5.3 Soil Classification

The soils prevailing in the Project Area are generally clayey due to alluvial sedimentation of fine particles transported by the river streams and frequent flooding from their overflow. Development of soil structure seems moderately well under the repeated alternation of water content during wet and dry seasons. Moreover, the texture varies widely with the deposit conditions, assuming many different soil profile characteristics.

5.3.1 Classification in High Categories

In 1972, the Bureau of Soils of the Department of Agriculture and Natural Resources, published for the first time a nation-wide soil map by adapting the USDA-Soil Conservation Service-Comprehensive System of Soil Classification and Soil Taxonomy (1970). Figure A.5.3-1 is a copy from the original map showing the soils of the Project Area including those around it.

In Southern Luzon Island there are ten soil groups which were classified under Order-Suborder-Great Group system as shown in legend of the map. Correlation between these Groups and Soil Units of Soil Map of the World, FAO/UNESCO (1978) are also reflected in the legend. The soil groups covering the Project Area are estimated to consist of four as follows;

Symbol	USDA System	FAO/UNESCO
I2a	INCEPTISOLS-Aquepts-Tropaquepts	Eutric Gleysols
I3a	" -Tropepts-Eutropepts	Eutric Cambisols
V1a	VERTISOLS-Usterts-Chromusterts	Chromic Vertisols
V1b	" - " -Pellusterts	Pellic Vertisols

INCEPTISOL are simply described as soils with pedogenic horizons of alternation or concentration but without accumulation of translocated materials other than carbonates or silica. Aquepts are seasonally wet and Tropaquepts (I2a) develop under continuously high temperature, assuming glei color horizons. Eutropepts (I3a) are highly base-saturated, being formed under long hot and moist conditions of Tropepts. These two groups correspond to Eutric Gleysols and Eutric Cambisols (FAO), respectively. The former represents areas of Candaba Swamp and those along Pampanga River; the latter appears to cover the whole southern areas of Angat River.

VERTISOLS are soils with a high content of swelling clays, showing deep wide cracks during the dry season. Usterts are soils with cracks for more than three months. They are divided into two Great Groups, Chromusterts (VIa) and Pellusterts (VIb) by the difference in chroma, hish and low, respectively. Same division was done in FAO's classification system. These groups on the map seem to stretch to terrace areas in the right side of the Angat River and along the eastern rolling lands of the Project Area.

In general, these soil groups are more or less associated with other Order groups.

5.3.2 Classification in Lower Categories

(1) Results of the Former Soil Surveys

Overall descriptions on the correlation of high order soil groups with low order soil series and types have not yet been reported by the Bureau of Soils in the Philippines. Survey reports of soils in Bulacan and Pampanga province published in 1939 and 1956, respectively, did not refer to this correlation, too. More recently in 1964, a more detailed survey was carried out also by the staff of Bureau of Soils, where about 600 bore holes were examined and a more detailed soil map was made. This survey was done by the Bureau of Public Works of which the present NIA became independent later in 1966, to provide new pedological information necessary to the facility improvement of the AMRIS Area. Only the soil map was available and the soil type descriptions are not at hand. A soil map (Figure A.5.3-2) instead was made based upon these three survey results (1939, 1956 and 1964). Their Soil Series and Types are listed as follows;

Soil Series and Types in AMRIS Area
(1939, 1956 and 1964)

	Type	Type No.
a. Soil of the Lowlands		
1. Obando Series	- Obando Fine Sandy Loam	(2)
2. Bigaa Series	- Bigaa Clay Loam	(3)
	- Bigaa Silty Clay Loam	(546)
3. Quingua Series	- Quingua Fine Sandy Loam	(4)
	- Quingua Silt Loam	(5)
	- Quingua Silty Clay Loam	(285)
	- Quingua Silty Clay	(899)
4. Candaba Series	- Candaba Silt Loam	(69)
	- Candaba Clay Loam	(70)
b. Soil of the Upland and Hills		
1. Buenavista Series	- Buenavista Silt Loam	(9)
2. Prensa Series	- Prensa Clay Loam	(6)
	- Prensa Silt Loam	(66)

In this list, Type No.82 was excluded because its description is not available. Profile characteristics of these Soil Types are summarized in later paragraphs.

Soils are divided into two topographic groups, the flat lowlands and the upland and hills. Those of the lowlands are sub-grouped into three areas;

1) The light colored soils which are mostly found in the well drained plains and are of sandy texture;

2) the darker colored soils which predominate the lower areas of clayey texture having poor drainage;

3) soils with reddish color shades that prevail on the higher, well-drained areas.

They are all suited to both general and specialized farming purposes. Rice is the principal crop followed by corn, sugar cane and melons. There, however, are the very low lying areas continue to the Candaba Swamps. They are under water during the wet season and are hardly cultivated for rice during the dry season. Most of the proposed expasion area belongs to this category.

The soils of the upland and hills were formed either from older alluvial deposits or from the weathered products of the underlaying rock materials. Due to the rolling relief, agricultural land use has been more or less limited on the terrace areas. Strip cropping and close-growing crops may be advantageously practiced in these areas.

On the basis of both external and internal characteristics, the soils are further subdivided into three principal classification units, Soil Series, Soil Type and Soil Phase. Their definitions are as follows;

1) Soil Series : A group of soils that have the same genetic horizons, similar important morphological characteristics, and similar parent materials. Its name is usually taken from the locality where the soil

is first identified. The lower part of the soil, that is, the subsoil has an important role in deciding the characteristics of the Series.

2) Soil Type : One or more Soil Types are identified in one Series according to the texture of upper part of the soil profile, or the surface soil. They are named according to the surface texture and are the principal mapping unit because of their inherent specific properties to which agronomic data are intimately correlated.

3) Soil Phase : This is a variation within a Type, differing only in some minor features, generally external, such as relief, stoniness and degree of erosion which may require some changes in agricultural management. Their segregation is usually desirable if the areas can be delineated on the soil map. The present survey which is semi-detailed in nature did not delineate these soil unit.

The Project Area comprises of nine (9) Soil Types in four (4) Soil Series of the lowlands and three Types in two Series of the upland and hills. Type numbers are not so significant since these have been coveniently used as mapping symbols in every soil survey work. A new Soil Series was established and is called Calumpit Series. Some Series with higher code numbers, more than 285, can not be fully described due to lack of the related survey data (1964).

(2) Results of the Present Soil Survey

1) Soil Profile Description

The soil survey was conducted from September to December, 1982, so as to examine the soil profiles in the proposed expansion areas which are sporadically located just outside of the service areas. Because of the investigative nature of the survey, a detailed reconnaissance level was taken to decide the density of profile examination.

During the survey, the soil was still submerged and a wet season paddy crop was partially being cultivated in the expansion area. Boring technique was often used by means of hand auger instead of pit digging. It totalled to 14 pits and 28 bores. Their locations including some sites within the service area are shown in Table A.5.3-1, and Figure A.5.3-2.

The pits were dug up to a depth of 80 to 120 cm from the surface with a width of 100 cm. To observe further the lower layers of the pit, boring was tried using a common posthole type auger. Field tests were conducted to determine soil hardness. A tester, a kind of cone penetrometer to measure soil compactness, was used since it is handy and portable for the field survey. Compactness of the soil layer is of much importance to determine workability of a land for potentiality classification as well as to distinguish genetic differences in the soil classification process.

In addition, quick chemical reagent tests were tried with every soil profile. These are;

a) Dilute hydrochloric acid solution (IN) for detecting carbonates (effervescence)

b) Benzidin (pp'-diamino-diphenyl salt) solution (one percent in 10 percent acetic acid solution) for detecting active manganese (dark blue color development)

c) αα'-dipyridyl solution (0.05 percent in 10 percent acetic acid solution) for detecting ferrous iron (Fe^{++}) (pink-red color development)

The soil profile descriptions followed by the method defined in the FAO Guidelines for Soil Profile Description which are now of wider use in the world.

Soil profiles thus examined are reported in Table A.5.3-2 where pits and bore holes are arranged in the order of Survey dates. Detailed descriptions of the representative pit profiles have been prepared and yet excluded for printing since the results are summarized in this report.

2) Soil and Water Analysis

Horizons Soil of the profiles were sampled and analysed for Eh (oxido-redox potential of wet sample), pH and EC (electrical conductivity of air-dried sample). In the course of the soil survey, water samples from various sources were collected and analyzed similarly to the soil samples. These totalled 161 of soil and 63 of water samples.

All determinations though not always for all samples were conducted by means of the portable electrode meters at the temporary laboratory in the NIA Region III Office at San Rafael, Bulacan.

Table A.5.3-3 gives the results of Eh determinations on some profile samples with pH and other observations related to the oxido-redox status of the soil. Eh is expressed as milli volts at pH 7.0 and at 25°C and is understood to assume a reduced state of the soil when it is below + 200 mv.

Table A.5.3-4 presents the values of pH and EC determinations of the soil samples together with those of compactness tests. EC was measured from a 1 : 2 soil-water mixture. In case of clayey soils, moisture of the water-saturated pastes ranges from 60 to 80 %. Accordingly the conductivity values of the saturation extracts, ECe, which is formally used in the laboratory analysis, must be estimated by multiplying those of EC_2 (1:2 extract) by 2.5 to 3.0.

Values resulting from the use of the Soil Hardness Tester are categorized as follows;

Criteria of Soil Hardness Evaluation

Hardness Category	Tester Index* (mm)	Resitance (kg/cm^2)	Easiness in Tilth Work
Soft	< 8	< 0.98	Very easy
Slightly hard	8 - 12	0.98 - 1.93	Easy
Hard	12 - 17	1.93 - 4.04	Slightly difficult
Very hard	17 - 23	4.04 - 10.0	Dificult
Extremely hard	> 23	> 10.0	Very difficult

* Dr. Yamanaka's Soil Hardness Tester. Index (mm) is a reading of the cone when it penetrates into the solum.

In general soil consistency varies with its moisture and clay content; the less moist and the more clayey, the more compact and hard becomes the clod. It also depends on permeability and drainability of the soil. Table A.5.3-4 shows that majority of the surface soils are slightly hard to hard (8 - 17). Some of the Candaba soil Series are extremely hard (22 - 27), making necessary land soaking at the time of paddy field preparation. Index value more than 23 (10 kg/cm^2) checks elongation of the rice roots (Takijima, Y., 1969). Root growth is restricted in subsoils, because their moisture content is not so changeable with seasons.

