REPUBLIC OF THE PHILIPPINES
MINISTRY OF PUBLIC WORKS AND HIGHWAYS

THE PANAY RIVER BASIN WIDE FLOOD CONTROL STUDY

SUPPORTING REPORT (2)

APPENDIX II GEOLOGY AND GROUND WATER
APPENDIX III FLOOD DAMAGE STUDY
APPENDIX IV FLOOD CONTROL PLAN
APPENDIX V MULTI-PURPOSE DAM PLAN

NOVEMBER 19[illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY

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APPENDIX II

GEOLOGY AND GROUND WATER

FOR

FINAL REPORT

ON

THE PANAY RIVER BASIN-WIDE

FLOOD CONTROL STUDY

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1.1 Introduction

The geological investigations for the Study includes (i) investigations of the general geological conditions of the Panay river basin, (ii) investigations of proposed damsites, (iii) investigation of geological conditions along the Panay river especially at proposed sites of diversion weir and river shortcut and (iv) investigation of probable quarry sites or borrow areas for construction materials for the proposed dams.

The investigation of general geological condition of the river basin was conducted mainly by air-photo interpretation and supplementary field checking.

The investigations of proposed damsites were made by means of surface inspections and core borings or trenchings.

The investigations of geological condition along the Panay river were made chiefly by means of air-photo interpretation and surface site inspection, and additionally core-borings were carried out at the sites of diversion weir and river shortcut.

Construction materials for dams were investigated mainly by air-photo interpretation, supplemented by field checking.

1.2 General Geology

The geological map of Panay river basin is shown in Fig. II.1-1.

The upstream portion of the Panay river basin is composed of the Upper Panay mainstream basin and three major tributary basins; Badbaran river basin, Mambusao river basin and Maayon river basin.

The Upper Panay river rises in a high mountain range, which constitutes the western divide of the Panay river basin. The Panay river flows first southward then changes the direction eastward and again north-eastward.

The Mambusao river, which rises in the northern part of high mountain range of western water-divide of the Panay river basin, flows eastward until it joins the Panay river at Dao.

Badbaran river rises in the eastern water divide, which is composed of low mountains having the heighest elevation of about 500 m. The Badbaran river basin is generally very gentle in the southern part compared with the northern part being formed by steep mountain ranges which bound on the Maayon river basin. The Badbaran river flows westward through numerous meanderrings in the low gentle plain.

The Maayon river, which flows westward and joins the Panay river near Maayon, rises in mountain ranges of several hundred meters, which constitutes eastern water-divide of the Panay river basin.

The regional geological map of the river basin is prepared mainly by means of air-photo interpretation making reference to Geological Map of the Philippines and Geology and Mineral Resources of Aklan-Capiz Province.

The upstream area of the Panay and the Mambusao rivers is composed of moderately hard consolidated conglomerate, sandstone and siltstone of Oligocene-Miocene age. By contrast, the upstream area of the Badbaran and Maayon rivers is composed of andesitic volcanic breccia of upper Miocene-Pliocene age and andesite of Oligocene age.

Along the main river channels, wide flat cultivated lands composed of Quaternary alluvial and diluvial deposits are developed.

Middle part of the river basin is hilly with low and gentle topography. These hills are composed of moderately soft consolidated siltstone, claystone, sandstone and conglomerte of upper Miocene-Pliocene age.

Except these lithologic units, several other types of rocks lie in the river basin. Those rock units are limestone of Pliocene-Pleistocene age, moderately hard consolidated sandstone of upper Miocene-Pliocene age, and hard sandstone of Oligocene age.

Limestone scatters in outstanding shape in the central part of the river basin from the north to the south.

Moderately soft consolidated sandstone is confirmed by core boring at the Mambusao B dam site in the right abutment. The continuation of this rock seems to extend to southern low hills near the Mambusao B dam site.

Hard sandstone lies in the northwestern part of the river basin. This sandstone seems to be grouped with the andesite which exposes in the Maayon and Badbaran river basins. On the Geological Map of the Philippines, this andesite group is not distinguished from early Miocene sedimentary rocks in some areas.

The andesite exposes not only in the Badbaran and Maayon river basins but also in the northern and central parts of the river basin and occupies high mountain areas.

Most lithologic units in the Panay basin belong to relatively young geological age. Therefore, rocks are normally in moderately soft consolidated condition except andesitic volcanic breccia, hard sandstone, hard conglomerate, and limestone.

1.3 Geological Investigations

For the geological investigations, air-photo interpretation, field reconnaissance, core boring and trench cutting were carried out. The location map of investigation is given in Fig. II.1-2.

The geological investigation for the Study includes;

(a) investigations of general geological condition of the Panay river basin

(b) investigation of proposed damsites

(c) investigation of areas along the Panay river

(d) investigation of construction materials

The air-photo interpretations were employed in all the above investigation items to find the lithologic boundary and other geological structures. The interpreted area covers most of the river basin except for the areas without air-photos.

Field reconnaissance were made to supplement air-photo interpretation by confirming rock types by sight at accessible locations.

Core borings were carried out for investigation of proposed damsites and of areas along the Panay river at proposed sites of diversion weir and river shortcut. The quantity of core boring carried out at each site is as shown below.

Quantity of core boring

Site	Number of Holes	Length (m)
Badbaran dam site	3	100
Panay C Dam site	3	100
Mambusao A Dam site	3	125
Mambusao B Dam site	3	85
Diversion weir site	2	40
River shortcut sites	6	60
Total	20	510

Together with the core boring, the SPT (Standard Penetration Test) and permeability tests were carried out.

SPT's were made at the intervals of 2 m in soil or intensively weathered rock zone.

The permeability test were made by open-end method and packer method, the former was employed in soil or weathered rock zone at the interval of 5 m and latter in consolidated rock zone at the same interval of 5 m.

The total number of the SPT, open-end permeability test and packer permeability test executed in the field are 79, 38 and 61 respectively.

At the Panay B damsite, instead of core borings, trench cuttings were made at four points, that is, two 4 m deep trenches on the left abutment and 2.3 m deep and 1.8 m deep trenches on the right abutment.

The summarized illustration of boring logs is given in Fig. II.1-3 and 4. And the results of experimental friction loss test are shown in Fig. II.1-5.

1.4 Geology of Proposed Damsite

(1) Badbaran damsite

The geological profile along the dam axis is shown in Fig. II.1-6. One 40 m deep bore hole and two 35 m deep bore holes were drilled at this damsite. The borings were accompanied by core sampling and field permeability tests. The packer test in solid or hard rock zones and open-end test in weathered zones were conducted for the permeability test.

The foundation rock at the Badbaran damsite is composed of andesite, forming most of the right abutment and volcanic breccia forming the left abutment and the lower slope of the right abutment.

Judging from the recovered core samples, andesitic volcanic breccia seems to overlie andesite. Both rock units are very hard and fresh, showing very good core recovery except for small parts of week and slightly fligile disturbed zones.

The both bank of the dam abutments are covered with talus deposits or weathered rock for about 2 to 3 m thick. Below the talus deposits, intensively weathered rock zones with the thickness of 2 to 3 m were observed, from which only fragmental weathered cores with soil materials are recovered.

In some parts below the intensively weathered rock zones, slightly weathered rock zones of about 3 m in thickness were confirmed.

River deposit materials were confirmed to be about 3 to 4 m thick in the bore hole BA-2.

Permeability of the foundation rocks ranges between the orders of 10^{-4} cm/s and 10^{-5} cm/s. The high permeable values of 10^{-4} cm/s order were confirmed in shallow zones of the bore hole BA-1 and BA-2. From these zones fractuated core samples were recovered.

The permeability of the foundation rocks at this site shall be carefully investigated in further stages of investigation in future.

Geological structures such as faults or landslides were not found so far at this site.

Geological condition of foundation rocks at this site seems to be suitable for construction of a fill type dam of about 30 m in height.

Foundation treatment will be performed by normal grouting method using cement milk.

(2) Panay A damsite

This site has very steep slopes on the both banks inclined at more than 40° in the dam abutments.

For this damsite, no investigations but field reconnaissance were made because of difficulty in approach and security problems.

One existing report, JALAUR RIVER MULTI-PURPOSE PROJECT by NIA, is referenced to evaluate the dam foundation condition. The geological map around the damsite is shown in Fig. II.1-7.

The surrounding area of the damsite is composed of moderately consolidated conglomerate, sandstone and siltstone of Oligocene-Miocene age of the same type as the foundation rocks at Mambusao A damsite.

The foundation rock is not very hard consolidated and the weathering seems to reach several meters in depth.

According to the report of JALAUR PROJECT, heavy water leakage was observed during field permeability test in bore holes.

Along the river channel of the Panay river, a clear lineament, crossing the proposed dam axis at almost the right angle, was observed by air-photo interpretation. Another clear lineament was found at several hundred meters upstream of dam axis in almost the same direction as the former.

Although topography at the damsite would be better suited for a high concrete gravity dam, the geological condition does not seem to allow a high gravity dam.

(3) Panay B damsite

The proposed damsite is in a narrow gorge with steep slopes, inclined at about 35° to 45°.

At this site, many rock outcrops are observed in the lower parts of the slopes and on the riverbed. Especially along a small tributary at slightly upstream side of the proposed dam axis, continual outcrops of very hard andesitic volcanic breccias are observed.

The foundation rocks seem to be almost same as those confirmed at the Panay C damsite.

They are probably very hard consolidated and very water-tight.

At this site, four test trenches were excavated, two of which were on the left abutment and the rest on the right. The schematic geological profiles of test trenches are shown in Fig. II.1-8 and those along the dam axis are shown in Fig. II.1-9.

Based on the observation of test trenches and field observation, the both abutments are covered with weathered top soil zone of one meter thick which is underlain by invensive weathered zone of about 1.0 m to 1.5 m in thickness and weathered rock zone of about 5 m to 7 m.

The topographic and geologic conditions seem to allow construction of a 50 m high concrete gravity dam. However, further geological investigation are recommended.

(4) Panay C damsite

The geological profile along the dam axis is shown in Fig. II.1-10.

Foundation rock at this site is andesitic volcanic breccia that seems to overlie massive andesite in deeper part, judging from the recovered core samples.

The massive andesite outcrops remarkably in the mountains west of the Panay C damsite.

The valley of this damsite is wider opened than other dam sites. The estimated crest length of the dam is about 130 m at EL. 38 m.

The width of river channel is nearly 60 m along the proposed dam axis. Conceivable amount of sand and gravel are extractable from the deposits on the riverbed, for use as construction materials.

The slopes are inclined at an average of 30^{o} on both abutments, though the slope is gentler on upper part of the left bank. On the slope of the abutments are 2 m - 3 m deep talus deposits which are generally composed of clayey soil with weathered andesitic gravels.

Below the talus deposits, the intensively weathered bedrock, composed of weathered gravels and rock fragments, is confirmed for less than 2 m in thickness.

Underlying the intensively weathered rock zone, there are weathered rock zones, which are mainly composed of oxidized weathered fragmental rocks.

Depth of river deposits is confirmed to be about 5 m in the bore hole PA-2 located at the side of river bed. The depth of river deposit seems to be around 7 m - 8 m in the central part of the river channel.

Permeability coefficient of the foundation rock ranges between the orders of 10^{-5} cm/s and 10^{-6} cm/s in the bore hole PA-1 and PA-2. This suggests the water-tightness of foundation condition.

However, the permeability coefficient in the bore hole PA-3 was exceptionally in the orders of 10^{-3} cm/s and 10^{-4} cm/s. Packer test was conducted at every 5 m section from 5 m to 30 m in depth. The highest value of the permeability coefficient, 2×10^{-3} cm/s, was recorded in the section between 20 m and 25 m. The second high value, 1.8×10^{-3} cm/s, was recorded in the section between 10 m and 15 m. LUGEON values of these two sections are 151.9 and 138.1 respectively.

The recorded permeability coefficients in the bore hole PA-3 are very high compared with the values obtained in the other bore holes, i.e., PA-1 and PA-2.

Recovered boring core samples indicate that there are several fractured or fragile parts in different depths in the bore hole PA-3. These parts seem to be caused by open cracks in the drilled sections. These fragile parts are not accompanied by clay materials as often seen in faults. However, the topography at the bore hole PA-3 is slightly concaved, and because such topographic condition is often related to concealed faults, special attention needs to be paid in further studies. The foundation rocks of this site have many calcite veins that are accompanied by small cavities.

Ground water table in the bore hole PA-3 was at 8 m below the ground surface. Which is almost the same as in the bore hole PA-1. This implies a rather water-tight characteristic of the foundation rock in natural condition.

The cause of the high permeability in the bore hole PA-3 was not made clear with the insufficient data obtained so far. Further investigation is recommended in the following stage.

Aside from the above, the obtained permeability coefficients seem to be improvable by foundation treatment, and no serious problems of dam stability seem to arise.

Except the relatively high permeability in the bore hole PA-3, it seems to have no further difficulties for construction of a concrete gravity dam of about 30 m in height.

(5) Mambusao A damsite

The geological profile along the dam axis is shown in Fig. II.1-11.

Mambusao A damsite is situated in the same lithologic group as that of the Panay A damsite. Moderately hard consolidated conglomerate, sandstone and siltstone are recovered alternately in three bore holes drilled along the proposed dam axis.

The right abutment is rather gentle with the slope inclination of about 20° to 25°. On the contrary, the left abutment is very steep with the slope inclined at about 40° or more in parts.

Talus deposits or weathered rock of about 7 m to 10 m in thickness cover the both abutments. The over-burden is extraordinarily thick compared with that of other damsites.

This seems to have been caused by depositing of gravels derived from more or less loosely compacted conglomerate on the gentle slope of the right abutment.

On the left abutment, there is an apparent slope change which implies possible presence of faults or liability to landslide above the location of the bore hole BA/U-3.

The presence of possible faults has to be investigated more in detail in the following stage. The above mentioned loose core condition for about 21 m from the ground surface seems to have some relation with the above mentioned topographic abnormalities.

The conglomerate is hard in outcrops near the damsite, but mostly the rounded volcanic gravels and some fragmental cores are recovered from the bore holes. This seems to suggest the rather weak consolidation condition of conglomerate. The conglomerate is predominant on the right abutment.

Core recovery is generally not very high, ranging between 50% to 90%.

Except the shallow part of the bore hole MA/U-2, fine to coarse sandstone and siltstone accompanied by conglomerate in parts are predominant in the bore holes MA/U-2 and MA/U-3.

The sandstone and siltstone are not consolidated hard. Therefore, the recovered cores of the sandstone and siltstone are frequently broken into thin pieces by vibration of core barrels during drilling, in spite of very good core recovery of nearly 100%.

According to the observation of the recovered cores, the sandstone and siltstone have gentle inclination of bedding planes which dip at about 10^{o} to 15^{o}.

The bedding plane seems to dip from the right bank to the left bank, judging from outcrops of rocks and observation of the recovered core samples. As the dipping has no remarkable change, the stratification of the rocks overlain this site is estimated to be a monoclinal structure.

The intensively weathered zone is about 6 m thick at most. The underlying weathered rock zones change their thickness between 2 m and 4 m on the right abutment. On the other hand, the depth of the weathered rock zone on the left abutment is about 10 m.

The depth of river deposit materials composed of big volcanic gravels is confirmed as about 0.7 m by hand excavation near the boring hole MA/U-2.

The average depth of the river deposits seems to be about 2 m to 3 m.

SPT (Standard Penetration Test) was made in talus deposit and intensively weathered zones in the bore holes, MA/U-1 and MA/U-3. The recorded N-values range 20 to 50 in the zones above 16 m below ground surface in the both bore holes.

The N-values do not seem to be sufficient to support a dam of more than 50 m high.

Permeability coefficient by the packer method and open-end method were in the order of 10^{-4} cm/s, with variations between the orders of 10^{-3} cm/s and 10^{-5} cm/s.

The highest permeability coefficient was obtained at the depth of 15 m in the bore hole MA/U-1, between the layers of intensively weathered conglomerate and weathered conglomerate. This seems to be caused by water leakage through open cracks or fractured zones.

The groundwater level observed was 22.3 m below the ground in the bore hole MA/U-1 and 28.2 m in MA/U-3. These deep groundwater levels seem to suggest rather pervious condition of the foundation rocks on both abutments.

Judging from the obtained data, not only thick loose materials but also deep weathered rock zones are developed on both abutments. Permeability coefficient itself is very high and deep groundwater tables show the possible high pervious condition of the foundation rocks.

The above mentioned condition of the foundation rocks might bring about some trouble in foundation treatment.

Judging from these results, the foundation rocks at the damsite do not seem to be suitable for construction of a high dam.

(6) Mambusao B damsite

The geological profile along the dam axis is shown in Fig. II.1-12.

The proposed damsite is situated in a valley with wide opening. The slope are inclined at about 10^{o} on the right abutment and at about 25^{o} on the left.

The upper part of the right abutment is composed of fine to medium grained sandstone. The section between the left abutment and lower part of right abutment seems to be composed of alternation of conglomerate, siltstone and sandstone.

The ground surface is covered with talus deposits and beneath that intensively weathered bed rock zones are developed for about 5 m to 10 m.

Below these zones, 3 m to 5 m thick weathered bedrock zones seem to be developed.

