Dizon Mining Dam	Mapanuepe Lake			
				A. Reservoir Area	B. U/S near Dam	C. Central area	D. D/S near channel	E. Inlet area
1	Organic Carbon	mg/kg	Blak& Walky Method	1,200.0	1,200.0	1,200.0	4,100.0	7,600.0
2	Total Nitrogen	mg/kg	Kjeldahl	285	284	443	354	308
3	Total Phosphorous	mg/kg	Colorimetric	8.2	1.53	1.19	2.86	46.4
4	Total Sulfur	mg/kg	Colorimetric	376	276	328	604	124
5	Mercury	mg/kg	Cold Vapor AAS	5.19	1.31	5.47	1.65	1.58
6	Zinc	mg/kg	AAS	70	41.6	67.8	46.4	111
7	Lead	mg/kg	AAS	32	27.5	31.5	9.9	27
8	Copper	mg/kg	AAS	271	120	172	486	382
9	Hexavalent Chromium	mg/kg	Colorimetric	<0.025	<0.025	<0.025	<0.025	<0.025
10	Cadmium	mg/kg	AAS	<0.003	<0.003	<0.003	<0.003	<0.003
11	Arsenic	mg/kg	Colorimetric	1.37	1.13	1.11	<0.01	0.03
12	pH	-	Gas Electrode	6.73	4.21	3.47	6.27	6.87
13	Iron	mg/kg	AAS	15,000.0	15,500.0	20,500.0	15,900.0	12,800.0
14	Manganese	mg/kg	AAS	566	174	351	204	1,952
15	Calcium	mg/kg	AAS	1,700.0	1,000.0	2,200.0	2,200.0	2,300.0
16	Magnesium	mg/kg	AAS	2,200.0	1,900.0	2,200.0	1,700.0	1,800.0

Table 7.1.1 Detailed Description of Installed Rainfall Gauges

ID	Gauge Name	Coordinates		Elevation (m)	Description
		Northing	Easting		
01	DPWH-Region III Office, San Fernando	15-05-02 N	120-38-04 E	EL.103	Gauge located in the DPWH Region III Office, Equipment Services Compound.
02	Mapanuepe Lake Observatory	14-59-08 N	120-16-02 E		From San Marcelino, take the road east towards Aglau. Upon reaching the left bank dike, head upstream and continue on to the old mining access road. Turn left onto a small road leading to the observation deck. Gauge is located on hill prior to reaching observation deck.
03	Paete Elementary School	15-02-24 N	120-07-40 E		From San Felipe, take the road heading east to the Paete Elementary School Compound. Gauge is located in open field adjacent to the school.
04	Baquilan Resettlement Center	15-17-04 N	120-05-08 E		From Botolan, take the road heading to San Juan and Baquilan Resettlement Center. Enter center and proceed uphill to the Iba-Tarlac highway. Gauge is located on northern side of the highway, overlooking the Bucao River.

Table 7.1.2 Detailed Description of Installed Water Level Gauges

ID	Gauge Name	Coordinates		Zero Elevation (m)	Description
		Northing	Easting		
01	Bucao Bridge	15-15-51 N	120-02-06 E	EL. 4.975	Gauge is located on the downstream side of the Bucao Bridge along the No. 7 Highway. Three sets were installed to facilitate easier reading.
02	Maloma Bridge	15-06-59 N	120-03-45 E	EL. 1.628	Gauge is located on the downstream side of the Maloma Bridge along the No. 7 Highway. Three sets were installed to facilitate easier reading.
03	Maculcol Bridge	15-02-04 N	120-04-33 E	EL. 1.530	Gauge is located on the downstream side of the Maculcol Bridge along the No. 7 Highway