All results of water sample analysis are presented in Table A.5.3-5. These will be discussed later.

3) Vegetation

The Project Area is not naturally endowed with forest resources such as Boho and Rattan which are used commercially in the manufacture of sawali and furniture sets, respectively. The lowland areas are mostly cultivated to rice and to a small extent to corn, root crops, vegetables, fruit trees, and legumes.

Outside of the arable lands, however, there are very impressive landscapes of Cogon and Talahib conspicuously growing on the upland and hills along the terrace areas or near the marshes. Another characteristic view is a luxuriant growth of water hyacinth in canals and drains. Such growth of wild water plants in the irrigation channels is nothing but an obstacle to contemplated water delivery and drainage in the service area. Table A.5.3-6 gives some conspicuous grasses with their land features in the AMRIS Area. This information on vegetation suggests the soil environments of the land. For example, a greater portion of the land covered with bamboos is coarse in texture and moderately well drained, while the land where leguminoseae dominates is rather clayey and endowed with more organic matter than the land with thick cover of graminaceae.

Of the natural trees, Nipa palms are scattered along the rivers in the southern most area. A delicious wine is being produced from its flower sap. Mango plantation, though fragmented, is most popular in many municipalities of Bulacan Province. Quality of the mango fruits has been claimed to be the best in the Philippines. This may be due to the comparatively fertile and well drained clayey soil conditions which is enough to sustain vigorous growth of the trees. It is very interesting to note that non-seasonal fruits can be harvested by spraying the trees with a chemical such as K No^3 in the month of August. In this case they become in full bloom in October to November, producing their fruits in January to February.

4) General Features Related to Soil Classification

Investigating the present survey results with reference to the data of monitoring study on the residual soil moisture which was conducted by the staff of NIA Region III Office in 1980, some problems related to soil classification must be pointed out as follows;

a) Soil Texture

In most of the profiles, texture of the surface soil was silty clay loam to silty clay with less portion of lighter texture such as silt loam. This is a wide variation from the former surveys which showed predominantly silt loamy soil texture in the soil maps.

b) Iron Concretions

As evidenced from the profile examination, concretions such as laterites were not detected at all of the sites although their presence is an important criterion which distinguishes Prensa and Buenavista Series from other lowland soil series. Pebbles of various sedimentary rocks, probably deposited by running water, were observed in the subsoil of some profiles. Such gravelly Layer was used to define Prensa Series developed on the terrace area.

c) Structure Development

The present survey revealed that except for deeply deposited sandy soils such as Obando Fine Sandy Loam, the subsoil showed more or less good structure development, especially in Candaba and Biga Clay Loam (70 and 3) giving moderate to strong fine granular or blocky structure. The soils have appeared to become matured under long tillage with repeated irrigation and drainage practices.

d) pH and Base Status

pH values are often lower than 7 in the top layer but increase to the alkaline side in the subsoil. From the results of laboratory analysis by the Bureau of Soils (1980) all soils seem to be fairy well saturated with base elements with more than 80 percent of CEC, mostly consisting of calcium followed by magnesium which have been derived from the limestone materials. Soils in the Candaba Swamp area (70 and 3) appear to accumulate base elements under annual flood conditions assuming high pH values more than 8. The field test with reagent showed no visible effervescence of carbonates.

e) Eh Status

Oxido-redox potential (Eh) was measured with fresh soil samples of 10 profiles. Data in Table A.5.3-3 indicate that profiles of P9, P14 and B20 which are classified into Bigaa Series (3) are rather reduced than other profiles. This may suggest more or less a problem on how to differentiate it from Candaba Series (70) with almost the same structure sequence and poor drainage.

Eh of the subsoils is, however, mostly more than + 500 mv that assume oxidized condition, in spite of the presence of some glei colored clay mottles.

f) New Soil Series and Types

Based on the texture sequence of the profiles, some of them were found not to conform with the existing characteristics of the classified series and types; these are located in lowland area along the rivers and have the shallow or deep top layer of silty clay loam which is underlaid with coarse textured subsoil.

This group of soils was tentatively named Calumpit Series from its first identified locality with two Soil Types. Detailed descriptions are presented in the next paragraph.

(3) Calumpit Soil Series and Types

The Soils of the Calumpit Series differ from the other lowland alluvial soils in their texture sequence of the profile, that is, having fine surface horizon underlaid by coarse subsoil. The surface relief is nearly level to undulating; the elevation ranges from 3 to 7 meters along the river levee or somewhat inside of the alluvial plain. Both the external and internal drainage are not ideal as compared with coarse Types of the Quinga Series. Some lands of this Series are under water to a depth of 1 meter or so during wet season. A greater portion of the area is cultivated to rice which is irrigated by the System or by pumping water from the Pampanga River.

Calumpit Sandy Loam and Calumpit Silty Clay Loam were mapped.

Calumpit Sandy Loam (17)

This type prevails in Calumpit Municipality and is developed inside natural levees along the Pampanga, Angat (near the confluence) and Bagbag Rivers. The areas are mostly situated at an elevation of two to four meters. It is frequently submerged during the wet season resulting in a low yield of rice.

The surface horizon is rather shallow, around 15 cm thick, and comprised of finer particles of silty clay loam or silt loam. The subsoil has a coarse texture of sandy loam or loamy sand, sometimes followed by a fine-textured horizon at a depth of more than one meter. Soil color is brown to dark brown with some reddish brown iron streaks throughout the profile. No apparent development in structure is observed except for the surface horizon. In many cases the groundwater level is found within 50 cm. The profiles of B9, B11, B27 and B28 belong to this Type.

The following is the profile characteristics of the soil;

[Soil Profile No. B-27]: Longos, Calumpit, Bulacan

Depth of horizon	Characteristics
0 - 6 cm	Top soil, dark brown silt loam with gray clay mottles and some reddish brown streaks; clear, smooth boundary; pH 6.9.
6 - 17 cm	Surface soil, dark brown silty clay loam with many brown streaks, moderately coarse blocky; clear, smooth boundary; pH 7.3.
17 - 41 cm	Subsoil, brown sandy loam with no streak, structureless; groundwater level at the depth of 32 cm; pH 8.2.
41 - 100 cm +	Substratum, brown loamy sand, loose and friable, no gravel; pH 8.1.

Lowland rice is grown generally once in the dry season or twice a year although the yield is poor because of low fertility of the soil; water melon is often planted in the Calumpit area in place of rice in the dry season.

Calumpit Silty Clay Loam (8)

This type of soil is found among the areas of Bigaa and Quingua Series, being situated at an elevation of from three to seven meters. It has a brown to yellowish brown, silty clay loam surface soil and a brown to dark yellowish brown, silt loam subsoil with frequent brown streaks; sandy loam substratum continues beneath the sub-soil. Medium to fine blocky or granular structure develops throughout the profile and consistency is generally hard in moist condition. Groundwater is sometimes shallow, appearing within 50 cm depth. The profile of P10, P11, P13, B13, B18, B21, B24 and B25 give the characteristics of this Type. These are briefly described as follows;

[Soil Profile No. 13]: La Purisima, Concepcion, San Luis, Pampanga

Depth of horizon	Characteristics
0 - 20 cm	Top soil, dark brown silty clay loam with some reddish brown streaks, weak coarse blocky; clear, smooth boundary; pH 7.6.
20 - 39 cm	Dark gray silt loam with gray clay mottles, moderate medium blocky; clear, smooth boundary; pH 7.8; Groundwater level at the depth of 51 cm.
39 - 67 cm	Lower surface soil, brown silty clay loam, weak medium blocky, very hard; pH 8.4.
67 - 102 cm +	Subsoil, dark yellowish brown silt loam with frequent brown streaks, weak medium granular, compact; pH 8.8.

Lowland rice is the principal crop in this Type, mostly grown twice a year served by the river irrigation system. The production of rice is medium level although it will increase easily under proper soil management and fertilization. Most of the crops grown in the locality can be profitably produced on this soil.

(4) Revised Classification in the Project Area

1) Revised Series and Types

The recent data and information mentioned above necessitate a revised classification of the soils in the Project Area for the following reasons;

a) Extent of each soil unit is mainly based on the texture sequence of the profile.

b) Adoption of new soil unit.

As a result, Prensa Clay Loam (6) was abolished because of its uncertain distribution, and a new Calumpit Series was adopted. The Area finally composed of seven Soil Series and 13 Soil Types as follows;

Soil Series	Soil Type	Type No.	(Soil Unit/FAO)
I. Soils of the Lowlands			
1. Obando	Fine Sandy Loam	2	(Dystric Cambisols)
2. Bigaa	Clay Loam	3	(Eutric Cambisols)
	Silty Clay Loam	546	(" ")
3. Quingua	Fine Sandy Loam	4	(Dystric Cambisols)
	Silt Loam	5	(Eutric Cambisols)
	Silty Clay Loam	285	(" ")
	Silty Clay	899	(" ")
4. Calumpit*	Sandy Loam*	17	(Dystric Cambisols)
	Silty Clay Loam*	18	(" ")
5. Candaba	Silt Loam	69	(Eutric Gleysols)
	Clay Loam	70	(" ")
II. Soils of the Upalnds and Hills			
6. Prensa	Silty Clay Loam	66	(Chromic Vertisols)
7. Buenavista	Silt Loam	9	(Pellic Vertisols)

* Newly established.

Figure A.5.3-4 gives a genetic diagram of these Series and Types estimated from the relationships between texture sequence and geological feature. Table A.5.3-7 summarizes the characteristics of each Soil Type. Excluding Calumpit Series and its Types, detailed information of the other soils is referred to the soil survey reports of Bulacan and Pampanga Provinces (Bureau of soils. 1939 and 1956).

2) Mapping and Area of Distribution

The soil map presented in Figure A.5.3-2 has been revised by changing the boundaries among the soil units with reference to the topography of the Area. As a result, Soil Types with silt loam surface layer such as Soil Type No. 5, 69 decreased in their hectarage as compared with Type No. 70, Candaba Clay Loam, which stretched down to the Angat River side. Two Types of Calumpit Series were distributed in the lowland area, respectively.