In the bore hole MA/D-1 drilled at rightabutment, loose sandy weathered soil was recovered from the upper portion, although the boundary between residual soil and talus deposit is not clear.

River deposits seem to be developed for about 12 m judging from the recovered cores from the bore hole MA/D-2. Concerning the section between 6.8 m and 12 m below the surface, it is not clear whether the soil belongs to the river deposits or to the weathered bedrock zones, because only andesitic gravels were recovered from this section. However, the bedrock conglomerate in this area is characterized by predominant whitish limestone gravels.

Based on these facts, the boundary between the river deposits and bedrock is estimated to be located at about 12 m in depth.

Judging from interbeded siltstones, the bedding plane of the conglomerate inclines at about 15^{o}.

From the bore hole MA/U-1, medium grained sandstone was recovered in moderately soft consolidated condition. This sandstone is almost homogeneous to the bottom of the bore hole. Bedding planes were observed in part, having inclination of dip at about 25^{o} to 30^{o}.

As there is no disturbance in inclination of bedding plane, structure of the sandstone seems to be in monoclinal condition, inclining from the right abutment to the left abutment.

The conglomerate seems to overlie the sandstone conformably. SPT's were carried out in the bore holes, and N-values of 5 to 50 in the section above 5 m deep were drained. However, the value exceeds 50 anywhere more than 5 m below the surface.

Permeability coefficients range mostly between the orders of 10^{-4} cm/s and 10^{-5} cm/s. Relatively high permeability coefficients of 7.9 to 8.3 x 10^{-4} cm/s were observed in the bore holeMA/D-1 in the section between 15 m and 25 m below the surface. Additionally, the groundwater table in the bore hole MA/D-1 was very deep 21 m below the ground surface, which implies a highly pervious condition.

The foundation rocks shall be capable of sustaining a fill type dam of about 30 m in height, despite foundation excavation will have to be very deep.

As the foundation rock is impervious and in moderately consolidated soft condition, the foundation treatment will be performed by trench excavation of the core zone of the dam body and driving steel sheet piles into bedrock zones beneath the core zone. The foundation treatment will be 20 m in depth.

1.5 Proposed Diversion Weir and River Shortcut Sites

(1) Proposed diversion weir site (Refer to Fig. II.1-13)

One of proposed diversion weir site is situated at about 700 m upstream from the bifurcation point of the Pontevedra river and the Panay river. At this site, the Panay river is about 75 m wide.

The water depth at this site was not continually surveyed but the depth seems to be shallower near the right bank and be deeper near the left bank. The both right and left banks are flat and the ground height from the water surface is normally about 5 m.

At this site two bore holes were drilled. The one was on the left bank near the river channel for confirming subsurface condition of the river bank. The other was in the river channel for confirming river deposit materials.

From the bore hole DW-1 on the left bank, loose sand, stiff clayey silt and very stiff clay including organic clay materials were obtained. N-values by SPT range from 4 to 23, which indicate rather weak foundation condition. Especially more than 7 m below the ground, N-values were less than 15. Permeability coefficients observed in this bore hole were all in the order of 10^{-4} cm/s.

The bore hole DW-2 was drilled in the river channel, and sandy materials of medium to coarse grains in homogeneous condition were recovered. N-values range from 8 to 35, exceeding 30 in the sections more than 8 m deep. The obtained N-values suggest that the sand is in loose to medium loose condition.

Judging from the obtained N-values, the bearing capacity will be about 10 t/m^2 at the depth of 15 m in the bore hole DW-1. By contrast, the bearing capacity is about 10 t/m^2 at the depth of 6 m and 25 t/m^2 at the depth deeper than 10 m in the bore hole DW-2.

If a larger bearing capacity is required, friction piles or grouping piles shall be necessary to increase the bearing capacity and avoide unequal settlement of gate structures.

(2) Proposed river shortcut site

Proposed river shortcut sites taken for the geological investigation were six in total. Core boring, SPT's and open-end method permeability test were carried out at every proposed river shortcut sites. The drilled depth was about 10 m at each site.

The locations of the drilling sites are as follows:

SC-1 : on the right bank of Pontevedra river at the bifurcation of Pontevedra and lower Panay rivers

SC-2 : on the left bank of Panay river at the upstream side of the bifurcation of Pontevedra and lower Panay river

SC-3 : about 1.5 km south of Panitan

SC-4 : just upstream side of the confluence of the Panay river and the Maayon river

SC-5 : about 1.8 km upstream from the confluence of the Panay river and the Maayon river

SC-6 : about 2.8 km downstream from the confluence of the Panay river and the Mambusao river

The geological conditions at each site are as follows.

SC-1 site (Refer to Fig. II.1-14)

From the borehole SC-1, clay and organic clay layers were obtained. The organic clay contains carbonated wood pieces.

The recorded N-values range from 4 to 13, representing very soft formation. In the section above 8 m below the ground N-values were less than 7.

Permeability coefficients are in the order of 10^{-4} cm/s.

SC-2 site (Refer to Fig. II.1-15)

The clayey materials and organic clay materials were recovered from the bore hole SC-2 except in shallow sections between 0 and 1.2 m deep from which sandy materials were recovered.

The recorded N-values were less than 10 in the section more than 5 m below the ground. Only one N-value slightly exceeded 10 at the depth of 2.5 m.

The measured permeability coefficients were in the order of 10 10^{-2} cm/s.

SC-3 site (Refer to Fig. II.1-16)

From this hole, sandy materials were recovered except in the section between 2.0 and 4.0 m deep where clayey materials were recovered.

The recovered materials are composed of fine to coarse gained silty to sandy materials.

Recorded N-values increase with depth, ranging between 3 to 40. Below 7 m deep, the sand is in dense condition with N-value of more than 30.

The measured permeability coefficients were in the orders of 10^{-2} cm/s and 10^{-3} cm/s.

SC-4 site (Refer to Fig. II.1-16)

The clay materials and organic clay materials were recovered from the bore hole SC-4. The clay is slightly greenish brown and highly plastic. The organic clay is blackish and very stiff in condition.

The recorded N-values were lower in clay layer, ranging 10 to 21. By contrast, the values range from 22 to 28 in the organic clay layer more than 7 m below the ground.

The permeability coefficients were in the order of 10^{-4} cm/s.

SC-5 site (Refer to Fig. II.1-17)

The silty clay, clay and sand were recovered from the sections 0 m to 4.3 m, 4.3 m to 8.0 m and below 8.0 m deep respectively.

The recorded N-values were less than 20 in the section above 6 m deep. Below 6 m, the N-values slightly increase with the depth and reach the values of 27 and 31.

The permeability coefficients were in the order of 10^{-4} cm/s.

SC-6 site (Refer to Fig. II.1-17)

The silty materials were recovered from the section above 6.5 m deep and the sandy materials were recovered from the section below 6.5 m deep.

N-values range from 4 to 20, which implies loose condition of sand materials. The silty materials are soft in condition.

The permeability coefficients were in the order of 10^{-2} cm/s.

The dredging capability of pump dredger or grab dredger allow extraction of sandy soil and clayey soil of which N-values are less than 30 without crushing.

Based on the above grounds, a pump dredger or a grab bredger seems capable of excavating the proposed river shortcut sections without difficulties except in deeper portions at the SC-3 and SC-5 site.

In deeper sections in the bore holes, SC-3 and SC-5, N-values increase to reach about 30 to 40. These sections seem to be dense or hard but the dredging or excavation of these sections still seems to be possible.

1.6 Construction Materials

(1) Badbaran dam (Rock-fill)

The core materials for this dam are presumably obtainable from gentle topographic area at the south of the damsite. This area is overlain by several meters of residual soil and weathered andesitic volcanic breccia. After stripping surface organic soil, the materials underlying will be suitable for core materials.

The rock materials will be obtained from the mountains extending towards north from the damsite. An alternative source will be limestone mountains located at the western part of the damsite for about 5 km in an air-line distance.

The sand and gravel materials for filter materials and for concrete aggregates were not found near the damsite. The river deposits, composed chiefly of sandy materials, are mostly under the river water and the obtainable amount will not be sufficient. The sand and gravel materials therefore will be obtained from hard andesite or limestone by crushing.

(2) Panay A dam (Concrete gravity)

Along the river bed of the Panay river, there are sand and gravel materials in the upstream and downstream sides of the damsite. However, the obtainable amount was not been confirmed yet.

Part of the required concrete aggregate will be supplied from the river deposit materials. The rest of the materials will have to be produced by crushing of hard consolidated limestone or conglomerate, which lie within one to the north and south from the proposed damsite.

(3) Panay B dam (Concrete gravity)

Panay B damsite is situated on a narrow gorge. The river section becomes open and wide at about 200 m or 300 m downstream from the damsite, forming a river channel of more than 50 m in this part downwards. The sand and gravel deposits were observed in the full width of the river channel. Therefore, the sand and gravels at several hundred meters downstream from proposed damsite will be produced from the river bed by power shovels on a small scale.

As the river channel is wide and sand and gravels are fully deposited in the river channel, the required amount of concrete aggregate will be sufficiently supplied.

(4) Panay C dam (Concrete gravity)

At this site, sand and gravel deposits are also observed fully in the river channel. The gravel size seems to be slightly smaller, 2 cm to 3 cm on an average diameter, than required for concrete aggregate. However, the sufficient sand and gravels will be supplied from the river deposits to cover required amount of concrete aggregate.

Hard consolidated andesite lies at the north of the damsite at the distance of about 5 km. Hard limestone outcrops, conforming outstanding high mountains, were observed at the south of the damsite at the distance of about 3 km. The large size aggregates will be supplied by crushing of hard andesite and limestone.

(5) Mambusao A dam (Rock-fill)

There are some sand and gravel deposits along the riverbed of the Mambusao river. The average diameter of the gravel size is about 5 cm to 10 cm with a leaning to a bigger size.

The sand and gravels will not probably be enough to cover the required amount of concrete aggregates and filter materials, because, the depositing depth was confirmed to be 0.7 m by excavation. The average depositing depth of the material seems to be 1.0 m to 2.0 m at this site at most. In case of insufficiency quantity of the materials, additional amount will be supplemented from crushing of the rock materials.

The rock materials will be supplied from the high mountains located to the north of the proposed damsite within the distance of 2 to 3 km. The mountains seem to be composed of moderately hard consolidated conglomerate that exposes near the damsite.

However, the recovered core samples of conglomerate at this damsite are in short cylindric or fragmental condition. From this, it is considered thatthe consolidation of the rock may not be hard enough to be used as rock materials. In this case, the supply source of the rock materials will have to be distant. One possibility of alternative rock material source is the northern side of the large mass of andesite mountains located at the northern part of Tapaz. However, in any case the hauling distance will be more than 12 km or 13 km in a air-line distance.

The core materials seem to be producible from the gently topographic area surrounding the proposed damsite, mostly in the downstream side. The obtainable core materials are weathered soil or residual soil of sandstone, conglomerate, and siltstone.

A rock-fill type dam was considered for a preliminary design. However, if the rock materials is not sufficient, an earthfill type dam will have to be considered as an alternative.

(6) Mambusao B dam (Rock-fill or earthfill)

Some sand and gravel deposits were confirmed by core boring, but the materials are submerged about 1 to 2 m deep near the proposed damsite. Accordingly, the excavation of the sand and gravel deposits seems to be difficult.

The required concrete aggregate and filter materials will be obtained by crushing of rock materials.

Core materials seem to be supplied sufficiently from the surrounding area of the damsite. The materials seem to be mainly composed of moderately soft sandstone, siltstone and conglomerate.

The rock materials will be supplied from the andesite mountain located at the north of Tapaz, or hard sandstone or limestone mountains located at the north west of Mambusao. These sources are the same as those for the Mambusao A dam.

The above description on the material sources are based on only observation during field reconnaissance. Therefore, detailed investigations on the materials will have to be performed in following stage, to confirm the availability of materials both in terms of quantity and quality.

2. Ground Water

2.1 Introduction

The ground water study was carried out to assess the possibility of exploiting and utilizing the ground water as an alternative source for irrigation and municipal water supply in the Panay river basin. The study was made in the preliminary access to evaluate the proved water potential by means of the review of existing data, the inventory of existing wells and the measurement of electrical conductivity of well water.

The existing data were provided by NWRC (NATIONAL WATER RESOURCES COUNCIL), which comprised the records of test wells gathered by Local Water Utilities Council and compiled by NWRC. These data are summarized in Table II.2-9. Other reports, particularly those published by Regional Mineral Resources Development Center were reviewed for reference.

An inventory survey was made on existing wells to collect data, such as actual daily demand, purpose of water use, water quality, groundwater table and well depth. Most of existing wells are equipped with a pump. They are normally shielded by concrete structures for a pump pedestal, and condition inside the wells were not easily observed. Therefore, hearing from users of the wells was the chief methods of the inventory survey.

The electrical conductivity measurement on the water bodies taken from existing wells and rivers was conducted to assess the water quality especially in terms of salinity caused by sea water intrusion and contamination.

2.2 Inventory Survey on Existing Wells

For obtaining actual condition of ground water, the inventory survey on existing wells was carried out. The inventoried wells are 136 in total numbers, including the wells located in surrounding areas of the Panay river basin. Among the inventorised wells, 108 wells are listed in Table II.2-1 to Table II.2-8 in this report since they carry complete data. Their locations are shown in Fig. II.2-1.

NWRC posses es a stock of data concerning wells located in Panay river basin. However, parts of the inventorized wells have not been confirmed properly in-situ, partly because number plates for identification of the existing wells have been removed or damaged. Therefore, changes in condition after being inventorized are not easily traced accordingly.

Most of existing wells are located in populated areas along the mainstream and tributaries of the Panay River, such as towns of Tapas, Dumalag, Dumarao, Cuartero, Dao, Sigma, Panitan, Mambusao, Jamindan, Maayon, Pontevedra, Panay and Roxas city. From convenience, the Panay river basin is divided into 13 divisions according to the above towns, as shown in Table II.2-9 and II.2-10.

The summary of the inventory survey is as follows:

The well depths range between 1.8 m below the ground surface and are 16.4 m on an average. The average depth of 5.4 m of the wells in Sigma is the shallowest among the 13 divisions, and that of 27.7 m in Tapas is the deepest.

The average static groundwater levels are grossly in the range of -0.3 m to -17.5 m below ground surface, though most of them are within the range of shallow depths above -5.0 m. The shallowest average static water level is -1.7 m below ground surface at Panay and the deepest average static water level is -5.6 m below ground surface in Dumarao. The measured water level is -5.6 m below ground surface in Dumarao. The measured static water levels are generally in a shallow depth.

The minimum and the maximum amount of pumped water from each well are 0.1 tons per day and 45 tons per day, respectively, based on the hearings. The average amount of water use is less than 4 tons per day per wll commonly, with exceptions of 7.38 tons per day per well in Cuartero and 12.29 tons per day per well in Potevedra. It is rational to presume that there exist permeable beds in alluvial deposits, where the wells yield a large amount of water.

Drawdowns during pumping were reported by users in the inventory survey: the minimum drawdown was 0.5 m and the maximum 46 m among the existing wells, and the average value of drawdowns was 7.6 m. It can be assessed rather a large value compared with the small amount of daily pumping quantity of 3.88 tons per day per well (Table II.2-10).

Questions might arise on accuracy of drawdowns gathered mostly from hearings, since most of the well are shielded. Pumping capacity per well per unit drawdown, that is specific capacity, was referred from the file of NWRC. The specific capacity of the existing wells recorded in the well file of NWRC, which was probably measured on their construction, are commonly less than 0.8 l/sec./meter except rather high value of 1.75 l/s/m in Pontevedra (Table II.2-9). This implies that in all the studied divisions, there do not seem to be any attractive wells in existence.

In Pontevedra, the average specific capacity is somewhat larger than that in other divisions. However, sea water instrusion might be taking place locally, because the town is located near the coastal swampy area.

2.3 Aquifer in Panay River Basin

The geology of Panay River Basin is described in the section of Geology (See Fig. II.1-1).

The outline of general geology related to the ground water aspect is summarized below. The middle and the lower reaches of the Panay river basin is composed of consolidated claystone, siltstone, sandstone, and conglomerate forming gentle hilly masses. Mountains in the Panay river basin are mostly composed of andesitic hard rocks and limestones. Those rocks are so well cemented that there is no room for aquifers to be formed there.

Permeability coefficients of the andesitic rocks, limestones, and consolidated sedimentary rocks were measured by field permeability tests at the proposed dam sites. The measured permeability coefficients range in the orders of *10-4 cm/s to *10-6 cm/s mostly, indicating low values. Judging from this, these rocks seem to be an aquitard.

Along the main river channels, there extends wide and flat cultivated plains formed of alluvial deposits. As the alluvial deposits have been derived from the weathered clayey materials, coarse deposits are generally less in quantity.

The depth of the alluvial deposits is about 10 m to 20 m on the middle reaches and about 30 m or more on the lower reaches, judging from the results of core boring at the proposed dam site and at the proposed river shortcut sites. Test well drilling by LOCAL WATER UTILITIES ADMINISTRATION near the branch point of the Pontevedra river and the lower Panay river indicated that the depth of the alluvial deposits was about 35 m.