A revised soil map of Figure A.5.3-5 has been made including the outside expansion areas. Although the map is tentative bacause of the survey intensity, areas of distribution of the Soil Types were measured by a planimeter. Table A.5.3-8 shows the areas in both north and south sides of the Angat River. The largest area belongs to Quingua Series where Silt Loam Type (5) predominates. The second area is Bigaa Series of which Silty Clay Loam Type (3) has the highest distribution, having an area of 12,000 ha or 28 percent of the total 42,700 ha of the gross area. Calumpit and Candaba Series occupy about 9 and 11 percent of the total area, respectively.

5.3.3 Salinity of Soil and Water

In the course of the present soil survey, special concern has been paid to the salinity values of the soil and water in relation to soil management and irrigation method adopted for the Project Area. For this purpose, most of the soil samples and all of the water samples collected by way of the soil survey were analyzed for their reaction (pH) and electrical conductivity (EC). The data are presented in Table A.5.3-4 and A.5.3-5, where 121 soil samples and 63 water samples were dealt with.

(1) Soil Salinity

Generally soil salinity values do not reach any detrimental level of more than 4 millimhos as ECe as estimated from EC_2 value. Only two soil profiles, B5 (Type No. 3) and P8 (Type No.70) that are located in the Candaba Swamp area showed high EC values exceeding the critical level in the subsoil. All of the adjacent profiles examined in the same area more or less assumed lower salinity values but still higher than those of the other areas. Considering the similarly higher salinity of water samples (No. 7, 8, 56 and 57) taken at the same time, soils in this submerged area might have been enriched with bases under annual flood and drought condition.

In the southern most part of the Project Area, two profiles, P1 and P14 (both Type No. 3) also revealed a higher salinity but lower than the criterion. Probably in the coastal areas further south of the Project Area, extremely high salinity will be observed, where a fluvio-marine soil formation has dominated.

(2) Water Salinity

The status of water salinity as determined for EC value of the samples can be simply summarized with the average value in each of the water groups;

Water Group	Number of Samples	Average EC (mmho at 25°C)
1. River		
Pampanga	2	0.240
Angat	1	0.154
Massim	2	0.261
2. Canal and Lateral		
Angat RIS	25	0.168
Massim RIS	5	0.283
3. Creek	10	0.280
4. Drain (Angat RIS)	3	0.269
5. Fish Pond	2	0.642
6. Ground Water (Pit and Bore)	13	1.551
7. Well for Drinking*	3	0.419

* Sampled at San Rafael Office and private houses. The others were calculated from Table A.5.3-5.

Although there were limited samples collected, a clear trend in EC value differences is shown in the following order;

1) River: Massim > Pampanga ≫ Angat
2) Canal and Lateral: Massim RIS ≫ Angat RIS
3) Angat RIS: River < Canal and Lateral ≪ Drain
4) Fish Pond ≫ Creek > Drain

The increase in salinity which is traced from river towards drain is illustrated in Figure A.5.3-6. So far as the irrigation water is concerned, no problem exists as to its quality in terms of salt content including the creek water which has been often used for irrigation source. Water of less than 0.3 mmhos has been regared as an excellent irrigation source. The slightly higher EC values observed in Massim RIS may be caused by the geological river water source.

As for the groundwater taken from the pits and bores, most of the samples gave EC values ranging from 0.3 to 0.8 mmhos. A few samples from P1, P4 and P14, soils of which have a higher salinity, too, show high EC values more than 2 mmhos, the highest being 7.6 mmhos from P14. Even this high value may not be detrimental to plant growth provided the drainage condition is maintained.

Reaction of various water sources is mostly alkaline and ranges from pH 7.0 to 8.5, and is not problem when used for irrigation.

5.3.4 Soil Fertility and Productivity

(1) Fertility

In general except for some sandy ones, soils of the Project Area can be regarded to be moderately fertile considering that most soils have high cation exchange capacity. Fertility of the soil is usually evaluated from the content of available nutrients. The followings are the average values of these elements in the heavier soils of the AMRIS Area. These were summarized from the existing results of chemical analysis and are evaluated from the viewpoint of edaphology;

Average Values and Evaluations of Chemical Components of the AMRIS Soils (Silty to Clayey Groups)

Item	Value	Rating	Item	Value	Rating
pH	6.2	optimum	K	95 ppm	sufficient
Humus	1.5 %	low	Ca	6,000 ppm	sufficient
Total N	0.26 %	low	Mg	640 ppm	sufficient
NH_4-N	8 ppm	low	Mn	50 ppm	sufficient
NO_2-N	14 ppm	low-medium	Fe	65 ppm	sufficient
P	9 - 12 ppm	low	CEC	45 m.e.	high

Most of the elements analysed are sufficient for plant nutrition except for nitrogen and phosphorus which clearly necessitate their supply to the field for profitable production of the crops.

Among the minor elements all of which have not yet been determined, a suspicion of zinc deficiency could be surmised in lowland rice grown in the fields of Candaba Clay Loam (70) and Bigaa Clay Loam (3). This is because these soils are liable to assume a high pH value after submergence and this may be accompanied by a substantial decrease in zinc concentration in the soil solution. The deficiency can be easily corrected by applying various kinds of zinc-containing materials such as ZnO and $ZnSO_4$.

Response of rice to fertilizer application and its optimum dose will be discussed later in the chapter on agriculture.

(2) Productivity

Rice production in the service area has been recorded to be very high (4 tons/ha); the unit yield is twice that in Central Luzon and four times that of the national palay average. Records of the last seven years show an annal increasing rate of four percent despite frequent flood damage caused by typhoons almost every wet season.

Yields as high as four tons per ha in recent years have been due not only to high productivity of the soils but also to the improved irrigation facilities and technically high level of field managements by trained farmers.

Soil productivity is basically composed of soil fertility and its physical properties mainly represented by texture, structure development, compactness, water holding capacity and drainability. These physical conditions regulating the tilth workability are not always ideal in the AREA, particularly soil hardness and moisture regime. The problems have been in fact dealt with by the improved cultural methods such as land soaking before plowing and water managements.

The land class is decided by combining soil productivity with surrounding land conditions as wil be explained in the next paragraph.

TABLE A.5.3-1 LOCATION OF PITS AND BORES TESTED AND THEIR LAND CONDITIONS IN AMRIS AREA

Pit or Bore No.	Location	Land Use	Remarks
B1	Pinagbaran, Baliuag	Double paddy (IR 37)	Milky stage, good
B2	Dulong Ilog, Candaba	Orchard (Mango, Bamboo)	Along Maasim River
B3	Dampol 1st, Pulilan	Double paddy, before harvest	Medium yield
B4	Tibag, Pulilan	Double paddy, before harvest	Medium yield
B5	Panglara, Candaba	Single paddy, grassy	Submerged area
B6	Panglara, Candaba	Single paddy (fish pond)	Submerged area
P1	Bulihan, Malolos	Single paddy (pump irri.)	10 ca/ha
B7	Papitangan, Anilao, Malolos	Upland for vegetables	Near the paddy
P2	Bambang, Bocaue	Upland for vegetables	Near the drain
P3	Caingin, San Rafael	Upland for vegetables	Grassy portion
B8	Ibid.	Upland for vegetables	Groundnuts
P4	Cansinala, Apalit	Single paddy, grassy	Submerged area
B9	Tabuyok, Apalit	Single paddy, grassy	Submerged area
B10	Cansinala, Apalit	Single paddy, grassy	Submerged area
P5	Sapang Bayan, Calumpit	Grass land, dried	Flood-affected
B11	Dampol 2nd, Pulilan	Single paddy, grassy	Submerged area
P6	San Nicolas, San Luis	Single paddy, soaked	Submerged area
B12	Sta Monica, San Luis	Grass land, dried	Single paddy area
P7	San Agustin, Sn. Luis	Single paddy, soaked	Submerged area

Note : Numbers of pit and bore were arraged in order of the survey date.

(Cont'd)

Pit or Bore No.	Location	Land Use	Remarks
B13	Su. Augustin, Sn. Luis	Grass land, dried	Single paddy area
P8	Paligue, Candaba	Fish pond, grassy	Submerged area
B14	Paligue, Candaba	Grass land (fish pond)	Submerged area
B15	Camachilihan, Bustos	Double paddy, newly harvested	Low yield, gravelly
B16	Talumpas, Bustos	Double paddy, newly harvested	Medium yield
B17	Cambaog, Bustos	Double paddy, newly harvested	Medium yield
B18	Pulong Gubat, Balagtas	Double paddy, newly harvested	Medium yield
B19	Busran, Balagtas	Double paddy, newly harvested	Low yield
P9	Bunga Menor, Bustos	Double paddy, newly harvested	High yield, IR 42
P10	Tabang, Plaridel	Double paddy, newly harvested	Medium yield
B20	Tikay, Malolos	Double paddy, newly harvested	Low yield, grassy
B21	Sta. Piligrena, Pulilan	Double paddy, direct seeding	Low (60 ca/ha) (IR 36)
B22	Bustos, Pandi	Double paddy, newly harvested	edium yield
P11	Bangbang, Bocaue	Double paddy, newly harvested	Medium yield (80 ca/ha)
P12	Pulangbayabas, San Rafael	Double paddy, direct seeding	edium yield
B23	Visal, Candaba	Double paddy, newly harvested	Low yield
P13	La Purisima, Concepcion, San Luis	Double paddy, slightly slopy	Low yield
B24	Talang, Candaba	Double paddy, harvested	Medium yield
B25	Dulong, Malabon, Pulilan	Double paddy, harvested	Medium yield
B26	Calawitan, Candaba	Grass land, dried in d.s.*	Submerged area

Note : Numbers of pit and bore were arraged in order of the survey date.
* d.s. = dry season

(Cont'd)

Pit or Bore No.	Location	Land Use	Remarks
P14	Mambog, Bulacan	Grass land, nearby d.c. area*	Medium yield
B27	Longos, Calumpit	Double paddy, harvested	Medium yield
B28	Iba, Calumpit	Double paddy, harvested	Low yield

Note : Numbers of pit and bore were arraged in order of the survey date.
*d.c. = double cropped

TABLE A.5.3-2 SOIL PROFILES EXAMINED IN AMRIS AREA

Pit or Bore No.	Layer No.	Depth (cm)	Texture	Soil Color		Mottlings	Structure	Wetness	Permeability
				Dry	Moist				
B1	1	0 - 8	SiCL	10YR5/4	10YR3/3(5GY4/1)	Fo+++	s.m.bl.	Moist	Moderate
	2	8 - 16	SiCL	" 4/3	5GY4/1	-	w.c.bl.	"	Well
	3	16 - 35	SL	" 5/4	10YR3/3	Fo++	s.m.bl.	"	
	4	35 - 80+	CL	" 5/4	" 3/2	Fo+, Mn+	s.f~mbl.	Sl.Wet	
B2	1	0 - 6	SiL	10YR5/2	10YR3/2	Mn+	s.f.gr.	Moist	Moderate
	2	6 - 15	SiL	" 5/3	" 3/2	-	m.m.bl.	"	Well
	3	15 - 60+	SL	" 5/4	" 4/3	-	m.m.bl-gr.	"	
B3	1	0 - 10	SiCL	10YR6/4	10YR4/3	-	w.c.bl.	Moist	Poor
	2	10 - 20	SiCL	" 5/3	5BG4/1	Fo+	massive	"	
B4	1	0 - 10	SiCL	10YR5/4	10YR3/4(5BG4/1)	-	w.c.bl.	Moist	Poor
	2	10 - 20	SiCL	" 6/4	7.5GY4/1	Fo+	massive	"	
B5	1	0 - 10	SiC	10YR4.5/1	5GY4/1(5YR3/4)	Fo+++	w.c.bl.	Moist	Poor
	2	10 - 35	SiC	" 4/2	" 4/1	Fo++	m.c.bl.	"	
	3	35 - 59	SiC	" 5/1	7.5Y5/1	-	massive	"	
	4	50 - 70+	SiC	" 5/1	" 6/2	Fo+	massive	"	
B6	1	0 - 10	SiC	10YR4/1	5GY4/1	-	w.c.bl.	Moist	Poor
	2	10 - 50+	SiC	" 6/1	5Y4/1(N1.5/0)	Fo++	massive	"	

(Cont'd)

Pit or Bore No.	Layer No.	Depth (cm)	Texture	Soil Color Dry	Soil Color Moist	Mottlings	Structure	Wetness	Permeability
P1	1	0 - 9	SiCL	10YR5/4	5YR4/4(5GY4/1)	Fo+++	m.m.bl.	Moist	Moderate
	2	9 - 31	CL	" 5/4	10YR3/4	Gl++	s.f.gr.	Wet	Well
	3	31 - 42	SiCL	" 5/3	5GY4/1	Fo+++	s.m.bl.	"	Groundwater-38cm
	4	42 - 100+	CL	" 6/3	" 4/1(10YR5/4)	Gl+	s.f.gr.	"	
B7	1	0 - 50	SiL	10YR5/3	10YR3/4	-	m.f.bl.	Al. dry	Imperfect
	2	50 - 71	SiL	" 5/3	" 3/4	-	m.f.bl.	Moist	
	3	71 - 76	SiL	" 4/4	" 3/4	-	w.c.bl.	"	
	4	76 - 84	CL	" 5/4	" 3/2	Fo+++	m.f.gr.	"	
	5	84 - 92+	CL	" 5/3	" 4/6(5GY5/1)	Fo+	massive	Sl. wet	
P2	1	0 - 20	FSL	10YR5/3	10YR4/3	-	m.m.gr.	Moist	Moderate
	2	20 - 38	LS	" 5/3	" 5/3	Fo+++	m.c.bl.	"	Well
	3	38 - 50	SL	" 5/4	" 5/3	Fo++	w.f.bl.	"	
	4	50 - 80+	SCL	" 4/4	" 3/3	Fo++, Mn++	m.f.gr.	"	
P3	1	0 - 8	FSL	10YR5/4	10YR4/3	Gr+, Mn+	w.m.pl.	Moist	Moderate
	2	8 - 20	SiL-SL	" 5/4	" 4/3	Gr+	w.c.bl.	"	Well
	3	20 - 59	SiCL	" 5/4	" 4/3	Gr+	w.m.bl.	"	
	4	59 - 100+	LS	" 4/4	" 3/3	-	massive	"	
B8	1	0 - 42	SiL	10YR5/4	10YR3/3	-	m.c.bl.	Moist	Imperfect
	2	42 - 49	SiCL	" 5/3	" 4/3	-	w.f.bl.	"	
	3	49 - 77	SL	" 5/4	" 4/3	-	m.f.bl.	"	
	4	77 - 100+	LS	" 5/4	" 4/3	-	massive	"	

(Cont'd)

Pit or Bore No.	Layer No.	Depth (cm)	Texture	Soil Color		Mottlings	Structure	Wetness	Permeability
				Dry	Moist				
P4	1	0 - 7	SiCL	10YR5/3	10YR4.3(5Y4/1)	Fo+++	m.m.bl.	Moist	Moderate
	2	7 - 25	CL	" 5/3	" 3/3	Fo++	m.c.bl.	"	Well
	3	25 - 47	SiCL-CL	2.5Y5/4	2.5Y4/4	-	w.f.gr.	"	Groundwater-80cm
	4	47 - 100+	SiCL	" 5/4	" 4/3	-	m.c.gr.	"	
B9	1	0 - 11	SiCL	10YR5/4	10YR4/3	-	w.c.bl.	Moist	Poor
	2	11 - 57	SiCL	" 5/4	" 4/4	-	w.c.bl.	"	
	3	57 - 71	FSL	" 5/4	" 4/4	-	massive	"	
	4	71 - 97	LS	" 5/4	" 4/4	-	massive	"	
	5	97 - 110+	FSL	" 5/4	" 4/4	-	massive	"	
B10	1	0 - 13	SiCL	10YR5/4	10YR3/2	Fo+++	w.f.pl.	Moist	Moderate
	2	13 - 32	SiC	" 4/4	" 3/2	Fo+	m.c.bl.	"	Well
	3	32 - 50	SiL	" 5/4	" 4/3	Gl+	w.c.bl.	"	
	4	50 - 100+	SiCL	" 6/3	" 5/3	Gl++	m.c.gr.	"	
P5	1	0 - 9	CL	10YR5/3	10YR4/3	Fo+	m.f.gr-bl.	Moist	Moderate
	2	9 - 35	CL	" 4/4	2.5Y4/4	Fo+++, Mn++	m.m.bl.	"	Well
	3	35 - 65	SiCL	" 5/4	10YR4/4	Fo+++, Mn++	m.m.bl.	Sl. wet	
	4	65 - 100+	SiCL	" 4/4	" 4/4	Fo+++, Mn++	m.f.bl.	"	
B11	1	0 - 15	CL	10YR5/2	5GY4/1	-	w.c.bl.	Sl. wet	Poor
	2	15 - 100	LS	" 5/3	10YR4/3	-	massive	Wet	Groundwater-20cm
	3	100 - 120+	SiCL	" 6/4	" 5/4	Fo++, Mn++	massive	"	

(Cont'd)

Pit or Bore No.	Layer No.	Depth (cm)	Texture	Soil Color Dry	Soil Color Moist	Mottlings	Structure	Wetness	Permeability
P6	1	0 - 9	SiCL	10YR5/4	10YR4/2	Fo+++	m.c.bl.	Al. dry	Moderate
	2	9 - 35	CL	" 6/3	" 4/1	Fo+++	m.m.bl.	Moist	Well
	3	35 - 65	SiCL	" 6/4	" 4/4	Fo+++	m.f.bl.	"	
	4	65 - 87	SiCL	" 6/4	" 4/3	Fo++	m.f.gr.	"	
	5	87 - 100+	SiCL	" 6/4	" 4/4	Fo++	m.f.gr.	"	
B12	1	0 - 20	SiCL	10YR6/4	10YR3/4	Fo++, Mn+	m.f.bl.	Al. dry	Imperfect
	2	20 - 57	SiCL	" 6/4	" 4/3	Fo+++, Mn++	m.m.gr.	Moist	
	3	57 - 85	SiCL	" 6/3	" 4/3	Fo+, Mn++	m.c.bl.	"	
	4	85 - 100+	SiCL	" 6/4	" 4/4	Mn+++	m.f.gr.	"	
P7	1	0 - 6	SCL	10YR5/4	10YR4/4	Fo+	m.f.gr.	Moist	Poor
	2	6 - 27	FSL	" 5/4	" 4/4	Fo+	massive	"	
	3	27 - 51	SL	" 5/4	" 4/4	Fo+	massive	"	
	4	51 - 69	FSL	" 5/4	" 4/4	-	massive	"	
	5	69 - 100+	SiL		" 4/4	Fo++	massive	"	
B13	1	0 - 10	CL	10YR6/4	10YR4/3	Fo+	m.f.bl.	Al. dry	Moderate
	2	10 - 36	CL	" 6/3	" 4/4	Fo++	m.c.bl.	Moist	Well
	3	36 - 74	SiCL	" 6/4	" 3/4	-	m.f.gr.	"	
	4	74 - 100+	SiL	" 6/3	" 4/4	-	m.f.gr.	"	
P8	1	0 - 13	SiC-C	10YR5/1	5GY4/1	Fo+	m.c.bl.	Moist	Moderate
	2	13 - 35	SiC	" 4/1	2.5GY4/1	Fo+	m.c.bl.	"	Well
	3	35 - 62	SiC	" 4/1	5GY4/1	-	s.f.bl.	"	
	4	62 - 100+	SiC	" 5/1	7.5GY4/1	-	s.m.bl.	Sl. wet	

(Cont'd)