Permeability coefficients of the river deposits, measured by open-end method at the proposed river shortcut sites, range in the order from *10-2 cm/s to *10-4 cm/s, and are mostly in the order of *10-4 cm/s.

Based on the geological condition and the result of the permeability test, existence of possible aquifers in the Panay river basin are limited only in the alluvial deposits extended along the rivers.

The alluvial aquifers of the alluvial deposits develop in several kilometers in width on the middle reaches of the Panay river and on lower reaches of the Mambusao river and the Maayon river.

A very wide extending alluvial aquifer exists in the areas of the lower Panay river and the Pontevedra river. However, the lower parts of these areas are close to the coastal swampy area, and sea water intrusion is commonly observed.

The extent of alluvial aquifer in the Panay river basin is not completely made clear so far; however, the alluvial aquifer will be roughly classified into 4 zones (See Fig. II.1-1): lower reaches of the Mambusao river, middle reaches of the Panay, Lower reaches of the Maayon, and lower reaches of the Panay.

2.4 Quality of Ground Water (See Fig. II.2-2, Fig. II.2-3 and TABLE II.2-1 to TABLE II.2-8)

During the period of the inventory survey, the water quality data including taste, smell, and colour were obtained by hearing with the user of the existing wells.

According to the summary of the inventory survey on the existing wells, only about 50 wells out of 108 inventoried wells supply potable water for drinking. The remaining wells supply water with salty taste, foul smell, and/or discernible color.

The main reasons accounting for inadequate water quality are poor functions of aquifers containing silt materials, pollusion by sewage water insufficient treatment of waste water and so on. Intrusion of accounts for salty taste of water, confirmed in 15 wells, especially in the areas along along the lower Panay and the lower Pontevedra.

Electrical conductivity measurement was carried out on water samples extracted from the existing wells and from the main river channels. The results of the measurement indicate that sea water intrusion reaches the towns of Pontevedra and Panay showing more than 1,000 micro s/m. These areas are located near the swampy area facing the Pilar Bay. Relatively high conductivities, between 500 micro s/cm and 1,000 micro s/cm, were observed in the divisions of Mambusao, Panitan, Dao, and Cuartero.

These relatively high conductivities are probably caused by pollution by infiltration, because water samples from rivers near the towns constantly indicate about 200 micro s/cm of conductivity.

Relation curve between electrical conductivity and contents of NaCl is shown in Fig. II.2-3 for reference.

2.5 Possibility of Ground Water Exploitation in Panay River Basin

As discussed in the above sections, a possible aquifer will be confined in alluvial deposits in the Panay river basin. The alluvial deposits are chiefly composed of clayey and silty materials which have relatively low permeability as observed in the bore holes tests at river shortcut sites. The thickness of the alluvial deposits is 36 m near estuary area and becomes thiner toward the upstream.

The well files of NWRC show that average specific capacities of existing wells in the populated town areas are less than 0.8 l/s/m, except one value of 1.75 l/s/m at Pontevedra. Pontevedra is located close to coastal swampy areas and sea water intrusion into this area is being suspected.

Relatively high electrical conductivity values were observed not only in coastal areas but also on inland areas. The water quality seems to be in general inadequate.

In the existing report of "GROUND-WATER INVESTIGATION PROGRAM FOR IRRIGATION IN SOME PARTS OF LUZON AND BOHOL AND PANAY ISLANDS" prepared by Regional Mineral Resources Development Center, some parts of the fluvial plains around Roxas City assessed preliminarily to be capable of providing relatively favorable condition for ground water exploitation.

In the report of "FRAMEWORK PLAN PANAY RIVER BASIN" by NWRC, the average annual precipitation over the Panay river basin is estimated to be 88 l/s per square km. The calculated ground water contribution on the Panay river and its tributaries is 25 l/s per square km. The balance of 63 l/s is estimated for evapotranspiration plus surface and subsurface runoff through preliminary study.

Detail observation of the existing wells, and the drilling of five test wells with pumping tests were carried out by Local Water Utilities Council in the lower reaches of the Panay river and Pontevedra river. The results of the investigation was described in the report of "FEASIBILITY STUDIES OF ROXAS CITY WATER DISTRICT". It is indicated

indicated that the alluvial aquifer is 35 m in depth in this region and that most of the overlying materials are clay to sandy clay which contains lenses of sand bed of lower permeability irregularly.

Judging from the result of the study, the potential of ground water exploitation will be concluded to be very poor in the Panay river basin. The large scale development of ground water will not be possible, although minor exploitation will be practical for local or private uses from the alluvial aquifer.

TABLES

FOR

APPENDIX II

TABLE II.2-1 List of Inventoried Existing Wells (1)

Well No.	Well Depth	Total Pumping Amount (t/d)	G.W.L	Drawdown Estimated	Usage	Remarks
1	4.55 m	0.30	1.50 m	2.00 m	Washing & others	Water taste no good
2	8.23 m	0.08	2.00 m	5.00 m	Washing & others	Water taste no good
3	3.00 m	0.30	2.00 m	1.00 m	Watering & others	Unsafe for drinking water becomes salty during dry season
4	3.65 m	0.30	2.13 m	1.52 m	Washing & others	Same
5	12.80 m	2.4	4.57	5.00 m	Cleaning	Salty water abandoned
6	9.76 m	2.4	2.44 m	0.91 m	Washing	Water taste salty, contaminated with brownish particles smell fishy, lessen during dry season but does not dried up
7	36.59 m	14.4	4.57 m	22.87 m	Washing & others	Water is potable for drinking
8	9.15 m	0.75	4.65 m	2.97 m	Drinking & others	Sufficient supply of water
9	8.54 m	0.01	4.57 m	3.97 m	Drinking & others	Sufficient supply of water
10	4.57 m	0.03	1.00 m	2.00 m	Watering & others	Not advisable for drinking, yellowish in color
11	15.24 m	1.52	3.05	12.19 m	Washing & others	Not advisable for drinking, contamitated by salty water, fishy odor
12	12.20 m	4.8	1.52 m	7.62 m	Drinking & others	Sufficient supply of water
13	18.29 m	1.52	3.05 m	15.24 m	Drinking & others	Sufficient supply of water
14	1.83 m	0.15	0.31 m	0.915 m	Washing & others	Unsafe for drinking. greenish in color

Table II.2-2 List of Inventoried Existing Wells (2)

Well No.	Well Depth	Total Pumping Amount (t/d)	G.W.L	Drawdown Estimated	Usage	Remarks
15	19.82 m	1.52	2.44 m	15.24 m	Washing & others	Water is salty brownish in color smell fishy odor
16	9.15 m	4.8	4.57 m	1.22 m	Washing & others	Potable water
17	7.62 m	0.91	1.20 m	6.42 m	Washing & others	Shortage of water
18	4.57 m	1.52	1.80 m	2.77 m	Washing & others	Not advisable for drinking shortage of water, blackish color
19	12.50 m	4.55	1.20 m	11.30 m	Washing & others	Water is salty
20	7.01 m	4.55	1.00 m	6.00 m	Washing & others	Not advisable for drinking
21	7.62 m	4.55	0.80 m	6.80 m	Washing & others	Salty during dry season Not advisable for drinking
22	25.00 m	4.55	1.20 m	24.00 m	Washing & others	Potable water
23	10.67 m	8	2.44 m	8.23 m	Washing & others	Potable water
24	4.00 m	3.00	2.50 m	1.00 m	Washing & cooking	Unsafe for drinking brownish in color
25	7.01 m	5.3	1.22 m	5.79 m	Drinking & others	Level decreases few centimeters during dry season sufficient for the barangay
26	15.25 m	2.27	1.83 m	2.00 m	Drinking & others	Same
27	6.00 m	1.5	2.13 m	3.96 m	Drinking & others	Same
28	3.00 m	2.00	1.00 m	1.00 m	Drinking & others	Potable water
29	6.10 m	0.02	1.52 m	0.61 m	Watering	At the deep of less than 3.50 meters the water is fresh but more deepened it is salty

Table II.2-3 List of Inventoried Existing Wells (3)

Well No.	Well Depth	Total Pumping Amount (t/d)	G.W.L	Drawdown Estimated	Usage	Remarks
30	6.10 m	0.45	0.97 m	2.50 m	Washing	Water is salty yellowish in color, smell fishy unsafe for drinking
31	2.13 m	0.22	0.61 m	0.61 m	Washing & others	Not safe for drinking water lessed during dry season
32	7.32 m	0.30	2.44 m	3.00 m	Drinking	Grayey in color
33	3.00 m	0.45	1.00 m	3.00 m	Washing & others	Not advisable for drinking brownish in color
34	9.15 m	4.55	1.52 m	7.63 m	Washing & others	Same
35	6.71 m	2.28	1.56 m	4.50 m	Drinking & others	Safe for drinking
36	6.00 m	0.75	1.50 m	4.50 m	Washing & others	Water is potable lessen during summer
37	6.10 m	1.52	2.74 m	4.26 m		Water is potable but salty during dry season
38	4.58 m	2.00	3.05 m	1.53 m	Drinking & others	Same
39	7.93 m	0.45	2.13 m	3.50 m	Washing	Water is salty abondoned
40	5.00 m	1.51	1.50 m	1.00 m	Washing	Not advisable for drinking brownish in color lessen during dry season digging deep salty lessen
41	3.00 m	6.00	1.00 m	0.50 m	Drinking & others	Potable water, the flow of water can supply one barangay
42	4.00 m	0.15	2.00 m	2.00 m	Washing & others	Water is salty, brownish in color dries up during dry season
43	6.71 m	4.55	1.52 m	5.00 m	Watering	Water is salty

Table II.2-4 List of Inventoried Existing Wells (4)

Well No.	Well Depth	Total Pumping Amount (t/d)	G.W.L	Drawdown Estimated	Usage	Remarks
44	6.71 m	1.51	1.82 m	4.50 m	Washing & others	Safe for drinking
45	10.67 m	4.55	0.91 m	3.00 m	Watering	Fishy odor, Brownish color
46	6.10	9.6	2.43 m	3.60 m	Drinking & others	Sufficient supply of water
47	36.59 m	9.6	1.00 m	25.00 m	Washing & others	Not safe for drinking, brownish in color fishy odor
48	4.88 m	30	1.63 m	3.00 m	Washing & others	Water is salty
49	12.80 m	4.55	2.13 m	1.83 m	Drinking	Safe for drinking
50	4.00 m	0.15	0.31 m	0.31 m	Washing & others	Water lessen during dry season but not dried up, grayey in color
51	24.38 m	4.55	6.00 m	15.50 m	Watering	No good for washing clothes become brown water clear
52	8.00 m	0.15	6.00 m	0.30 m	Drinking	No water during dry season
53	4.88 m	0.08	1.52 m	0.30 m	Drinking	Water lessen during dry season not dried up
54	10.06 m	2.40	3.35 m	3.96 m	Drinking	Safe for drinking
55	9.15 m	0.30	3.05 m	1.00 m	Drinking	Lessen during summer not dried up sufficient for the whole barangay
56	9.15 m	0.91	6.10 m	0	Drinking	Continuous flow of water even summer
57	60.98 m	1.51	17.49 m	10.00 m	Drinking	Continuous flow of water sometimes with fishy odor
58	9.15 m	3.03	6.10 m	3.00 m	Drinking	Potable water
59	24.39 m	0.30	15.24 m	5.50 m	Drinking	Potable water

Table II.2-5 List of Inventoried Existing Wells (5)

Well No.	Well Depth	Total Pumping Amount (t/d)	G.W.L	Drawdown Estimated	Usage	Remarks
60	9.15 m	0.45	1.50 m	3.50 m	Watering & others	Water is yellowish in color & fishy odor continuous
61	3.00 m	3.00	1.00 m	1.50 m	Drinking	Water potable, lessen dry season few centimers not dried up, supply whole barangay
62	25.61 m	0.30	6.10 m	1.50 m	Watering	Contaminated by soil, unsafe for drinking
63	12.19 m	4.55	3.66 m	7.32	Drinking	Potable water
64	2.50 m	9.10	0	0	Drinking & others	Continuous overflow throughout the whole year
65	36.59 m	45.46	3.05 m	26.95 m	Drinking	Potable water
66	28.05 m	45.46	2.44 m	23.76 m	Drinking	Water contaminated septic tank build by people near well, no operation since 1979
67	38.46 m	45.46	2.74 m	26.30 m	Drinking	Unsafe for drinking, contaminated
68	11.58 m	4.55	0.30 m	5.00 m	Drinking	Sufficient for school and barangy water is potable
69	7.62 m	2.40	1.00 m	7.62 m	Drinking	Insufficient supply of water fishy odor during wet season
70	24.39 m	0.76	6.10 m	24.39 m	Drinking	Shortage of water during dry season water clear, fishy odor wet season
71	7.62 m	0.23	2.13 m	5.00 m	Washing & others	Smell fishy
72	9.15 m	0.20	4.57 m	4.57 m	Watering & others	Contaminated, fishy odor

Table II.2-6 List of Inventoried Existing Wells (6)

Well No.	Well Depth	Total Pumping Amount (t/d)	G.W.L	Drawdown Estimated	Usage	Remarks
73	6.10 m	0.55	6.10 m	0	Drinking & others	Level to river
74	2.13 m	8	0	0	Drinking & others	Continuous overflow
75	2.13 m	8	2.13 m	0	Drinking & others	Continuous overflow
76	12.20 m	4.55	2.44 m	6.50 m	Washing & others	Not advisable for drinking
77	15.24 m	4.55	2.89 m	7.75 m	Watering & others	Not advisable for drinking
78	20.12 m	4.55	3.50 m	10.50 m	Watering & others	Not advisable for drinking
79	17.38 m	3.64	2.44 m	13.50 m	Washing & others	Not advisable for drinking
80	7.93 m	4.55	3.05 m	4.88 m	Washing & others	Not advisable for drinking
81	20.43 m	4.55	6.10 m	12.20 m	Drinking & others	Potable
82	8.00	0.5	2.00 m	3.00 m	Washing & others	Not advisable for drinking, fishy odor dry up during dry season
83	9.15	64	4.58 m	4.57 m	Washing & others	Not advisable for drinking, source connected to river
84	13.72 m	4.55	1.22 m	3.35 m	Drinking	Water is potable
85	13.41 m	4.55	4.57 m	3.05 m	Drinking	Water is potable
86	17.07 m	4.55	1.52 m	4.50 m	Drinking	Water is potable
87	48.78 m	1.50	8.00 m	30.00 m	Drinking	Water is potable
88	51.83 m	1.50	15.00 m	27.00 m	Drinking	Water is potable
89	5.49 m	1.00	1.50 m	0	Drinking & others	Level to river
90	12.80 m	0.50	1.83 m	2.50 m	Watering & others	Safe for Drinking

Table II.2-7 List of Inventoried Existing Wells (7)

Well No.	Well Depth	Total Pumping Amount (t/d)	G.W.L	Drawdown Estimated	Usage	Remarks
91	18.90 m	4.55	1.98 m	9.00 m	Watering & others	Safe for drinking
92	31.71 m	4.55	2.13 m	25.00 m	Watering & others	Safe for drinking
93	26.22 m	4.55	2.34 m	23.61 m	Drinking & others	Safe for drinking
94	13.12 m	0.98	1.75 m	1.20 m	Drinking	Safe for drinking
95	6.00 m	8	2.20 m	1.00 m	Drinking	Level to river, safe for drinking
96	10.67 m	16	3.05 m	7.50 m	Drinking & others	Safe for drinking
97	36.59 m	0.18	12.20 m	6.10 m	Watering	Unsafe for drinking brownish fishy odor,washing clothes blackish, lessen dry season
98	15.24 m	0.76	3.05 m	15.00 m	Watering	Contaminated with brownish particles fishy odor, no water during dry season
99	9.15	3.64	1.52 m	3.05 m	Drinking	Water lessen during dry season
100	54.88 m	7	3.05 m	45.73 m	Drinking & others	Observed muddy during raining insufficient supply of water
101	12.20 m	0.50	3.05 m	4.00 m	None	Contains orange particles, not good for washing clothes water level decrease during dry season
102	13.41	4.55	3.05 m	5.49 m	Drinking	Safe for drinking
103	18.29 m	1.36	4.57 m	13.72 m	Washing & others	Shortage of water not potable for drinking
104	6.10 m	4.55	1.83 m	4.00 m	Washing & others	High contain of iron, potable
105	39.63 m	0.045	9.14 m		Washing & others	Water is salty, shortage of water

Table II.2-8 List of Inventoried Existing Wells (8)

Well No.	Well Depth	Total Pumping Amount (t/d)	G.W.L	Drawdown Estimated		
106	36.69 m	0.045	6.20 m		Washing & others	Water is salty, shortage of water reddish in color not advisable for drinking
107	10.06 m	0.02	3.35		Washing & others	Brownish color, not advisable for drinking
108	24.39 m	4.55	4.57 m	15.00 m	Washing & others	Blackish in color, salty

Table II.2-9 Summary of Well Files of National Water Resources Council

	Town	Average Static Water Level (m)	Average Discharge lps	Specific Capacity	Total Well Number	Completed Year	Average Well Depth (m)
1.	Tapaz	2.27	0.40	0.18	9	1954-1956	18.05
2.	Dumalag	3.96	0.55	0.70	8	1949-1962	31.91
3.	Dumarao	7.04	0.93	0.80	14	1949-1962	23.09
4.	Cuartero	3.44	0.66	0.31	9	1948-1962	18.07
5.	Dao	3.49	0.67	0.54	12	1948-1962	20.74
6.	Sigma	2.44	0.52	0.59	4	1955-1957	16.77
7.	Panitan	4.06	0.47	0.43	10	1955-1962	14.19
8.	Mambusao	3.99	0.43	0.15	14	1953-1965	17.71
9.	Jamindan	3.28	0.57	0.28	5	1955-1966	38.11
10.	Pontevedra	2.60	0.74	1.75	22	1954-1958	10.64
11.	Panay	2.82	0.67	0.61	19	1954-1957	14.43
12.	Roxas City	1.72	1.17	0.49	25	1953-1971	13.38
		3.13	0.72	0.66	151	1948-1971	17.50

Table II.2-10 Summary of Wells Inventoried in This Stage

	Town	Average Well Depth (m)	Average Static Water level (m)	Estimated Daily Average Usage Quantity (ton/day)	Well Number	Spring Water	Abandoned Well number
1.	Tapaz	27.69	5.82	1.17	4		5
2.	Dumalag	20.98	3.11	3.59	5		2
3.	Dumarao	20.33	5.59	1.53	3	2	
4.	Cuartero	14.00	2.34	7.38	4		
5.	Dao	21.14	1.98	3.20	3		
6.	Signa	5.43	2.99	3.40	5		
7.	Panitan	10.69	3.22	1.98	6		1
8.	Mambusao	14.47	3.20	3.84	8		1
9.	Jamindan	25.05	5.30	2.94	6		
10.	Maayon	14.53	2.47	2.57	3	1	
11.	Pontevedra	20.64	5.27	12.29	13		
12.	Panay	7.36	1.66	3.78	25		1
13.	Roxas City	10.97	2.35	2.78	23		1
	Average	16.41	3.48	3.88	*108	3	11

*One of the well in Mambusao leads water from the river directly.