Pit or Bore No.	Layer No.	Depth (cm)	Texture	Soil Color		Mottlings	Structure	Wetness	Permeability
				Dry	Moist				
B14	1	0 - 15	SiCL-C	10YR5/1	10GY4/1	-	w.m.bl.	Moist	Imperfect
	2	15 - 46	SiCL	" 6/1	" 4/1	-	w.c.bl.	"	
	3	65 - 100+	SiC	" 6/1	5GY5/1	-	w.c.bl.	"	
B15	1	0 - 6	SCL	10YR5/4	10YR4/6(2.5GY4/1)	Gl+++	massive	Moist	Imperfect
	2	6 - 15	SCL	" 6/4	2.5GY4/1	Gv+	massive	Wet	Groundwater-34cm
	3	15 - 25	SCL	" 5/4	10YR3/3	Gv++	single	"	
	4	25 - 45	SCL	" 5/3	" 5/2	Gv+++	single	"	
	5	45 - 60	SCL	" 6/4	" 4/4(7.5YR5/6)	Gv+, Fo+++	massive	"	
	6	60 - 75+	SCL(G)		" 4/4	-	single	"	
B16	1	0 - 6	SiC		10YR4/6(7.5YR4/1)	Gl+++	w.c.bl.	Moist	Mederate
	2	6 - 21	SiC		7.5GY5/1	-	w.c.bl.	"	Well
	3	21 - 37	SiCL		10YR4/3	-	m.f.bl.	"	
	4	37 - 82	SiCL		" 4/3	-	w.c.bl.	"	
	5	82 - 100+	SiCL		" 4/4	-	w.f.bl.	Wet	
B17	1	0 - 10	SiC		10YR4/3	Fo+++	w.c.gr.	Moist	Moderate
	2	10 - 30	SiCL		" 3/4	Fo+++	m.c.gr.	"	Well
	3	30 - 100+	SiC		" 4/4	Fo+++	w.f.gr.	"	
B18	1	0 - 8	SiL		10YR4/4(7.5GY4/1)	Gl+++,Fo+++	w.c.bl.	Moist	Moderate
	2	8 - 40	SiCL		" 4/3	Gl+, Fo++	w.f.bl.	"	Well
	3	40 - 87	SiL		" 5/4	Fo+, Mn++	m.w.pl.	"	
	4	87 - 100+	SiL		" 4/3(4/4)	Fo+++, Mn++	m.m.bl.	"	

(Cont'd)

Pit or Bore No.	Layer No.	Depth (cm)	Texture	Dry	Moist	Mottlings	Structure	Wetness	Permeability
B19	1	0 - 10	SiCL	10YR6/4	10YR4/3	Gl+, Fo++	w.c.bl.	Moist	Moderate
	2	10 - 22	SiC	" 6/2	2.5GY4/1	Fo+	w.m.bl.	"	Well
	3	22 - 79	SiC	" 5/3	7.5GY5/1	-	m.f.bl.	"	
	4	79 - 100+	SiC	" 6/1	5GY4/1	-	w.c.bl.	"	
P9	1	0 - 13	SiCL	10YR5/4	10YR4/4(5GY3.5/1)	Gl+++,Fo+++	w.m.bl.	Moist	Moderate
	2	31 - 22	SiCL	" 6/4	" 3/3	Fo++	w.m.bl.	"	Well
	3	22 - 50	CL	" 5/4	" 3/2	Fo++, Mn+	s.f.gr.	"	
	4	50 - 80+	SiCL	" 6/3	" 3/2	FO++, Mn+	s.f.gr.	Wet	
P10	1	0 - 11	SiCL	10YR5/3	10YR4/3	Fo++, Gr+	w.m.bl.	Moist	Moderate
	2	11 - 42	SiL	" 6/3	" 5/3	Fo+, Gr+	m.c.bl.	"	Well
	3	42 - 63	SiL	" 4/4	" 4/4	Fo+, Gr++	m.m.gr.	"	(Surface-cracked)
	4	63 - 100+	FSL	" 6/1	" 4/3	Fo+	w.c.bl.	"	
B20	1	0 - 15	SiC	10YR4/4	10YR4/3(7.5GY4/1)	Gl+++, Fo++	m.c.bl.	Moist	Moderate
	2	15 - 40	SiCL	" 6/3	" 4/3	Fo+, Gl+	m.m.bl.	"	Well
	3	40 - 68	SiC	" 6/4	" 4/4	Fo+, Gv+	m.c.gr.	Wet	Groundwater-47cm
	4	68 - 100+	SiL	" 6/2	" 4/3	Fo+, Gv+	w.f.gr.	"	
B21	1	0 - 18	SiCL		10YR5/4(5GY4/1)	Fo+++, Gl++	m.c.bl.	Moist	Moderate
	2	18 - 40	SiCL		" 4/4	Fo++	m.c.bl.	Wet	Well
	3	40 - 67	SiL		" 3/4	Fo++	m.c.bl.	"	Groundwater-20cm
	4	67 - 100+	SiL		" 4/5	Fo+++,Mn++	m.f.bl.	"	

(Cont'd)

Pit or Bore No.	Layer No.	Depth (cm)	Texture	Soil Color Dry	Soil Color Moist	Mottlings	Structure	Wetness	Peameability
B22	1	0 - 6	SiL		10YR3/4	Fo+++, Gv+	m.m.bl.	Moist	Moderate
	2	6 - 53	SiCL		" 4/3	Fo+, Gv+	m.c.bl.	"	Well
	3	53 - 100	SiCL		" 4/4	Fo+,Mn++,Gv++	m.m.bl.	"	
P11	1	0 - 8	SiCL	10YR5/4	10YR4/4	Fo++	m.m.bl.	Moist	Moderate
	2	8 - 24	SCL	" 5/3	" 4/3	Fo+	m.c.gr.	"	Well
	3	24 - 61	SiCL	" 5/3	" 4/4	Fo+	m.f.gr.	"	
	4	61 - 100+	SiL	" 5/4	" 4/3	Fo+	m.c.gr.	"	
P12	1	0 - 6	CL	10YR5/3	10YR3/3	Fo++	m.c.bl.	Moist	Moderate
	2	6 - 27	SiC	" 6/3	" 3/4	Fo+	w.m.bl.	"	Well
	3	27 - 56	SiCL	" 6/3	" 2/3	Fo+	w.c.bl.	"	
	4	56 - 100+	SiC	" 6/4	" 4/5	Fo++	m.f.gr.	"	
B23	1	0 - 18	SiL		10YR4/3(7.5GY5/1)	Fo+++,Gl++	m.c.bl.	Moist	Moderate
	2	18 - 40	FSL		" 4/4	Fo++	w.m.bl.	"	Well
	3	40 - 63	LS		" 4/3	Fo+	m.m.gr.	"	
	4	63 - 92+	SiL		" 3/4	Fo+	m.c.gr.	"	
P13	1	0 - 20	SiCL	10YR5/2	10YR3/3	Fo+	m.c.gr.	Moist	Moderate
	2	20 - 39	SiL	" 6/2	10YR3/1(7.5GY4/1)	Gr+	m.m.bl.	"	Well
	3	39 - 67	SiCL	" 5/4	" 4/3	Fo+	w.m.gr.	Sl. wet	Groundwater-51cm
	4	67 - 102+	SiL	" 5/3	" 4/4	Fo+	w.f.gr.	Wet	
B24	1	0 - 27	SiCL		10YR4/3	Fo+	m.m.bl.	Moist	Moderate
	2	27 - 65	SiL		" 3/3	Fo+	w.f.bl.	"	Well
	3	65 - 98+	SiL		10YR5/4	-	m.c.gr.	"	

(Cont'd)

Pit or Bore No.	Layer No.	Depth (cm)	Texture	Soil Color Dry	Soil Color Moist	Mottlings	Structure	Wetness	Peameability
B25	1	0 - 18	SiCL		10YR4/3(10GY5/1)	Fo+++	w.c.bl.	Moist	Moderate
	2	18 - 39	SiC		" 4/4	Gl+	m.m.bl.	Wet	Well
	3	39 - 83	SiL		" 3/4	Fo++	m.c.gr.	"	Groundwater-15cm
	4	83 - 102+	LS		" 4/4	Fo+	massive	"	
B26	1	0 - 15	SiC	10YR5/3	10YR3/2 (5YR4/6)	Fo+++	s.f.bl.	Moist	Imperfect
	2	15 - 27	SiC	" 4/3	" 3/2	Fo++, Mn++	s.m.bl.	"	
	3	27 - 80+	SiC	" 5/2	" 5/2(10YR4/6)	Fo+++,Mn++	massive	"	
P14	1	0 - 13	SiC	10YR4/2	10YR3/3 (5GY3/1)	Gl+++	w.vc.bl.	Moist	Imperfect
	2	13 - 28	CL	" 5/2	10Y4/1	Fo+	w.c.bl.	Moist	Groundwater-35cm
	3	28 - 80+	SCL	" 6/3	10Y5/1(2.5Y4/4)	Fo++	m.f.bl.	Wet	
B27	1	0 - 8	SiL	10YR5/3	10YR3/3(7.5Y5/4)	Fo+, Gr++	m.m.bl.	Moist	Moderate
	2	8 - 17	SiCL	" 5/3	" 3/2	Fo++	m.c.bl.	"	Well
	3	17 - 41	SL	" 5/4	" 4/3	-	massive	Wet	Groundwater-32cm
	4	41 - 83+	LS	" 5/4	" 4/3	-	single	"	
B28	1	0 - 15	SiCL		10YR4/3(10GY5/1)	Fo+++,Gl++	w.c.bl.	Moist	Imperfect
	2	15 - 45	SL		" 4/3 (5GY5/1)	Fo+, Gl+	massive	Wet	Groundwater-26cm
	3	45 - 63	LS		" 4/3	-	single	"	
	4	63 - 95+	SiCL		" 4/4	-	massive	"	

Note : 1) Mottlings: Fo - reddish brown iron streaks; Mn - oxidized manganese mottlings; Gr - gray clay mottles; gl - gley clay mottles; Gv - gravels. Grade is expressed as + ~ +++ from few to abundant.

2) Structure (Grade, Size, Shape): Grade - w (weak), m (moderate) and s (strong); Size - f (fine), m (medium) and c (coarse); Shape - bl (blocky), pl (platy) and gr (granular).

TABLE A.5.3-3 RESULTS OF REDOX POTENTIAL DETERMINATION ON THE SOIL SAMPLES COLLECTED IN AMRIS AREA

Pit or Bore No.	Layer No.	Mottlings	Wetness	pH (1:1)	Eh7 (mv/25°C) 1:0*	1:1*	1:2*
B15	1	Gl++	moist	5.20	-	+221	+161
	2	(Gr+)	wet	6.50	+94	+49	+124
	3	(Gr++)	"	5.60	+75	+60	+100
	4	(Gr+++)	"	6.08	+344	+314	+324
	5	(Gr+),Fo+++	"	7.05	+482	+482	+402
B19	1	Gl+, Fo++	moist	5.50		+534	
	2	Fo+	"	7.26		+535	
	3	-	"	7.62		+481	
	4	-	"	8.12		+601	
P9	1	Gl+++,Fo+++	moist	7.50		+259	
	2	Fo++	"	8.35		+425	
	3	Fo++, Mn+	"	8.25		+539	
	4	Fo++, Mn+	wet	8.40		+583	
P10	1	Fo++, Gl+	moist	7.20		+554	
	2	Fo+, Gl+	"	8.23		+565	
	3	Fo+, Gl++	"	8.45		+584	
	4	Fo+	"	8.75		+609	
B20	1	Gl+++, Fo++	moist	7.10		+175	
	2	Fo+, Gl+	"	7.70		+446	
	3	Fo+, (Gr+)	wet	7.95		+555	
	4	Fo+, (Gr+)	"	7.65		+483	
P11	1	Fo++	moist	5.90		+473	
	2	Fo+	"	6.80		+532	
	3	Fo+	"	6.85		+530	
	4	Fo+	"	7.00		+524	

(Cont'd)

Pit or Bore No.	Layer No.	Mottlings	Wetness	pH (1:1)	Eh7 (mv/25°C) 1.0*	1:1*	1:2*
P12	1	Fo++	moist	5.98		+518	
	2	Fo+	"	7.60		+513	
	3	Fo+	"	7.75		+524	
	4	Fo++	"	7.80		+547	
P13	1	Fo+	moist	6.50		+437	
	2	Gl+	"	7.24		±473	
	3	Fo+	sl. wet	7.83		+509	
	4	Fo+	wet	7.42		+494	
B26	1	Fo+++	moist	7.95		+436	
	2	Fo++, Mn++	"	7.05		+402	
	3	Fo+++,Mn++	"	7.45		+461	
P14	1	Gl+++	moist	7.70		+116	
	2	Fo+	"	8.00		+159	
	3	Fo++	wet	8.05		+272	

Note : Millivolts read by the meter were adjusted at pH 7.0 and at 25°C to get values of Eh_7.

*Soil: water ratio at the preparation of soil mixture.

TABLE A.5.3-4 FIELD ANALYSIS OF THE SOIL SAMPLES COLLECTED IN AMRIS AREA

Pit or Bore No.	Layer No.	Compactness	pH (1:2)	EC (1:2) mmho/25°C
B1	1	Soft	5.20	0.100
	2	Soft	6.00	0.110
	3	Sl. hard	6.90	0.110
	4	Very hard	7.40	0.100
B2	1	Hard	7.40	0.380
	2	Hard	7.90	0.300
	3	Very hard	7.80	0.110
B3	1	Sl. hard	6.05	0.073
	2	Hard	6.85	0.086
B4	1	Sl. hard	6.30	0.113
	2	Hard	7.00	0.063
B5	1	Hard	6.00	1.430
	2	Soft	7.00	1.140
	3	Soft	7.60	1.040
	4	Soft	6.80	1.880
B6	1	Sl. Hard	6.62	0.876
	2	Soft	8.00	0.793
P1	1	5	7.35	0.390
	2	16	7.78	0.405
	3	18	7.80	0.670
	4	20	7.90	0.795

(Cont'd)

Pit or Bore No.	Layer No.	Compactness	pH (1:2)	EC (1:2) mmho/25°C
B7	1	Hard	7.58	0.088
	2	Hard	7.86	0.116
	3	Sl. hard	8.95	0.166
	4	Sl. hard	7.77	0.045
	5	Sl. soft	8.02	0.170
P2	1	17	7.40	0.048
	2	18	8.20	0.176
	3	14	7.80	0.037
	4	14	7.30	0.038
P3	1	26	7.20	0.040
	2	25	7.40	0.038
	3	23	7.80	0.055
	4	20	7.90	0.040
B8	1	Soft	7.40	0.060
	2	Sl. soft	7.78	0.067
	3	Sl. hard	7.60	0.050
	4	Sl. hard	7.60	0.045
P4	1	10	7.90	0.823
	2	18	8.10	0.508
	3	16	8.60	0.345
	4	13	8.75	0.380
B9	1	Hard	8.29	0.046
	2	Hard	7.96	0.061
	3	Sl. hard	7.98	0.082
	4	Sl. soft	8.20	0.047
	5	Sl. soft	8.00	0.058

(Cont'd)

Pit or Bore No.	Layer No.	Compactness	pH (1:2)	EC (1:2) mmho/25°C
B10	1	Hard	8.05	0.067
	2	Very hard	8.40	0.054
	3	Hard	8.45	0.073
	4	Very hard	8.60	0.063
P5	1	18	7.30	0.235
	2	20	7.60	0.240
	3	14	8.45	0.132
	4	12	8.80	0.153
B11	1	Sl. soft	7.81	0.245
	2	Hard	8.04	0.094
	3	Soft	8.32	0.118
P6	1	25	6.20	0.048
	2	27	7.36	0.054
	3	26	7.75	0.050
	4	22	7.80	0.043
	5	16	7.95	0.046
B12	1	Very hard	7.35	0.057
	2	Very hard	7.96	0.041
	3	Very hard	8.08	0.037
	4	Sl. soft	8.00	0.044
P7	1	7	8.38	0.084
	2	20	7.98	0.032
	3	22	8.22	0.063
	4	14	8.35	0.046
	5	15	8.51	0.039

(Cont'd)

Pit or Bore No.	Layer No.	Compactness	pH (1:2)	EC (1:2) mmho/25°C
B13	1	Very hard	8.10	0.066
	2	Very hard	8.40	0.047
	3	Hard	8.26	0.049
	4	Hard	8.24	0.045
P8	1	22	6.98	0.400
	2	14	6.65	0.735
	3	15	6.54	1.300
	4	17	7.46	1.780
B14	1	Sl. hard	8.61	0.255
	2	Sl. soft	8.50	0.197
	3	Sl. soft	8.37	0.258
B15	1	Soft	5.82	0.108
	2	Soft	6.80	0.047
	3	Hard	6.90	0.071
	4	Hard	7.70	0.036
	5	Soft	8.25	0.048
B19	1	Sl. hard	6.40	0.087
	2	Hard	7.20	0.083
	3	Sl. hard	7.55	0.063
	4	Sl. hard	8.60	0.181
P9	1	12	5.93	0.086
	2	15	7.10	0.134
	3	18	7.25	0.096
	4	21	7.37	0.096

(Cont'd)

No or Bore No.	Layer No.	Compactness	pH (1:2)	EC (1:2) mmho/25°C
P10	1	13	6.05	0.130
	2	19	7.20	0.060
	3	22	7.48	0.073
	4	17	7.45	0.057
B20	1	Sl. soft	7.63	0.096
	2	Hard	7.73	0.087
	3	Hard	7.75	0.061
	4	Sl. loose	7.80	0.079
P11	1	15	5.95	0.134
	2	20	6.90	0.137
	3	20	7.05	0.221
	4	20	7.90	0.125
P12	1	10	7.20	0.269
	2	20	7.80	0.080
	3	22	8.40	0.073
	4	19	8.58	0.069
P13	1	15	7.55	0.117
	2	20	7.80	0.081
	3	22	8.43	0.115
	4	18	8.80	0.136

(Cont'd)

Pit or Bore No.	Layer No.	Compactness	pH (1:2)	EC (1:2) mmho/25°C
B26	1	Very hard	5.80	0.096
	2	Hard	6.55	0.083
	3	Sl. hard	6.80	0.317
P14	1	10	6.60	0.461
	2	17	8.05	1.200
	3	18	8.00	1.440
B27	1	Sl. hard	6.90	0.105
	2	Sl. hard	7.25	0.085
	3	Soft	8.20	0.134
	4	Friable	8.13	0.180

TABLE A.5.3-5 pH AND ELECTRICAL CONDUCTIVITY OF THE WATER SAMPLES COLLECTED IN AMRIS AREA

Sample No.	Water	Sampling Site (Pit or Bore No.)		pH	EC mmho/25°C
1	I	ANMC: D-O	(B1)	7.02	0.157
2	I	LMSMC:	(B2)	7.07	0.166
3	I	ANMC: J	(B4)	7.10	0.157
4	I	ANMC: J	(B4)	7.10	0.162
5	I	ASMC: J-5, Bangcal		7.10	0.157
6	I	ASMC: J-2, Ticay		7.15	0.157
7	F	Pangclara, Candaba	(B6)	8.40	0.943
8	C	Pamigatigan creek	(B6)	7.60	0.269
9	C	Malanggam creek	(P1)	6.40	0.466
10	G	PI, Bulihan, Malolos		7.10	4.224
11	C	Anilao creek	(B7)	7.15	0.328
12	I	ASMC: D (Wakas)	(P2)	7.60	0.158
13	I	ANMC	(B8)	7.80	0.154
14	R	Angat river	(B8)	7.92	0.152
15	G	P4, Cansinala, Apalit		7.30	2.050
16	I	ANMC: D-1-A, Ext-1	(P4)	7.35	0.270
17	D	Tabuyoc drain	(B9)	7.25	0.390
18	C	Cansinala creek		7.20	0.390
19	I	Balite Canal-#2	(B11)	7.35	0.340
20	G	B11, Dampol 2nd, Pulilan		7.80	0.780
21	C	Kanyukan creek	(B12)	7.30	0.297
22	D	Sta Monica drain	(B12)	7.60	0.236
23	R	Pampanga river	(P6)	7.65	0.258
24	C	Matigue creek	(P6)	7.60	0.231
25	I	LMSMC: C-1	(P7)	7.70	0.166
26	I	ANMC (Ulingao) (R.III)		8.02	0.144
27	I	ANMC (Tangos)		8.18	0.156
28	I	ANMC: C-9 (Pulong Plazan)		7.98	0.163
29	I	LMSMC (Bahay Pare)		8.10	0.173

(Cont'd)