FIGURES

FOR

APPENDIX II

Fig. II.1-1 REGIONAL GEOLOGICAL MAP OF THE PROJECT AREA

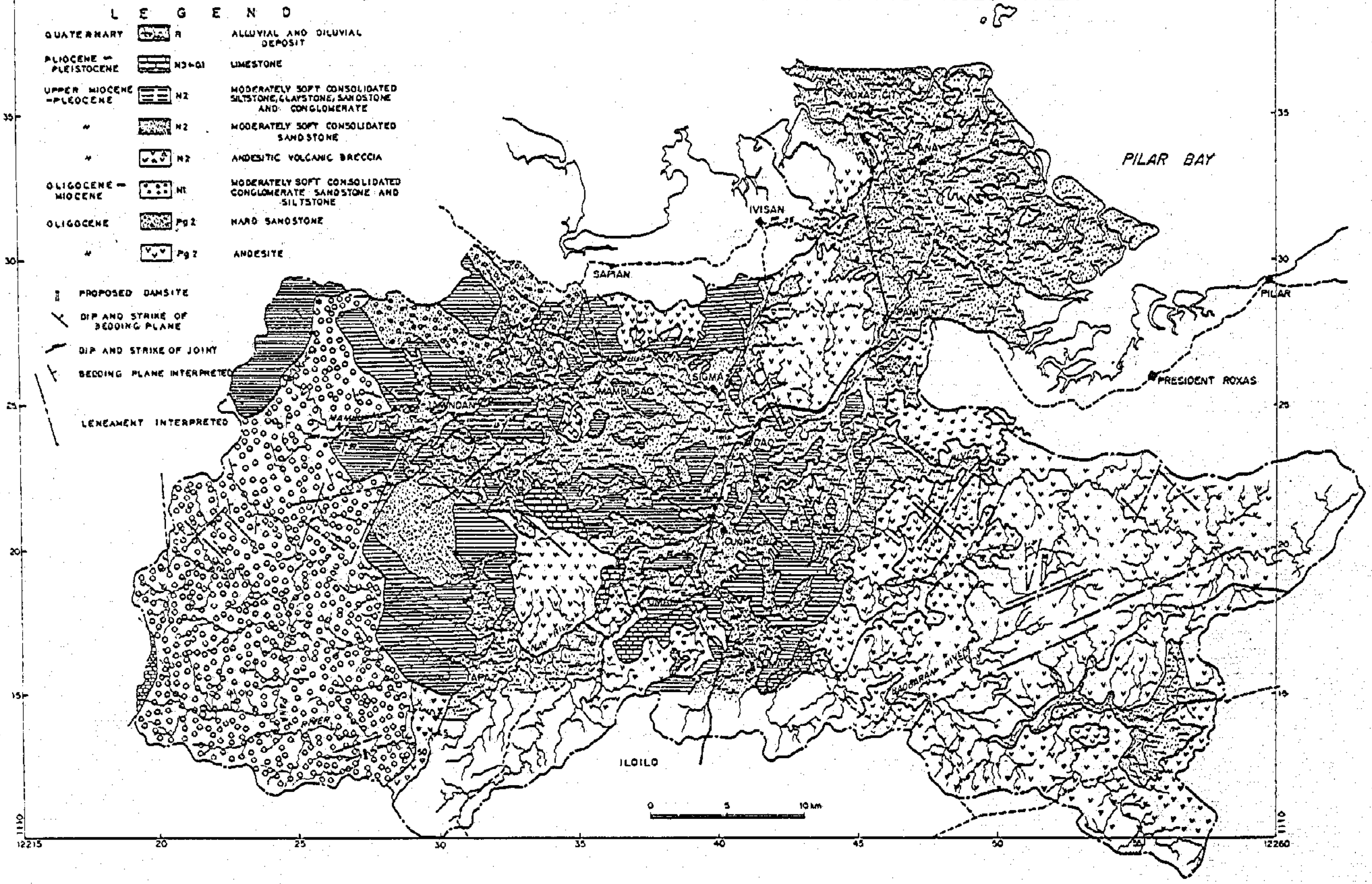


Fig. II.1-2 LOCATION MAP OF DAM SITES AND INVESTIGATION SITES

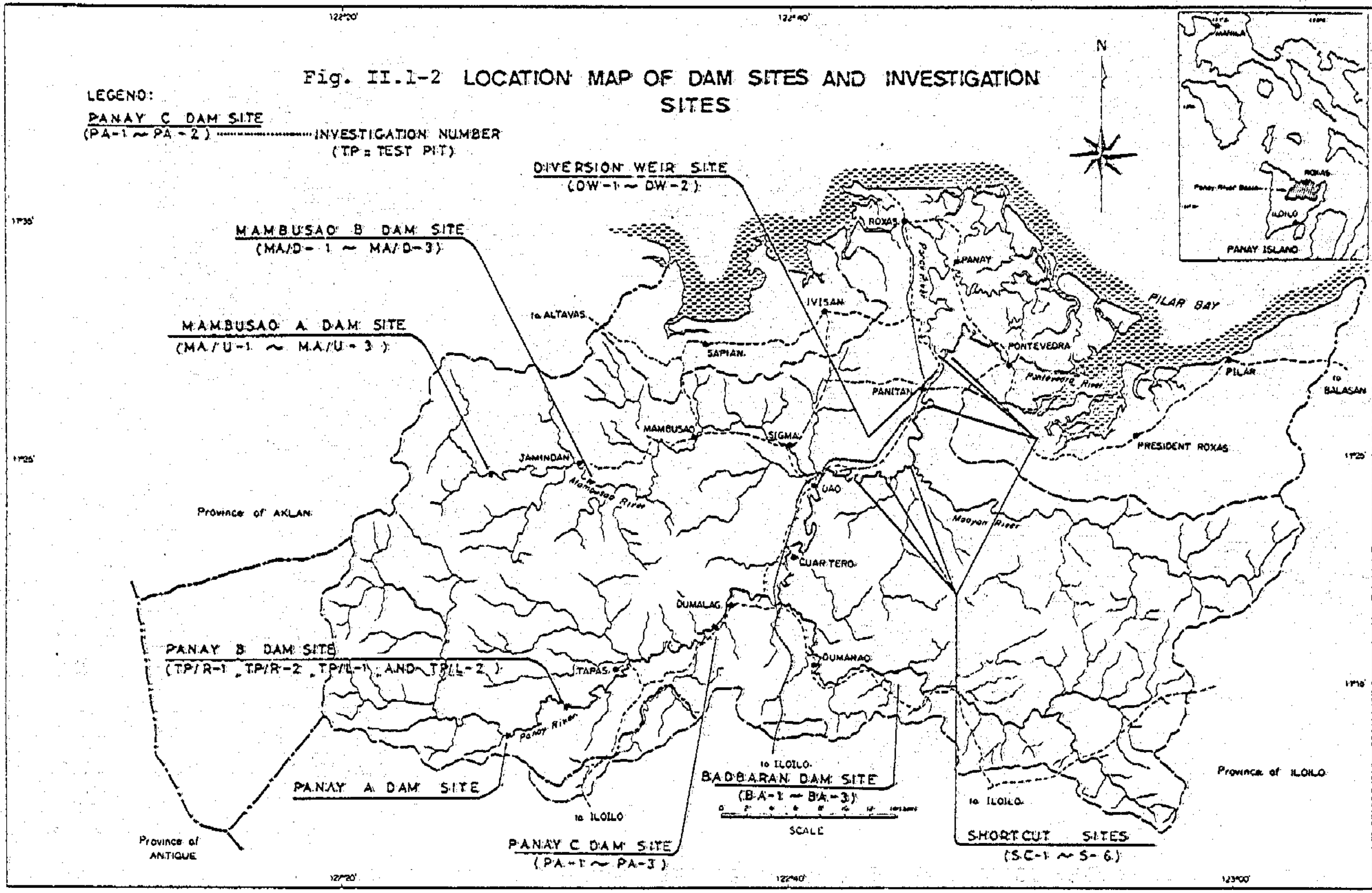


Fig. II.1-3 SUMMARY OF BORING LOGS (1/2)

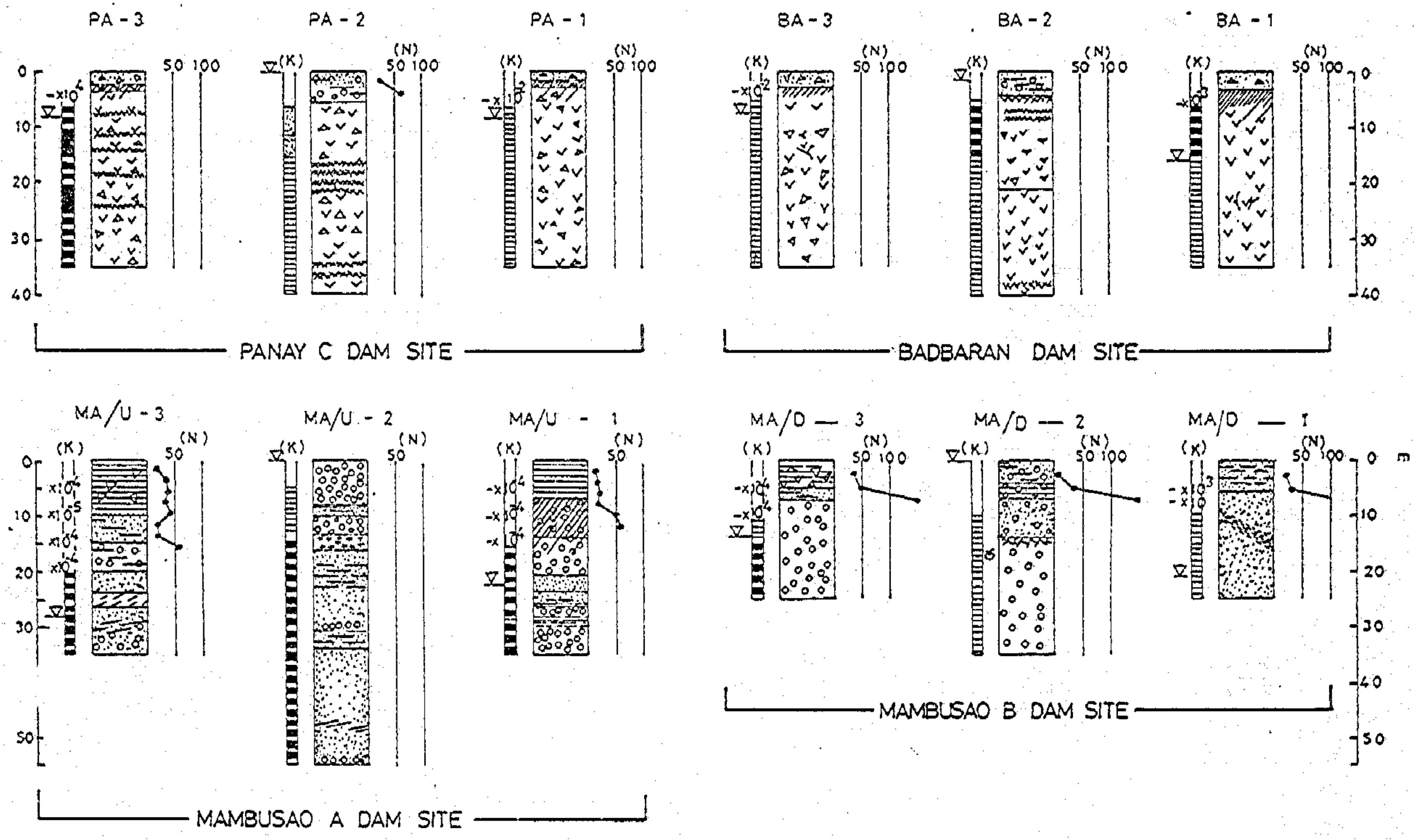


Fig. II.1-4 SUMMARY OF BORING LOGS (2/2)

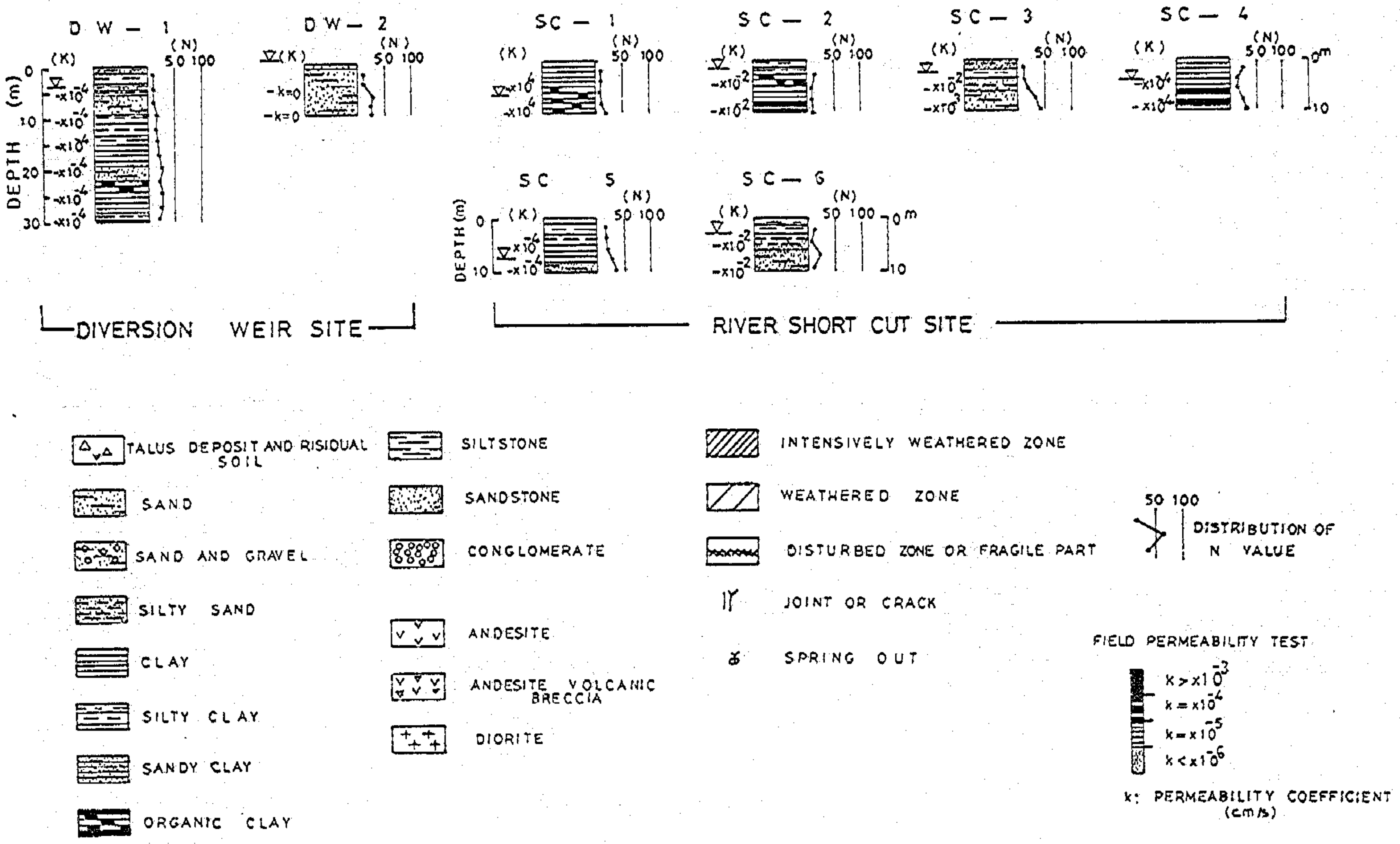


Fig. II.1-5 EXPERIMENTAL FRICTIONAL LOSS TEST

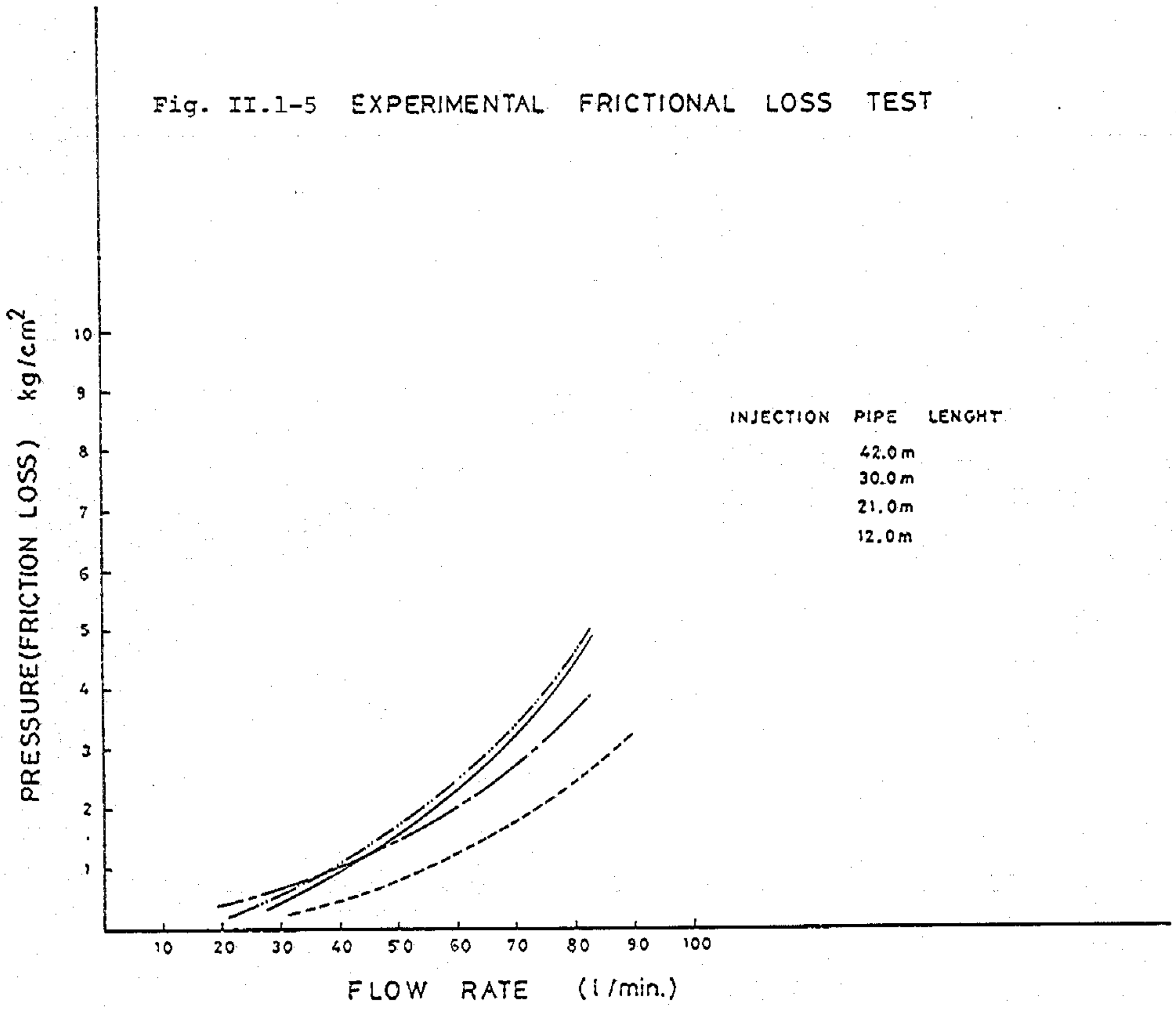
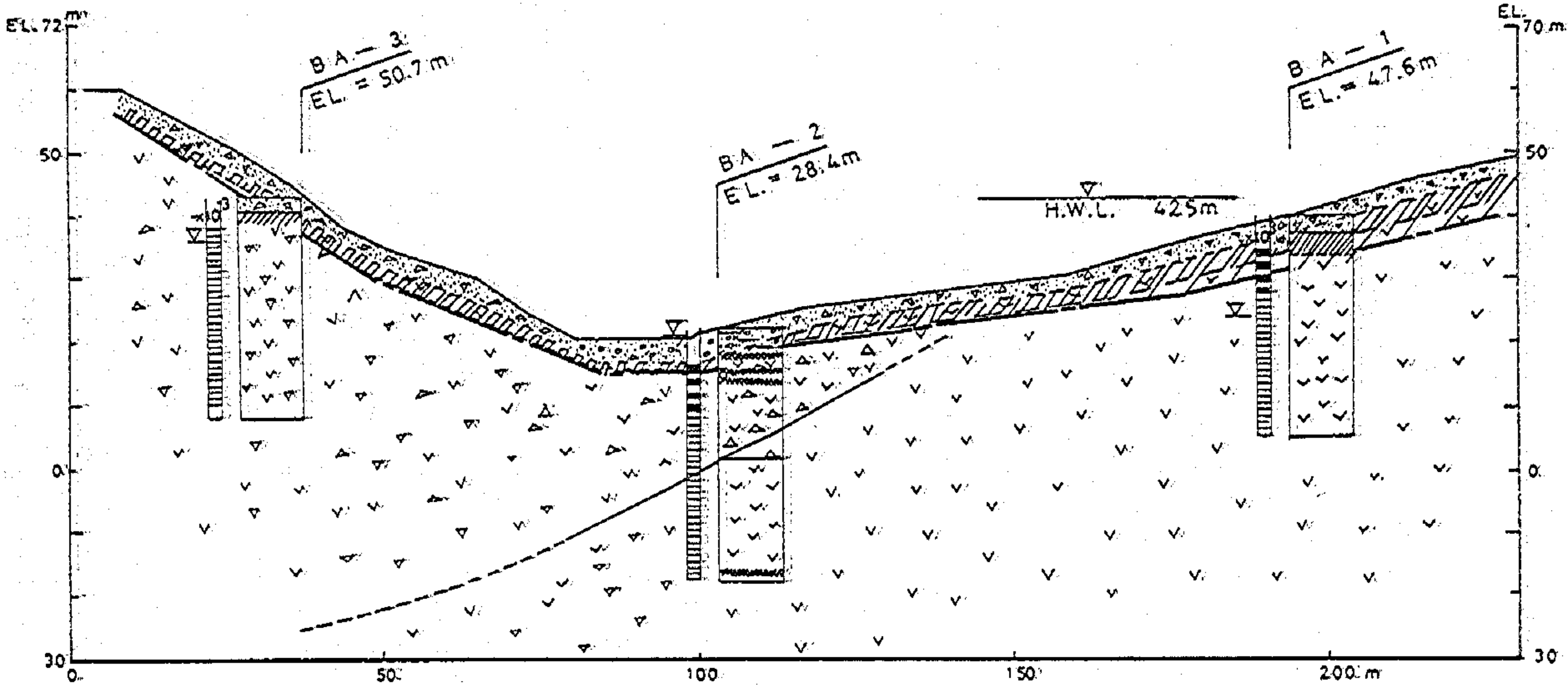
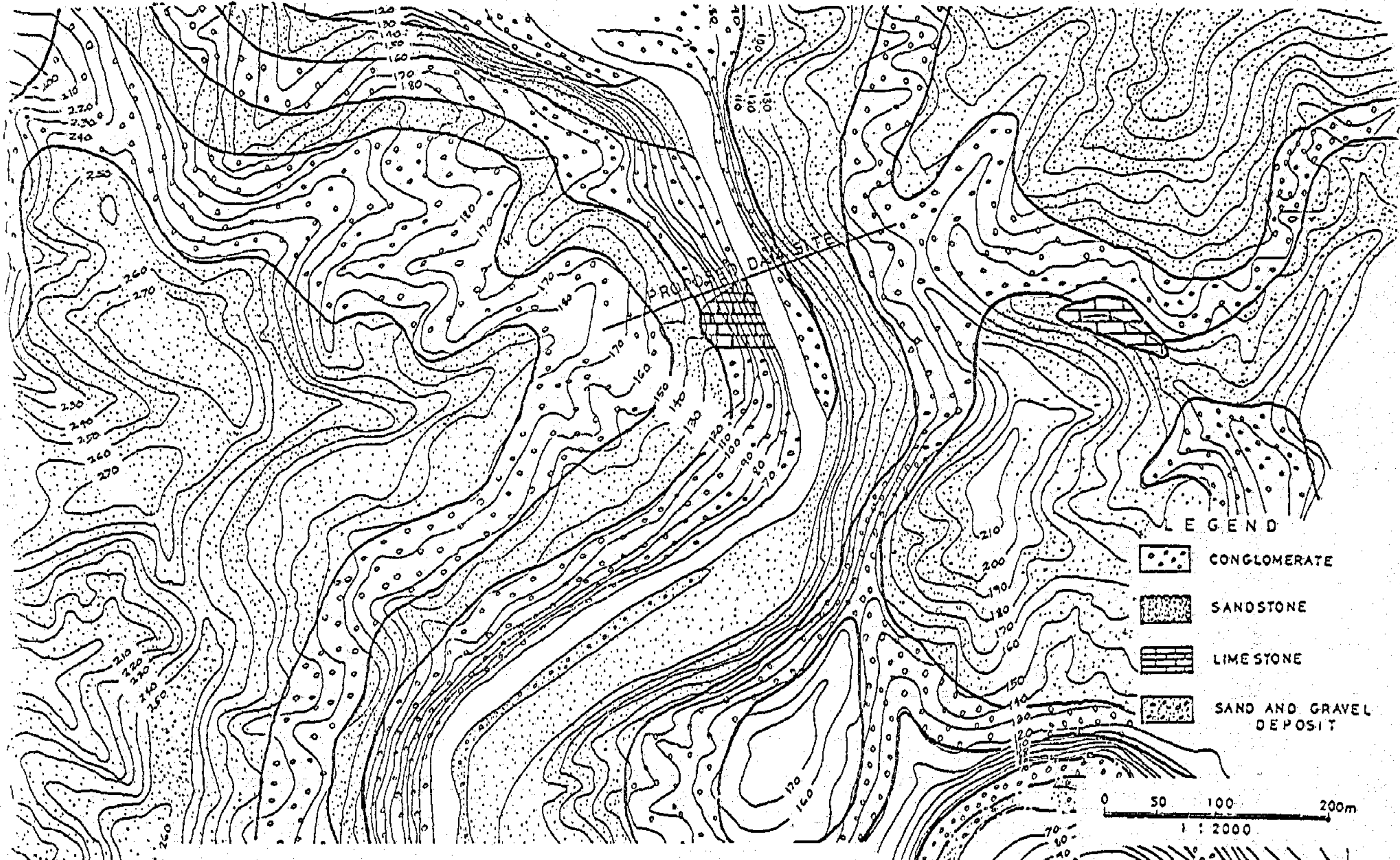


Fig. II.1-6 GEOLOGICAL PROFILE ALONG THE DAM AXIS OF BADBARAN DAM SITE



LEGEND: refer to the LEGEND for SUMMARY OF BORING LOGS except following

—·—·— assumed excavation line



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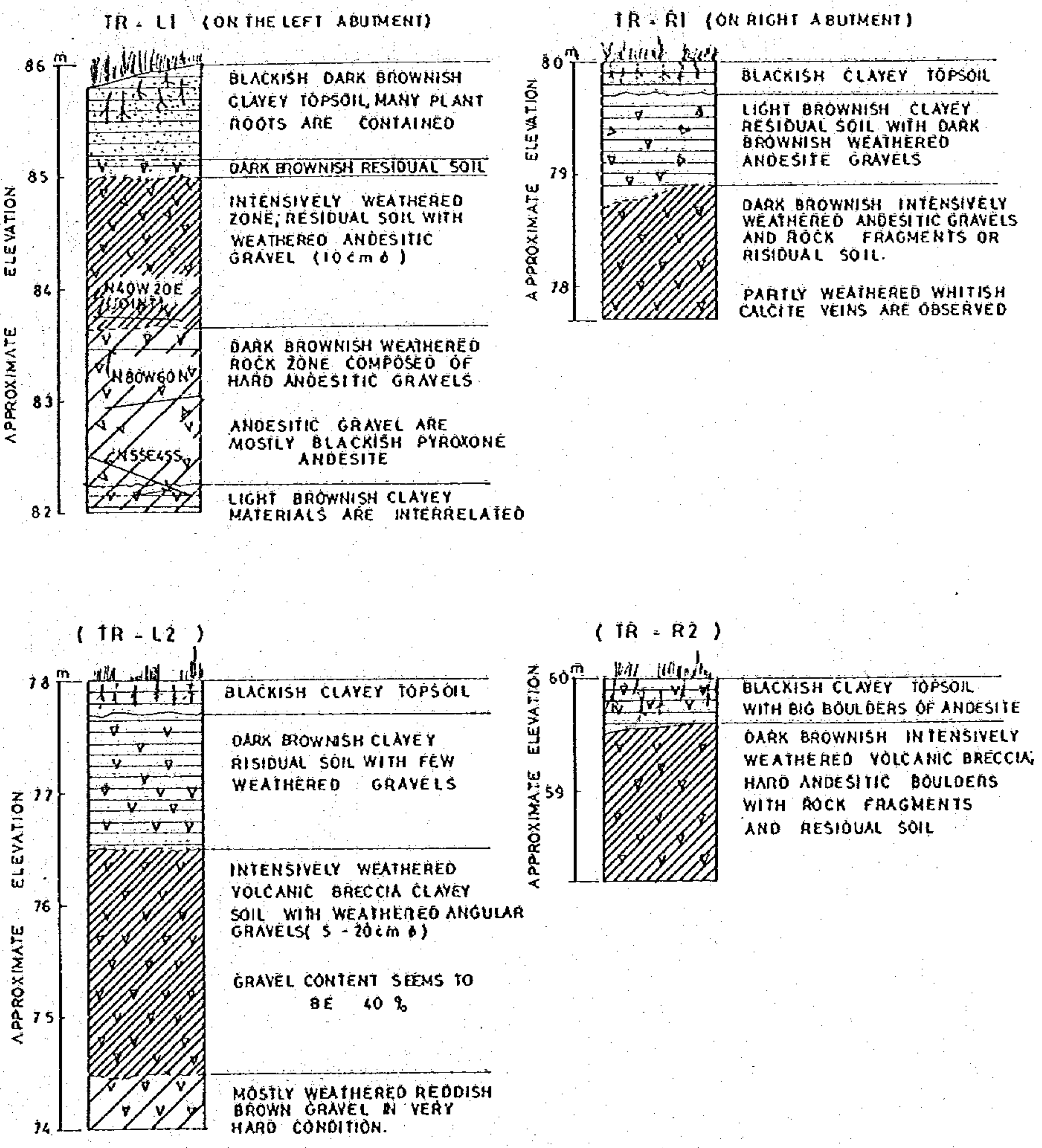