Sample No.	Water	Sampling Site (Pit or Bore No.)	pH	EC mmho/25°C
30	R	Maasim river (Tilapatio)	8.22	0.282
31	C	Cruz Nadaan creek	9.08	0.174
32	R	Maasim river (Bahay Pare)	8.29	0.240
33	C	Sapang Pagkasinta creek	7.94	0.314
34	I	ASMC: E	7.42	0.165
35	G	B15, Camachilihan, Bustos	6.60	0.682
36	I	ASMC: C-Extra (B16)	7.51	0.333
37	I	ASMC: C-2 (B17)	7.25	0.235
38	I	ASMC (B17)	7.59	0.144
39	G	B18, Pulong Gubat, Balagtas	8.30	0.629
40	C	Sanfol creek, Busuran, Bal.	7.90	0.176
41	I	ASMC: D-2, Busuran, Bal.	8.25	0.168
42	G	P9, Bunga Menor, Bustos	7.80	0.336
43	I	ASMC: B Talampas, Bus.	8.05	0.146
44	C	Talampas creek, Bustos	8.25	0.152
45	I	ASMC: J-Extra (P10)	7.98	0.158
46	G	B20, Tikay, Malolos (47 cm)	7.65	0.563
47	I	ASMC: J-3 (B20)	8.10	0.145
48	G	B21, Sta Piligrena, Pulilan	7.85	0.603
49	I	ANMC: E (B21)	7.90	0.202
50	I	L-LMC-TPIP: D, Bustos-Pandi	7.70	0.288
51	G	P13, La Purisima, Conc., S. Luis	7.25	1.152
52	I	ANMC: D-2-Ext. 3 (P13)	7.50	0.173
53	I	ANMC: C-2-H (B24)	7.12	0.269
54	G	B25, Dulong, Malabon, Pulilan	6,80	0.355
55	I	ANMC: K (B25)	7.20	0.171
56	F	Calawitan, Candaba (B26)	8.20	0.340
57	I	MNMC: D-5, stagnant (B26)	8.50	0.620
58	R	Mambog River (P14)	8.38	0.222
59	G	P14, Mambog, Bulacan	7.66	7.591

(Cont'd)

Sample No.	Water	Sampling Site (Pit or Bore No.)	pH	EC mmho/25°C
60	G	B27, Longos, Calumpit	7.50	0.460
61	I	ASMC: M (B27)	8.18	0.160
62	G	B28, Iba, Calumpit	7.40	0.738
63	D	Iba-Clumpit drain (B28)	8.00	0.180

Note : Water samples were classified as follows according to their sources:

I	Irrigation canal and lateral
D	Drain
R	River
C	Creek
F	Fish Pond
G	Ground water taken from pit or bore
T	Well and tap water
ANMC	Angat river-north main canal
ASMC	Angat river-south main canal
IMSMC	Lower Maasim river-south main canal
TPIP	Tibagan pump irrigation project

TABLE A.5.3-6 SOME CONSPICUOUS VEGETATIONS IN AMRIS AREA

Place (Texture)	Family	Genus	Species	Tagalog Name (English Name)
River, Swamp,	Pontederiaceae	Eichornia	crassipes	(Water hyacinth)
Creek	Convulvulaceae	Ipomoea	aquatica	Kang kong
(Clayey)	Cyperaceae	Fimbristylis	squarrosa	-
	Typhaceae	Typha	latifolia	(Cattail)
	Palmae	Nypa	fruticans	(Nipa)
River, Levee,	Leguminoseae	Mimosa	pudica	Makahiya
Country road	Graminaceae	Cynodon	dactylon	(Bermuda grass)
(Silty)	Compositae	Ageratum	conyzoides	-
	Labiatae	Plectranthus	inflexus	-
Upland, Hills	Graminaceae	Saccharum	spontaneum	Talahib
(Silty to clayey)	"	Imperata	cylindrica	Cogon
	"	Panicum	repens	-

TABLE A.5.3-7 PROFILE CHARACTERISTICS OF SOIL TYPES IN AMRIS AREA

Soil Series	Soil Type	Type No.	Texture: Surface Soil	Texture: Subsoil	Color: Surface Soil	Color: Subsoil	Special Feature	Topography and Drainage
1. Obando	Fine sandy loam	2	FSL	FS → C	brown	brown	marine shells in subsoil, weak structure	Sea-level deposits, poorly drained
2. Bigaa	Clay loam	3	CL	C → CL	brown-dark-brown	light gray-dark brown gray	reddish brown streaks, yellow-red. brown clay mottles, fine granular, concreations	Flat, partly submerged imperfectly drained
3. Bigaa	Silty clay loam	546	SiCL	C → CL	brown-dark-brown	light gray-dark brown gray	ibid.	ibid.
4. Quingua	Fine sandy loam	4	FSL	SiL	light brown-pale brown	light brown-pale brown	deep deposits of sandy materials, almost no change in structure	River flood teraces, flat, moderately well drained
5. Quingua	Silt loam	5	SiL	SiCL - CL → SiL - SiCL	brown-yellowish brown	dark-brown-brown -red brown	reddish brown streaks in subsoil. descent of clay	Slightly undulating, well drained
6. Quingua	Silty clay loam	285	SiCL	SiCL - CL → SiL - SiCL	brown-yellowish brown	dark brown-brown -red brown	ibid.	ibid.
7. Quingua	Silty clay	899	SiC	SiCL - CL → SiL - SiCL	brown-yellowish brown	dark brown-brown -red brown	almost, ibid.	Slightly undulating, imperfectly drained
8. Calumpit	Sandy loam	17	SiCL - SL	SL - LS	brown-dark brown	brown-dark brown	deep deposits of sandy materials, few reddish brown streaks, almost structureless subsoil	Level to undulating, inside levels, often flooded, imperfectly drained
9. Calumpit	Silty clay loam	18	SiCL	SiL → SL	brown-yellowish brown	brown-dark yellowish brown	some reddish brown streaks, weak to moderate structure	Higher than the former type area, sometimes flooded, imperfectly drained
10. Candaba	Silt loam	69	SiL	CL	pale brown-dark gray-black	pale brown-dark gray-black	compact surface, dark brown clay mottled subsoil	Candaba swamp area, poorly drained
11. Candaba	Clay loam	70	CL(SiL)	SiC	pale brown dark gray-black	pale brown-dark gray-black	friable surface, reddish brown clay mottled subsoil	Candaba swamp area, submerged
12. Prensa	Silty clay loam	66	SiCL	CL - C	brown yellowish -light red brown	light grayish brown	Fe concretions, gravelly, impervious subsoil	Rolling and hilly, poor internal drainage
13. Buenavista	Silt loam	9	SiL	CL - C	brown yellowish -light red brown	light grayish brown	Fe concretions, impervious clay, compact	Rolling and hilly, poor internal drainage

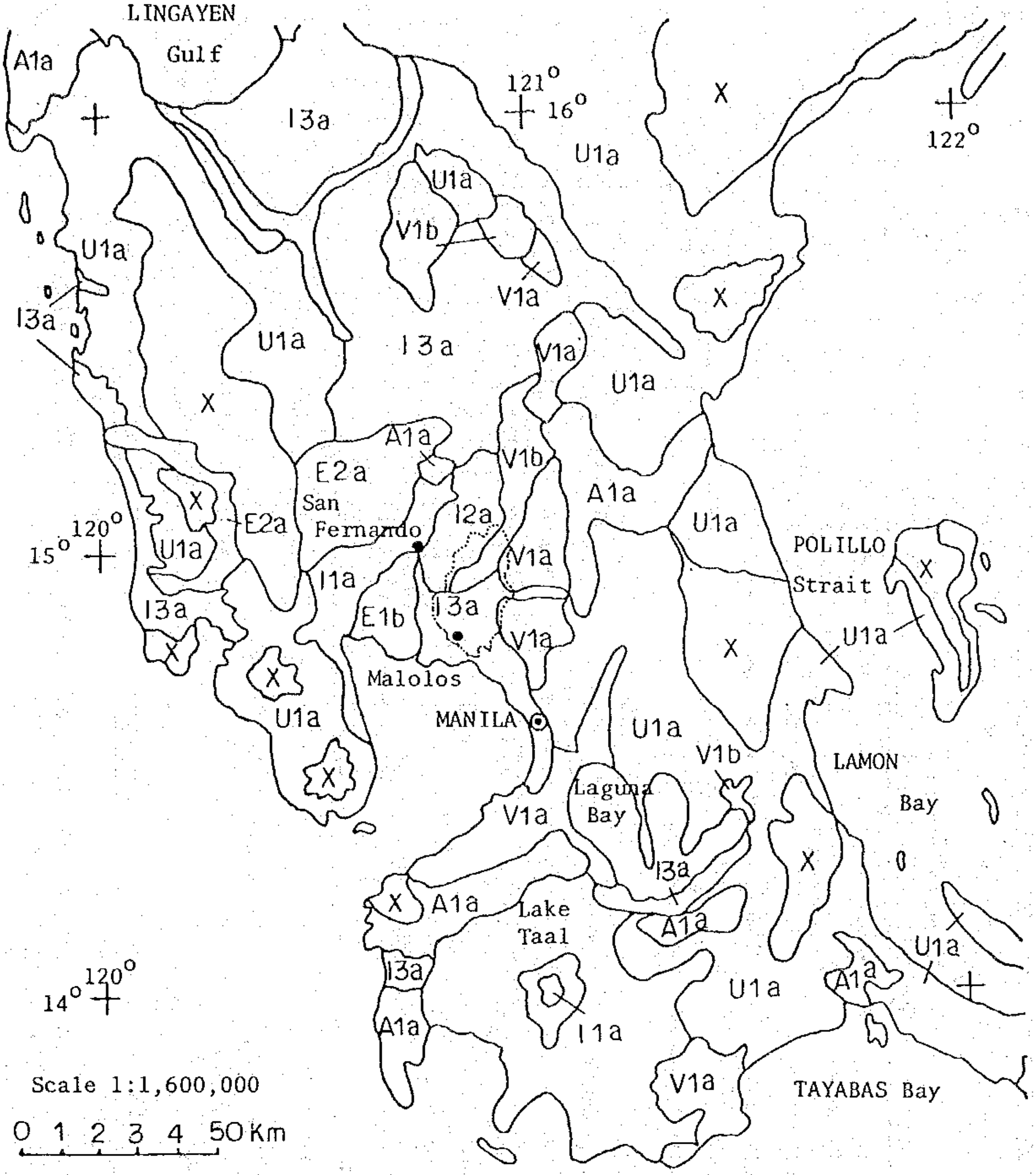
Source : Soil Survey of Bulacan and Pampanga Province, Bureau of Soils, DANR (1936 and 1956)

TABLE A.5.3-8 DISTRIBUTION AND AREA OF SOIL SERIES AND TYPES IN AMRIS PROJECT AREA

(ha)

Soil Series	Soil Types	Symbol No.	North Side	South Side	Total	%
1. Obando	Fine sandy loam	2	0	1,725	1,725	4.0
2. Bigaa	Clay loam	3	5,685	6,310	11,995	28.1
3. Bigaa	Silty clay loam	546	-	175	175	0.4
	(Sub-total)		(5,685)	(6,485)	(12,170)	(28.5)
4. Quingua	Fine sandy loam	4	770	40	810	1.9
5. Quingua	Silt loam	5	4,325	4,690	9,015	21.1
6. Quingua	Silty clay loam	285	0	3,950	3,950	9.2
7. Quingua	Silty clay	899	0	1,150	1,150	2.7
	(Sub-total)		(5,095)	(9,830)	(14,925)	(34.9)
8. Calumpit	Sandy loam	17	235	1,200	1,435	3.4
9. Calumpit	Silty clay loam	18	2,075	455	2,530	5.9
	(Sub-total)		(2,310)	(1,655)	(3,965)	(9.3)
10. Candaba	Silt loam	69	1,280	0	1,280	3.0
11. Candaba	Clay loam	70	3,405	0	3,405	8.0
	(Sub-total)		(4,685)	(0)	(4,685)	(11.0)
12. Prensa	Silty clay loam	66	1,570	1,210	2,780	6.5
13. Buenavista	Silt loam	9	2,485	0	2,485	5.8
Total		(13)	21,830	20,905	42,735	100.0

Note : Area was divided into north- and south- side of Angat River and represents the Present service areas including all of the non-agricultural lands inside the Project boundary.