Fig. II.1-9 GEOLOGICAL PROFILE ALONG THE DAM AXIS OF PANAY B DAM SITE

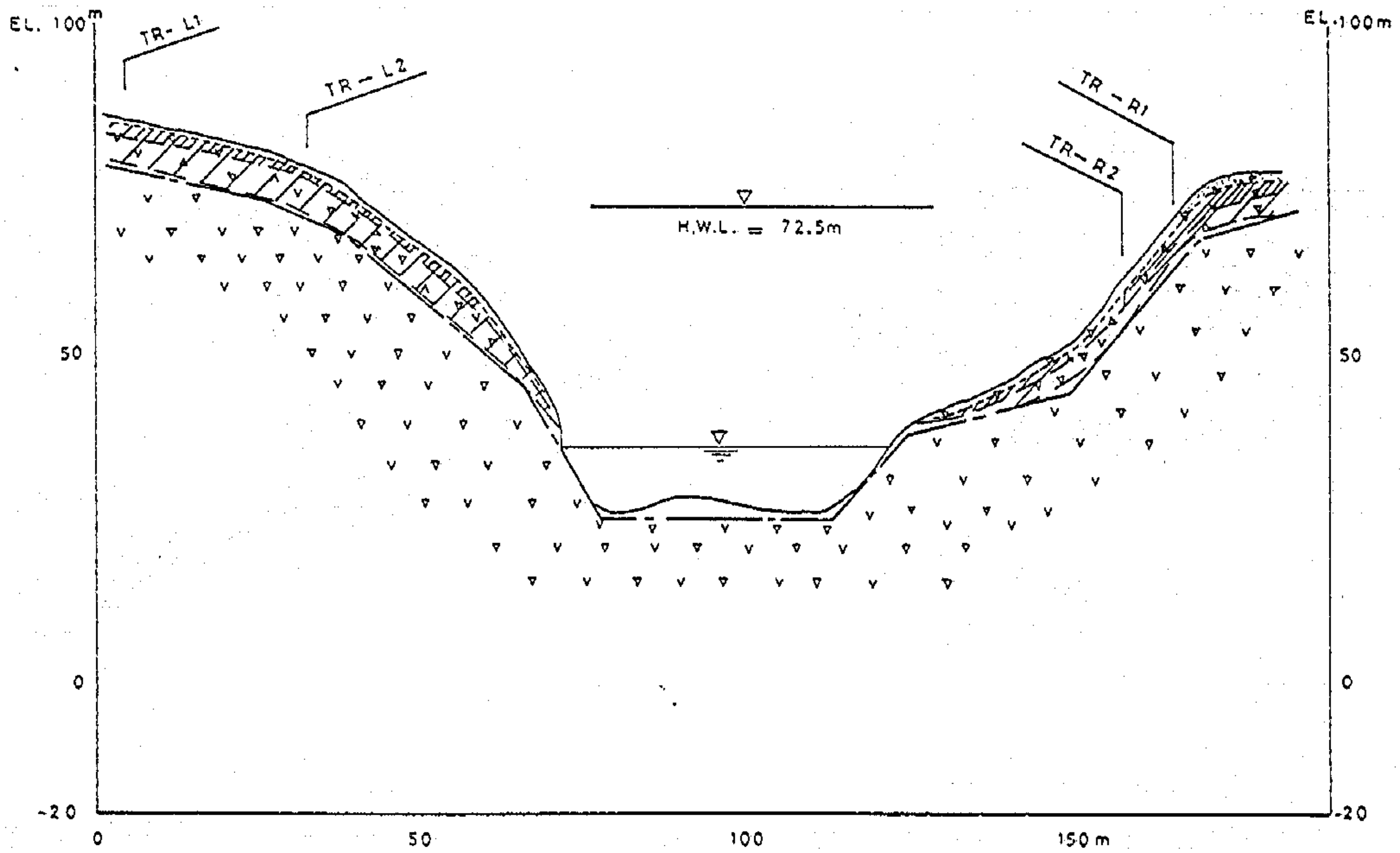
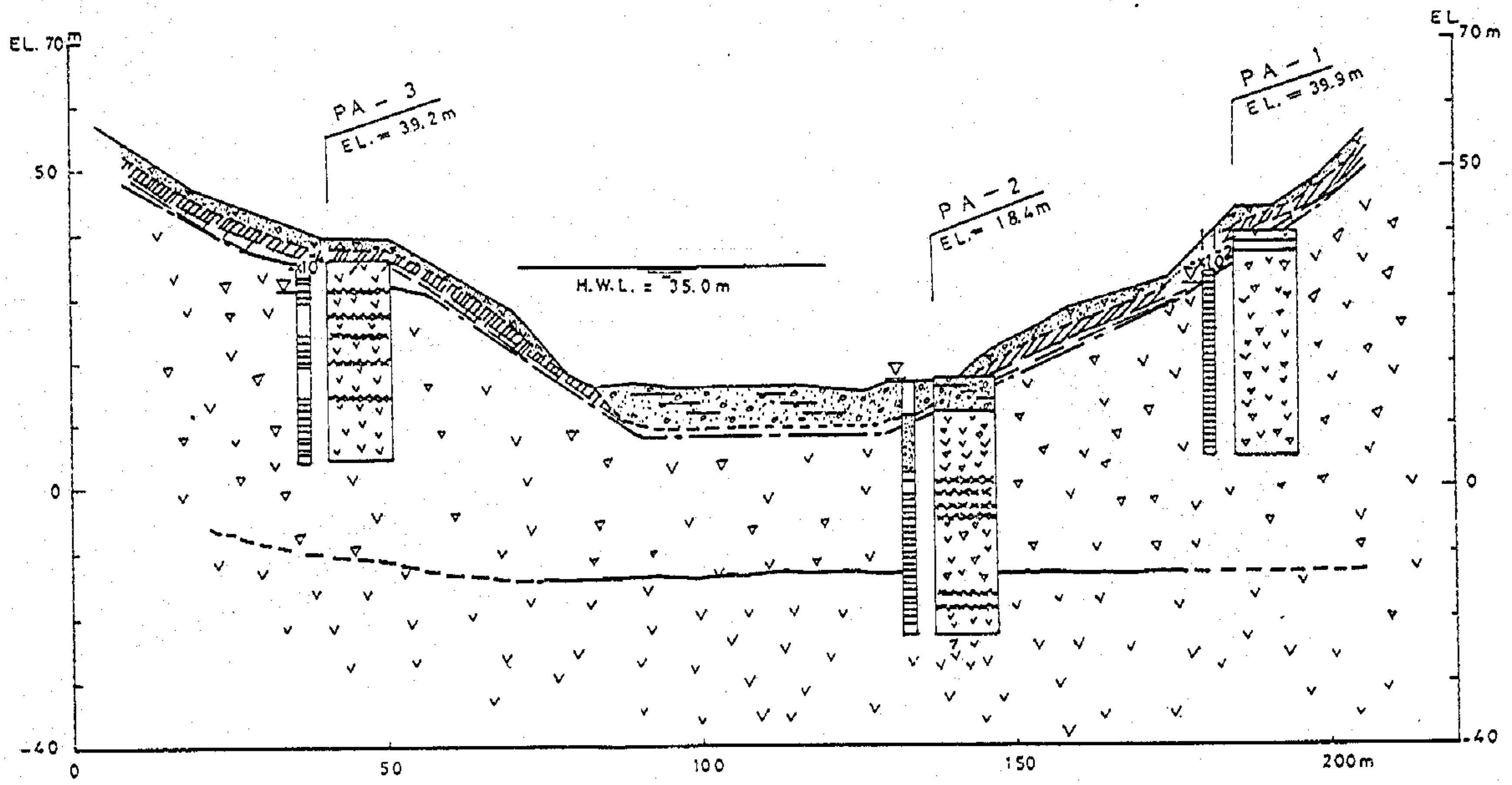


Fig. II.1-10 GEOLOGICAL PROFILE ALONG THE DAM AXIS OF PANAY C DAM SITE



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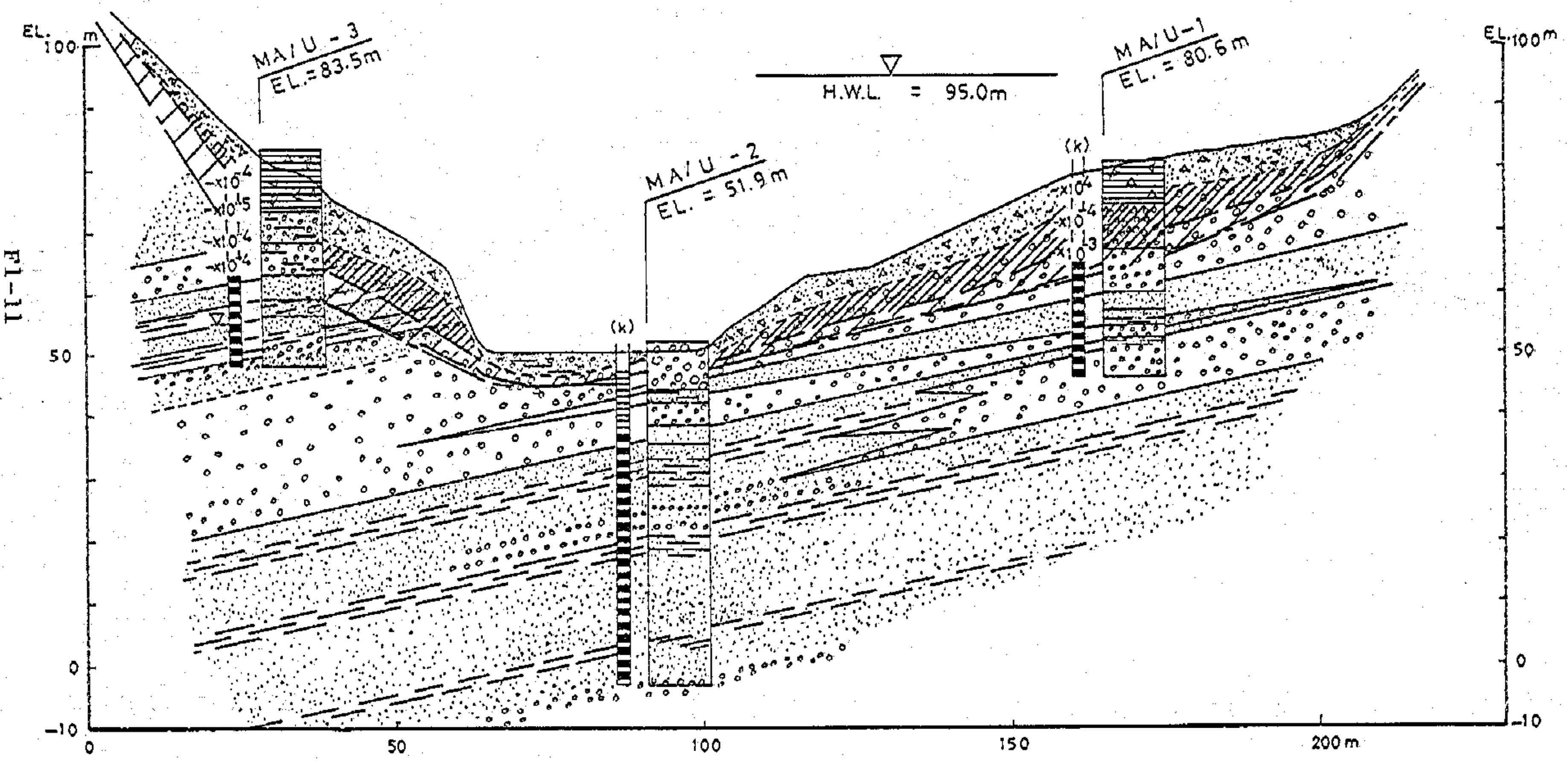
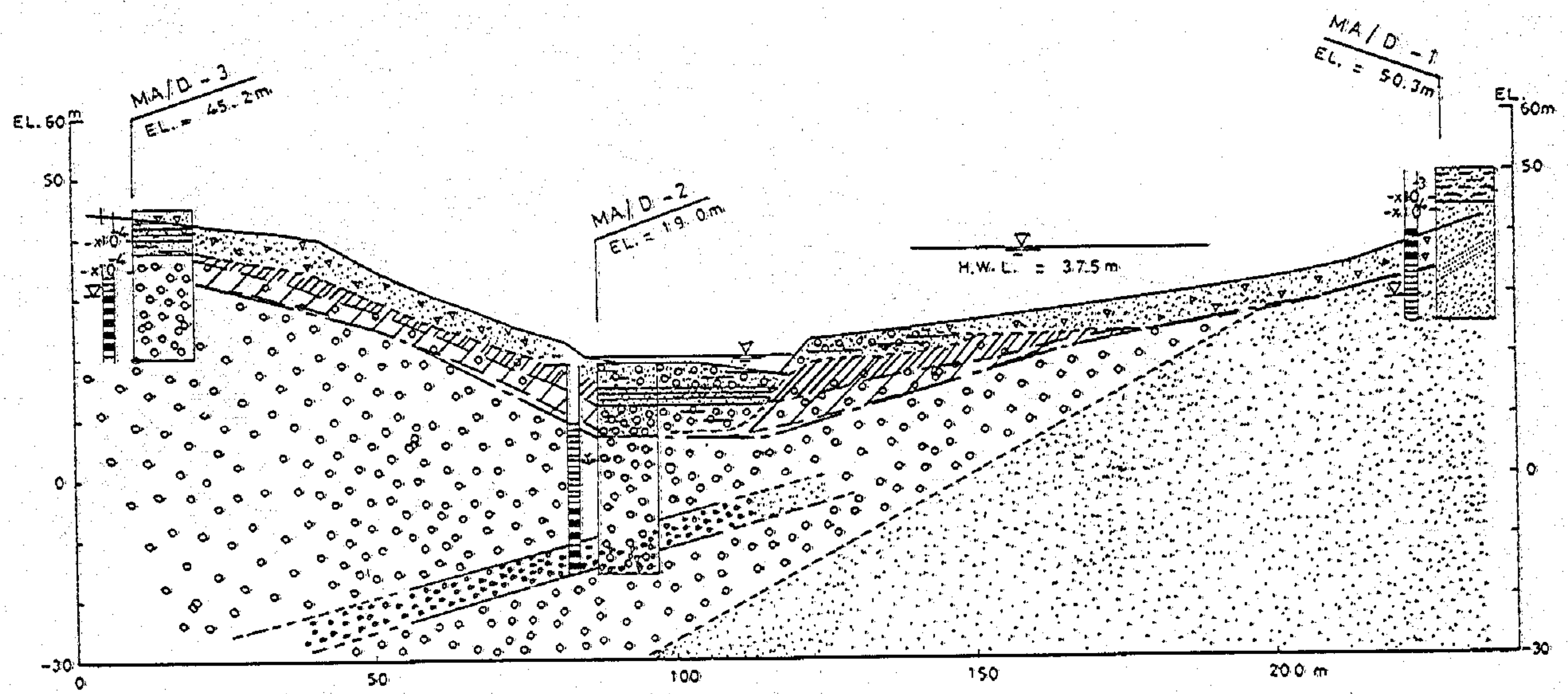


Fig. II.1-12 GEOLOGICAL PROFILE ALONG THE DAM AXIS OF MAMBUSAO B DAM SITE



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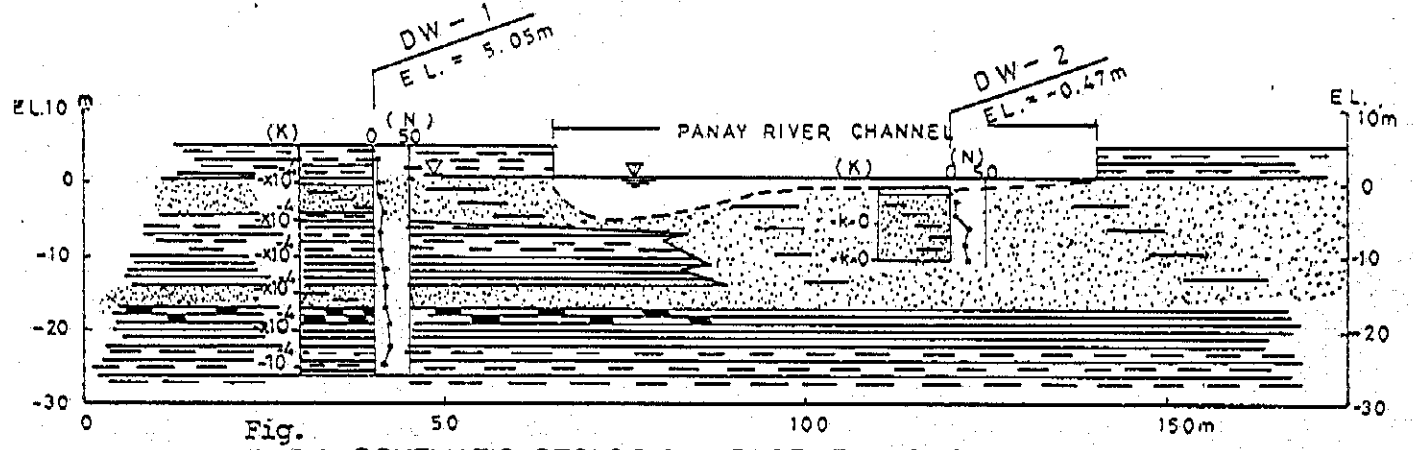

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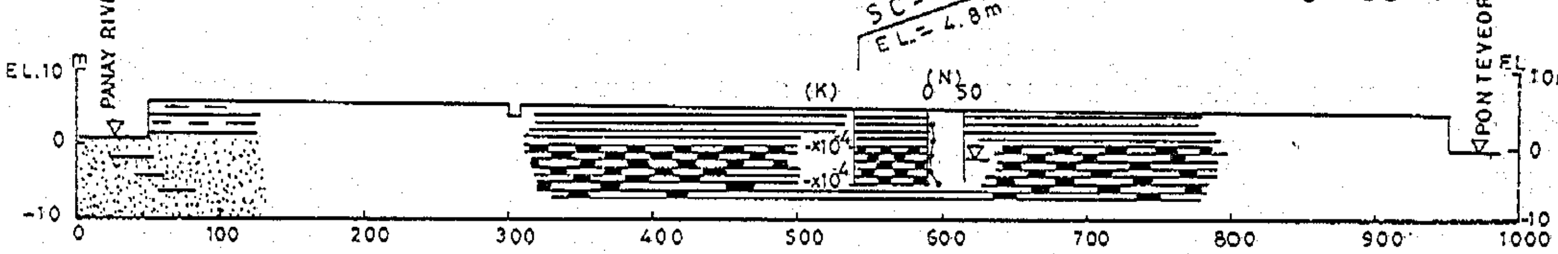

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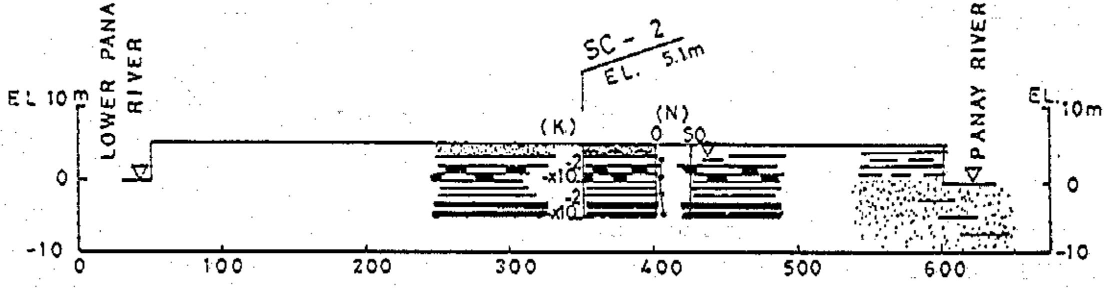

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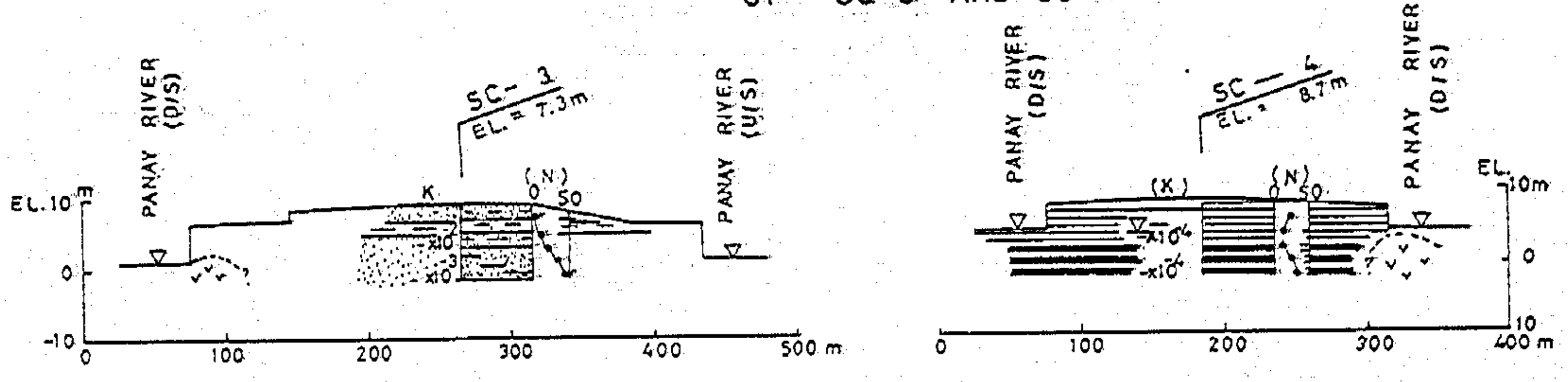

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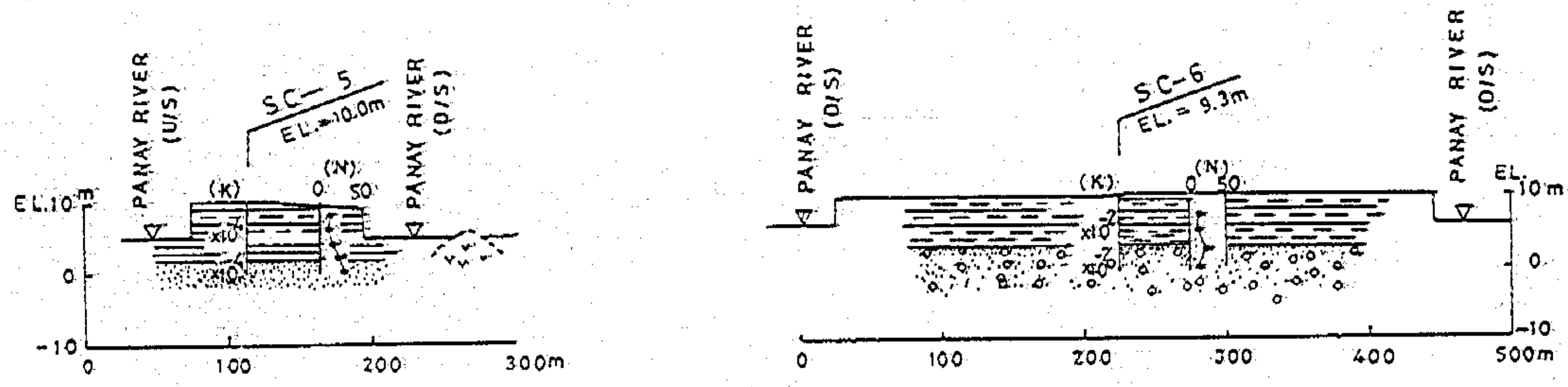


Fig. II.2-1 DISTRIBUTION MAP OF INVENTORIED WELL

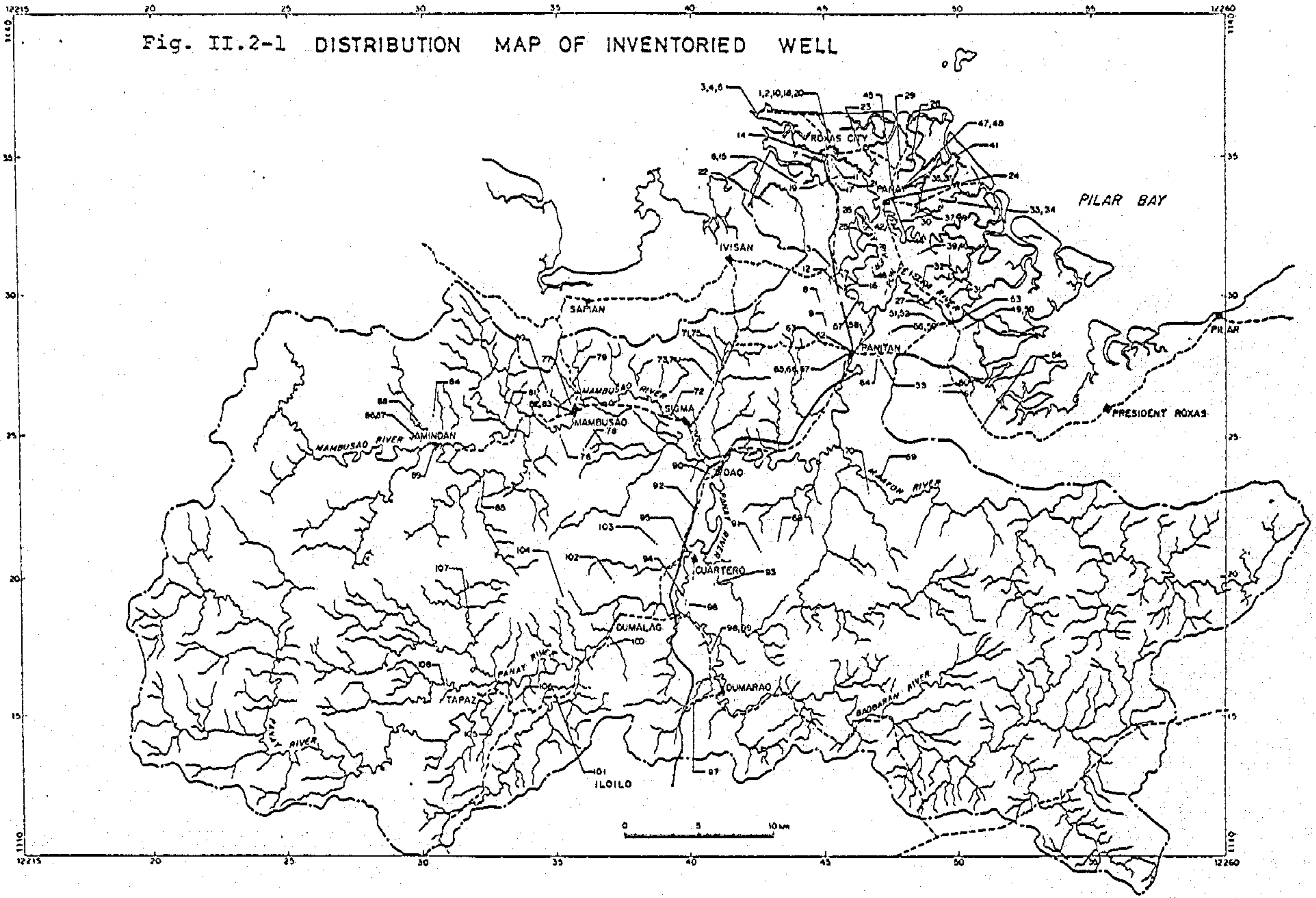
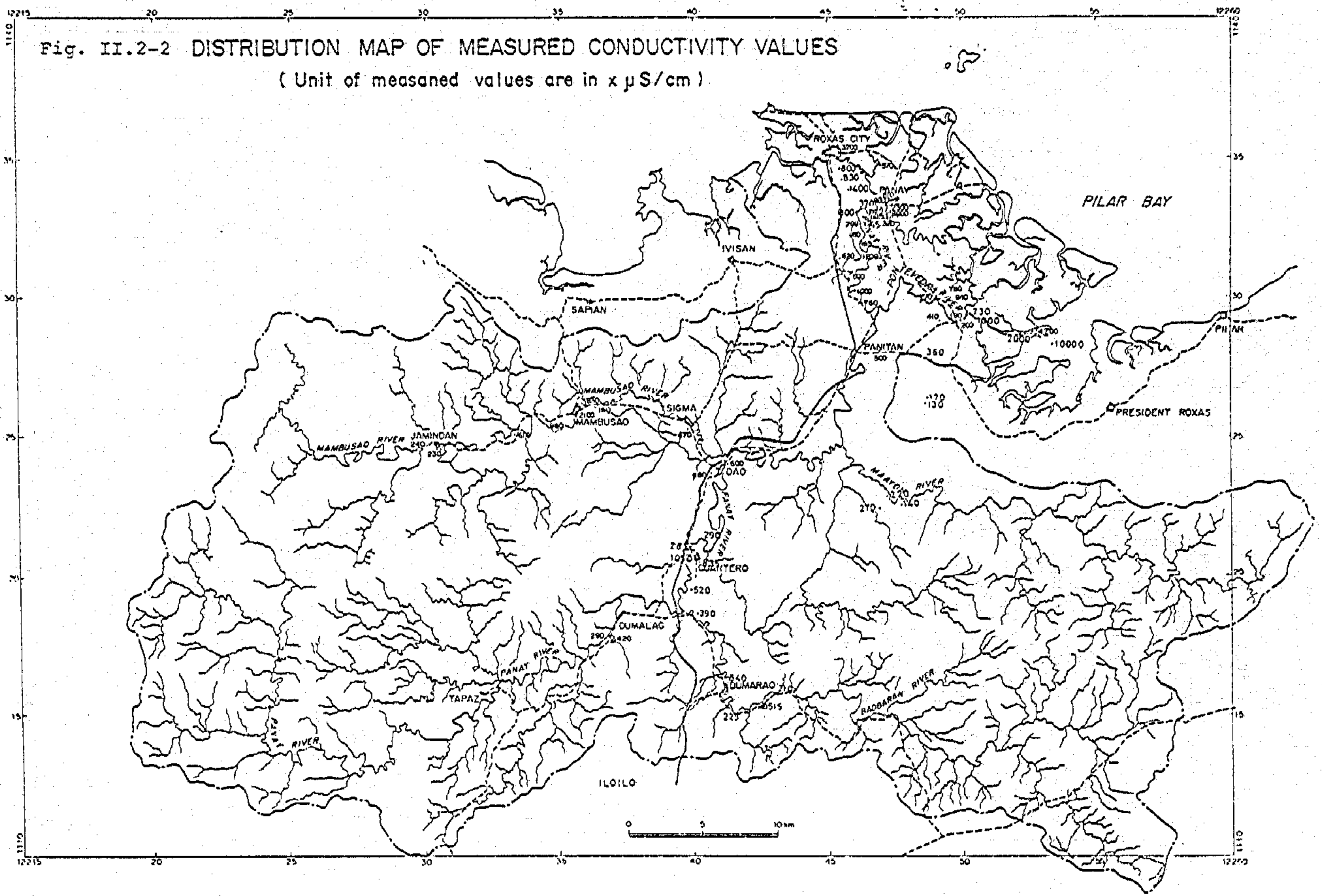
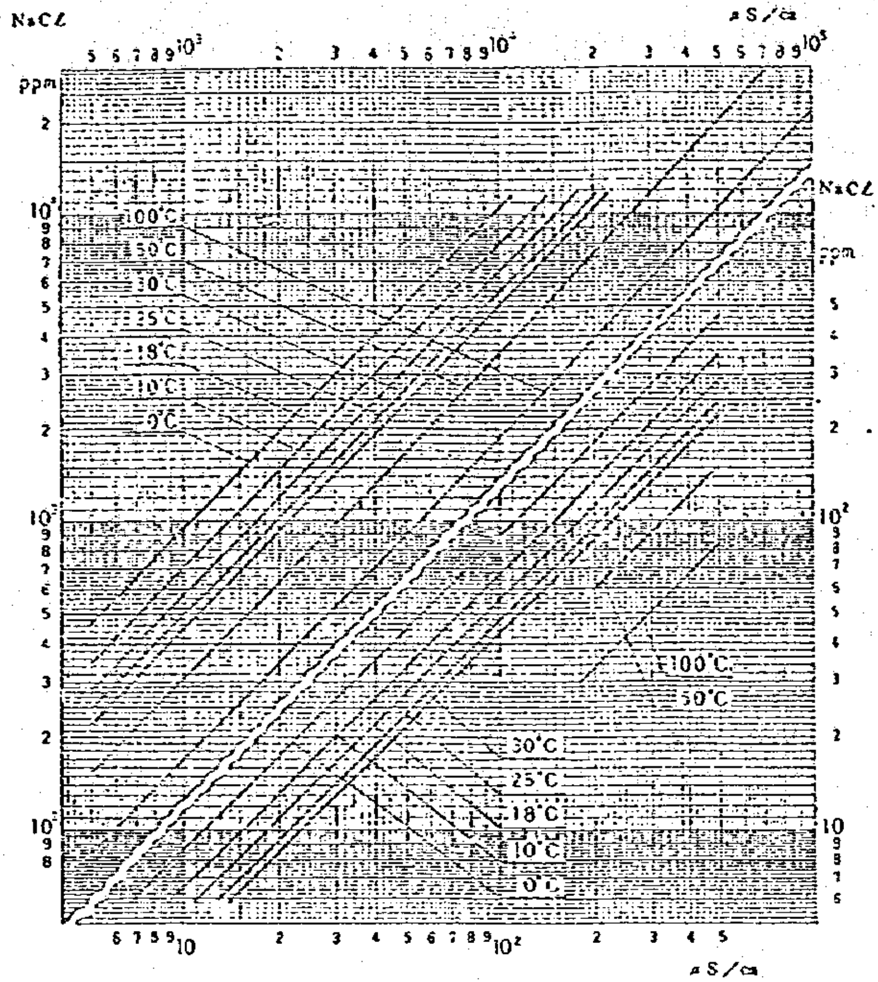


Fig. II.2-2 DISTRIBUTION MAP OF MEASURED CONDUCTIVITY VALUES
(Unit of measaned values are in x μS/cm)





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APPENDIX III

FLOOD DAMAGE STUDY

FOR

FINAL REPORT

ON

THE PANAY RIVER BASIN-WIDE

FLOOD CONTROL STUDY

THE PANAY RIVER BASIN-WIDE FLOOD CONTROL STUDY

APPENDIX III FLOOD DAMAGE STUDY

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1. Introduction

The flood damage study aims at enumerating the amount of damages due to floods in the Panay river basin. The flood damage is estimated for the planning and economic evaluation of the flood control projects contemplated in this basin-wide study.

The flood damage study is divided into hydrological analysis of flood characteristics and flood damage analysis. General procedure of the study is illustrated in a flowchart in Fig. III. 1-1.

The hydrological analysis of flood characteristics is directed at determining the area, depth and duration of inundations due to different magnitude of flood, of which results are the bases of the estimation of damage rates to production and properties in the inundated area.

The ultimate values worked out in the flood damage analysis are the average annual flood damages under with-flood control and under without-flood control conditions, from which the benefits of flood control projects are derived as the difference between average annual flood damages under two (2) conditions. The flood damages are computed as the damageable values multiplied by damage rates, in principle, for each property and production.

The amounts of the flood damage and production loss are estimated at June, 1984 economic price constant. The amounts in the future condition take the increase of productivity and property in the flood prone area into consideration. Despite the fact that the basin still has comparatively low productivity and property , some improvement is brought about in proportion to regional economic developments in the future.

In this flood damage study, the direct and indirect benefits are taken into consideration for flood control benefits. The direct and indirect benefits accrue from the reduction in flood damage and production loss. The flood damage including production loss is estimated in this study divided into the following six (6) major items of damage.

(1) Crop damage

(2) Livestock damage

(3) Building damage

(4) Fishpond damage

(5) Infrastructure damage

(6) Indirect damage

2. Hydrological Analysis of Flood Characteristics

The flood flow analysis aims at identifying the inundated area, depth and duration for different flood magnitudes. The analysis of the flood characteristics consists of:

(1) flood flow analysis by simulation method;

(2) field survey and study of actually-exhibited flood characteristics.

In this study, the former method is principally adopted. Afterwords, the results are checked with actually exhibited-flood characteristics.

The identification of flood characteristics is made mesh by mesh of 100 x 100 m of flood prone area. The inundation conditions in the flood plain are identified for the floods with different return periods such as 1.1, 2, 5, 10, 25, 50 and 100 years.

2.1 Inundation Area and Depth

In the flood flow analysis, the inundation area and depth are decided for different probable floods assuming that the points falling in a line which make a right angle with the direction of flood flow have the same water level as that of the flood way. The points which have higher water level than the ground elevation are regarded as flooded and the difference in elevation between the flood water level and ground elevation is defined as the inundation depth.

The flood water level at the point along the river channel is estimated in the flood flow analysis. The inundation depth of each mesh of land is decided from the water level of the point along river channel corresponding to the mesh in the same way as above. Ground elevation is measured from 1/10,000 topographic map prepared from aerial photographs.

Inundation depth in the flood is estimated mesh by mesh in the mesh map based on the stage hydrograph corresponding to the mesh which is constructed by interpolation using the stage hydrographs calculated by the flood flow analysis at the upstream and downstream base points.

Inundation area of flood prone area is complied using inundation depth of mesh for each flood with different return period of occurrence. The details of the method are described in Appendix I, Meteorological and hydrological study.

Amoung the results of the calculation, distribution of inundation in the flood plain for 5, 25 and 100 year floods is shown in Figures IV. 4-3 to IV. 4-5 in Appendix IV. The inundation depth shown in the figures indicates the average maximum depth in each mesh of 500 m x 500 m occurred during the flood.

From the figures, the followings can been seen:

(a) In case of smaller flood (5 year flood), deep inundations occur in the area along the middle reaches of the main river downstream from Dumalag to the confluence with the tributary Maayon and in the area of vast paddy field located south of downstream reaches of the tributary of Mambusao.

(b) In case of 25 year flood, the above deep inundation areas increase their width and at the same time extend to the downstream up to the area near Pontevedra.

(c) In case of 100 year flood, the above deep inundation areas expand further but the expansion is more conspicuous in the downstream area from confluence with the tributary Maayon.

2.2 Inundation Duration

The inundation duration of each mesh of land is estimated by the stage hydrograph corresponding to the mesh. The stage hydrograph is constructed by interpolation based on the stage hydrographs simulated by the flood flow analysis at upstream and downstream base points. In the said interpolation, the actually-exhibited flood flow characteristics are taken into account.

3. Procedure for Estimation of Flood Damage

Flood damage is estimated for six (6) major items as explained in the foregoing chapter 1. The livestock, infrastructure and indirect damages are estimated multiplying the other damage or the sum of damage by ratio developed from flood damage records, while the crop, building and fishpond damages are calculated multiplying damageable values by a damage rate.

3.1 Crop Damage

Crop damages are broken down into the following categories:

(a) Irrigated paddy damage

(b) Rainfed paddy damage

(c) Vegetable damage

(d) Sugar cane damage

Crop damage is generally defined as the difference in the net income of crop production or the difference in net value increased by crop production, between in with-flood and in without-flood conditions. It is expressed as follows assuming the production cost decreases in proportion to the yield decrease rate:

Crop damage = (crop damage rate) x (expected net income + production cost already spent when damage occurred)

The procedure taken in the calculation of crop damage is shown in Figure III. 3-1. The formula used here is as follows:

Crop damage = (crop damage rate) x (damageable value of each categories) x (inundated area data)

The crop damage rate which is dependent on inundated depth and duration, crop growth stage and flood flow velocity is determined based on the criterion prepared by the Ministry of Construction and Ministry of Agriculture, Forestry and Fishery in Japan. The Japanese criterion has parameters for the former three (3) as shown in Tables III. 3-1 and III. 3-2.

The damageable value is assessed with the following parameters:

(a) Crop yield

(b) Price of products

(c) Production cost

(d) Land use (Planted area)

(e) Seasonal frequency of flood

The information on yield and prices of crops come from BAECON, NFA, Provincial Statistic, while that on production cost and its structure from BAEX, NIA, PHILSUCOM and BPI. The annual growth rates of crop yield are estimated by nation wide trend in Fig.III.3-3 as follows:

(a) Paddy : 0.036 kg/ha/year

(b) Vegetable : 0.196 kg/ha/year

(c) Sugar cane : no change

Prices of products are estimated applying the economic prices as shown in Table III. 3-3(1) to III. 3-3(10). The crop production costs with their breakdown for the year 1984, 1989 and 1994 are estimated applying the World Bank projection as shown in Table III. 3-3(1). Tables III.3-3(4) to III.3-3(5) also shown economic production cost per ha of irrigated paddy, for an example. Growth rate of production costs is assumed to be proportional to the crop increase per unit area.

The monthly frequency of flood occurrences and the cropping pattern of crops, i.e.,seasonal change in planted area are also taken into account for the damage estimation. The flood frequency for each month is expressed as the percent distribution of the yearly maximum 3-day rainfall over 12 months, which is decided on the basis of rainfall record at Roxas for 34 years.

Based on the above conditions, the damageable value of crop per ha of each crop category for the year 1984, 1989 and 1994 is illustrated in Tables III. 3-4 to III. 3-9.

The future crop damageable value is estimated taking the growth rates of yield, growth rates of crop production cost and projected future crop prices into consideration, all of which are mentioned above. Table III. 3-10 shows the projection of future damageable value of crops.

3.2 Livestock Damage

The livestock damage is estimated at about 6.5 % of the crop damage based on the flood damage record in the province of Capiz in 1984.

3.3 Building Damage

The building damage consists of the four main items as follows:

(a) Residential building damage

(b) Household effects damage

(c) Non-residential building damage

(d) Inventory stock damage

Each damage is assessed as the sum of the product of a damage rate and an economic damageable value of each asset. The detail steps taken for estimation of flood damage are illustrated in Figure III. 3-2.

The number of buildings by type, i.e., residential and non-residential, in the flood prone plains is enumerated by mesh on the topographic maps with the scale of 1:10,000. Table III. 3-11 shows population and the number of buildings by type within the flood prone areas and within municipalities related to flood plains.

The criteria of flood damage rate is presented in Table III. 3-12. It is based on the Japanese criteria prepared by the Ministry of Construction of Japan in the absence of the same kind of criteria in the country.

The determination of average damageable value of residential building is based on the registered value which is estimated by the Capiz Provincial Assessor Office and the Roxas City Assessor Office. The models for sample survey are chosen from buildings located in principal flood prone areas such as Municipalities Cuartero, Panay and Sigma and the Barangay Adlawan, Bago, Loctugan in Roxas City.

Residential buildings are classified into four (4) types according to their structural characteristics such as I) reinforced concrete, II) semi-concrete, III) strong materials and IV) light materials. The number of each type in the areas and the average registered value are shown in Table III.3-13. Since this value was assessed in 1979, the average registered value is converted into the 1984 price by applying conversion ratio, taking the inflation and the depreciation during 1979 to 1984 into consideration. Furthermore the actual market value ratio, the actual market value to the registered one is 2.2 on the basis of a sample survey. As a result of calculation, the average actual market value becomes ₱20,443 as shown in Table III.3-14.

The average actual market value is derived from dividing the total market value by the number of houses. The total value of the following year is calculated as the sum of a value of newly constructed houses and a value of exsisting houses. New houses are classified into two (2) categories: newly constructed units and re-built units. The number of newly constructed units is derived from dividing the incremental population for a year by family size. For instance, in 1985, 2,020 dwelling units would be built based on the population projection. Furthermore 7% of existing units would be reconstructed every year based on the statistical data. So, about 9,800 units are reconstructed in 1985. As a result, 11,820 units of new houses would be constructed in 1985. The construction cost of a new unit amounts to average ₱45,000 in 1984 for all kinds of structure. Thereafter the cost is assumed to increase in proportion to the GRDP per capita growth in Capiz.

On the other hand, although 93% of existing units still lies in 1985, the market value decreases the amount of depreciation during a year. The depreciation rate is 7.4% on the average. In other words, the market value of ₱20,443in 1984 decreases to ₱18,930 in 1985. The total market value in the following year is derived from the sum of both total amounts of new houses and existing houses. Finally, the new average market value of a dwelling unit is derived from dividing the total market value by the number of dwelling units in the following year. The average market value of a dwelling unit in the target year is calculated on the basis of this procedure. Table III.3-15 shows the average market value of an unit every five (5) years in the future.

Since any statistical data of household effects are not available, sample survey is carried out in flooding areas of Cuartero, Panitan and Sigma Municipalities in February 1984. In spite of limited number of the sample, the average values of household effects of each municipality are quite similar as shown in Table III.3-16. The entire average actual value is ₱5,190.

The market value of non-residential buildings is estimated by the same procedure as the residential buildings (refer to Tables III.3-17 and III.3-18). The average actual market value becomes ₱146,226.

Beside the value of building structure, the non-residential buildings have two (2) other values, that is, equipment installed in them and inventory stock. Sample survey for non-residential building is made within the flood prone areas. Samples are chosen from small scale industries such as cottage industries, retail stores, etc., because there are no big industries within the area. In pursuance of the statistical calculation of sample survey, average market values of equipment of commercial industrial, educational, medical and religious buildings are ₱3,443, ₱16,188, ₱29,150, ₱7,950 and ₱14,220 respectively. Those of inventory stock of commercial and industrial buildings are ₱8,067 and ₱6,463 respectively, as shown in Table III.3-19.

On the basis of the results of sample survey and the actual number of non-residential buildings in the basin, average market values of building, equipment and inventory stock are estimated at ₱28,125, ₱11,167 and ₱4,500 respectively. Using the ratios of equipment and invertory stock to building value and actual market value of non-residential building of P146,226, actual market values of equipment and inventory stock are P58,052 and P23,396 respectively as shown in Table III.3-19.

All market values estimated so far are based on financial prices. Financial prices are converted into economic values by applying a standard conversion factor (SCF). SCF of the country might be 0.90, taking recent five (5) years' conversion factors into consideration. Furthermore conversion factor for building construction is 0.82. By means of these conversion factors, economic damageable values of residential building, household effects, non-residential building and inventory stock are determined to be P17,000, P5,000, P165,000 and P21,000 respectively, as shown in Table III.3-20. The future economic value of each asset is derived from using the same growth rate as the residential buildings, which is already described. As shown in Table III.3-21, economic damageable values of residential building, household effects, non-residential building and inventory stock in 2029 will be P103,681, P30,497, P1,006,410 and P128,089 respectively.

3.4 Infrastructure Damage

The infrastructure damage in the Panay river basin is estimated at 35% of the building damage in accordance with the flood damage records of the typhoon "Undang", November 5, 1984. The details of the damage are illustrated in Appendix XIII, "Additional Survey on Nov. '84 Flood".

3.5 Fishpond Damage

The area of fishpond damage is enumerated mesh by mesh on land use maps. The flood damage to fishponds consists of damages to the fish stock and the facilities.

Fishpond damage estimates are highly dependent on the culture species, culture area for each species, culture systems, pond design and composition, etc. The main culture species dominated in the basin are milkfish and prawn. For these two species, the following considerations are taken for the damage estimates in this Study:

(1) Milkfish

Item	Nursery pond	Transition pond	Rearing pond
Pond composition (%)	3	10	87
Stocking rate (pcs/ha)	2,640	1,320	1,320
Rearing period (month)	1	3	1.5
Value at each stage (₱/pc)	0.18	1 - 2	3
Average production per crop (kg/ha)		330	
Harvesting (time/year)		3	
Crop season	1st May - October 2nd June - November 34d August - January		
Fish size for market (kg/pc)		0.25	

(2) Prawn

Item	Nursery pond	Transition pond	Rearing pond
Stocking rate, Fry (pcs/ha)		3,000	
Market size (pcs/ha)		3,400	
Rearing period (month)		4	
Harvesting (time/year)		3	
Crop season	1st June - September 2nd October - January 3rd February - May		
Average production per crop (kg/ha)		96	
Value (₱/pc)	Fry 0.38 Market size 4		

Using these data, the damageable values for milkfish and prawn are estimated at about ₱9,694/ha/year and ₱9,580/ha/year respectively. The details of estimates are shown in Table III.3-23 and III.3-24.

The damage to the facilities is estimated at about 20% of the fish stock damage referring to the data on flood damage recorded in the Pampanga deltaic area from 1979 to 1980. The damage rate is estimated at 80% for milkfish and 30% for prawn in the inundated fishpond area.

The unit yield of ponds in the future is projected based on the historical trends of the unit yield is estimated at 12.94 kg/ha/year. The future damageable value of fish stock is estimated assuming that the value incleases in proporation to the unit yield as shown in Table III.3-10.

3.6 Indirect Damage

The indirect damage consists of the income losses and the emergency costs. The income losses cover wages lost, commercial trade lost, industrial production lost, transportation losses, and losses from interruption of utility services resulting from the disruption of normal activities due to flood. The emergency costs include the cost of evacuation, reoccupation, flood fighting and disaster relief operations. The indirect damage can be usually estimated by multiplying a factor to direct damages. According to a survey conducted by US Corps of Engineers in New England areas, the following rates were worked out:

Category of Damage	Indirect loss/direct loss
Agricultural Damage	0.2
Building Damage	1.5
Highways	1.0

In a survey report by JICA in Malaysia, the indirect damage ratio is from 10% to 77% as shown in table III.3-22. On the other hand, there is no records in terms of the income losses caused by the typhoon "Undang". Accordingly, a conservative ratio of 15% is adopted in this study.

4. Estimated Flood Damage

4.1 Damageable Properties

The Panay river basin has a flood prone area of 334 km^2 encompassing a city and twelve (12) municipalities. There are Roxas City and the municipalities of Cuartero, Dao, Dumalag, Dumarao, Jamindan, Maayon, Mambusao, Panay, Panitan, Pontevedra, Tapaz and Sigma. The predominant land use of the plain is paddy field, which accounts for 56% of the flood prone area. The breakdown of the land use is as follows:

Paddy field	56%	18,734 ha
Sugar cane	11%	3,765 ha
Fishpond	4%	1,137 ha
Others	29%	9,754 ha
Total	100%	33,390 ha

The number of buildings subject to floods in the flood prone plain is estimated at about 22,000 for 1984. Of the total number, residential building covers 20,218 or 92%. The breakdown of building by types is shown as follows:

Reinforced concrete	1.9%
Semi-concrete	6.2%
Strong materials	5.2%
Light materials	86.7%

Source: 1980 Census of Population and Housing, Capiz

The above percentage, however, is estimated not within the flood prone plain but all over the province of Capiz. Since the data of building structure types within the flood plain proper are not available, the above percentage applies in case of calculation of damageable properties.

The details of the building structure types are described in Appendix IX, Socio-economy.

4.2 Floods

Floods are the perennial problems in the basin. Big floods occurred once every 5 to 10 years. The latest big floods were in November 1984, May 1976 and November 1973. The damages caused by the 1973's flood are estimated at ₱57.4 million based on 1973 prices, which correspond to ₱341 million at the price level of 1984 by applying price index. The details of those damages are described in Appendix IV, Flood Control Plan.

The inundated areas and the number of buildings are estimated for each flood magnitude as follows:

	Flood Magnitude (Return Period)						
	1.1	2	5	10	25	50	100
Inundated Area (km^2)	110	163	213	253	286	313	334
Number of Buildings (1,000 units)	5.1	7.7	11.3	14.9	17.5	20.3	22.0
Affected Population (1,000 persons)	28.7	42.7	63.5	82.1	97.1	112.3	121.3

The details of the inundated areas and the number of buildings are shown in Table III.4-1.

4.3 Estimated Flood Damages

The flood damages in the present and future conditions for a given flood magnitude are calculated using a 100 x 100 m mesh map. The results are shown in Tables III.4-2(1) to III.4-2(10). Based on these tables, the average annual flood damage in 2029 is about ₱1,011 million at 1984 prices constant, which is about 9.7 times bigger than that in 1984 of about ₱105 million.

Table III.4-3 shows the average annual flood damage by each river stretch in the present condition. The river stretches are illustrated in Figure IV.5-5 in Appendix IV. The biggest damage among the river stretches occures in the stretch P1 of the Panay river. It amounts to ₱32 million as shown in Table III.4-4(1), which accounts for 30% of the total damage in the basin. In the case of the propable flood of 100 years, its area of about 107 km^2 is submerged, which forms 32% of the total flood prone area of 334 km^2. Furthermore, more than seven (7) thousand buildings in the stretch of P1 are inundated, which accounts for 33% of the total damaged buildings of 22 thousand. Flood damage intensity for each river stretch in the case of 100-year flood and 5-year flood is illustrated in Figures IV.5-2 and IV.5-3 in Appendix IV respectively.