L E G E N D :

Map Symbol	Order	Suborder	Great Group	Soil Units, FAO/UNESCO (Soil Map of the World)	
A1a	ALFISOLS	Udalfs	Tropudalfs	Eutric	Nitosols
E1a	ENTISOLS	Aquents	Fluvaquents	Eutric	Fluvisols
E1b	"	"	Tropaquents	"	"
E2a	"	Psamments	Tropopsamments	Eutric	Regosols
I1a	INCEPTISOLS	Andepts	Eutrandepts	Humic	Andosols
I2a	"	Aquepts	Tropaquepts	Eutric	Gleysols
I3a	"	Tropepts	Eutropepts	"	Cambisols
U1a	ULTISOLS	Udults	Tropudults	Dystric	Nitosols
V1a	VERTISOLS	Usterts	Chromusterts	Chromic	Vertisols
V1b	"	"	Pellusterts	Pellic	"
X	Mountain Soils with E, I, U and A soils				

FIGURE A.5.3-1 SOIL MAP OF THE PHILIPPINES AROUND THE PROJECT AREA (1972)

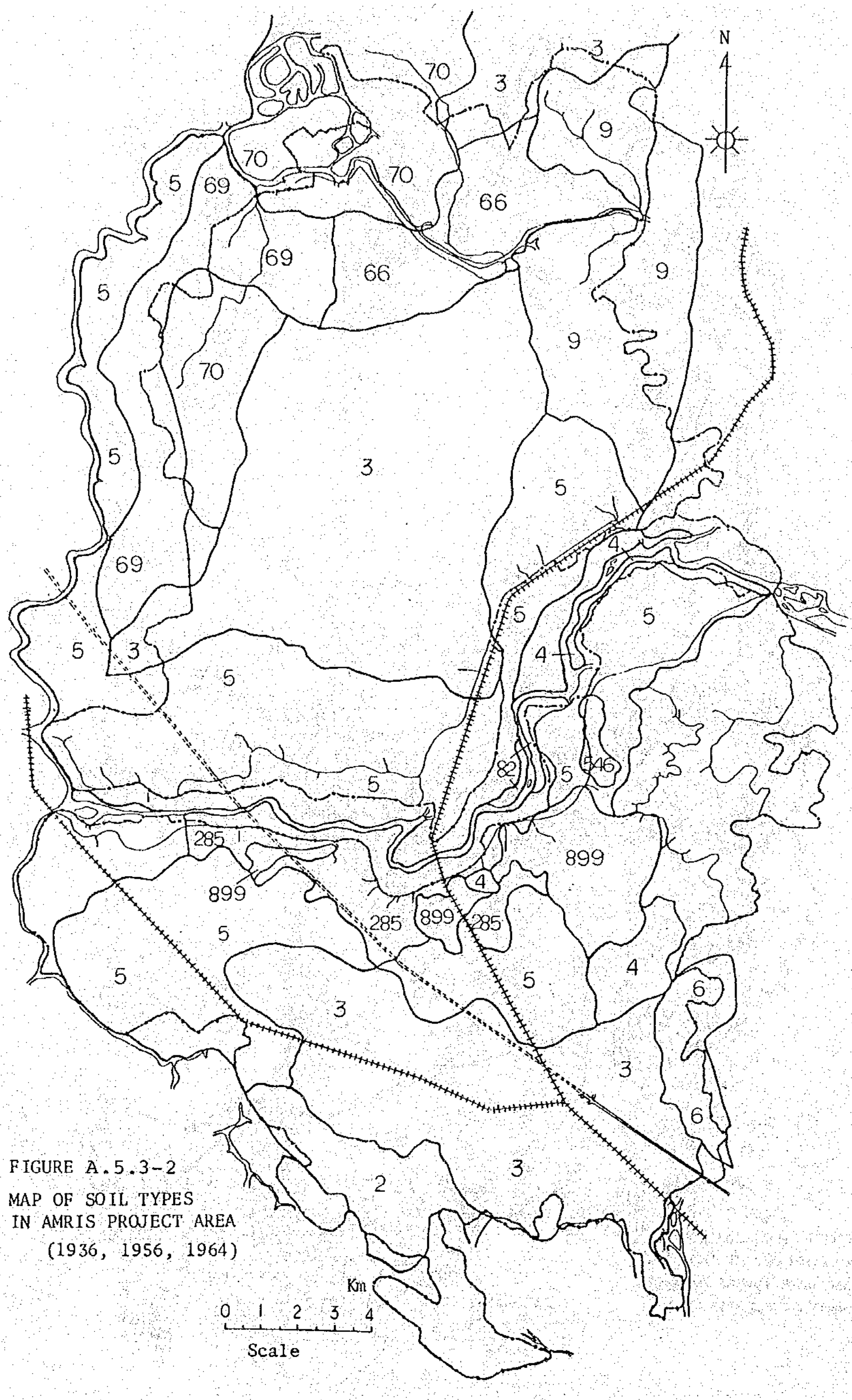


FIGURE A.5.3-2
MAP OF SOIL TYPES
IN AMRIS PROJECT AREA
(1936, 1956, 1964)

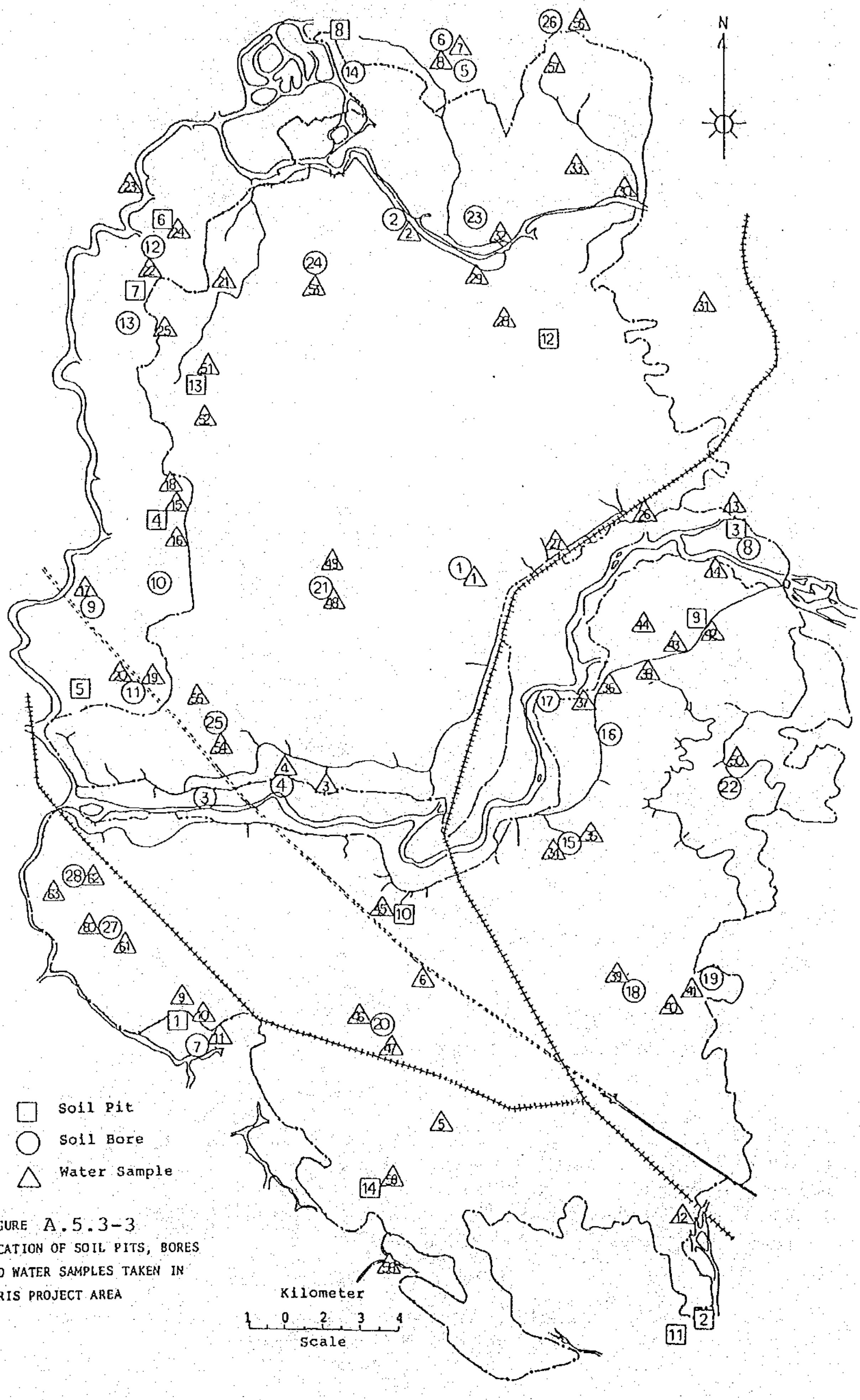


FIGURE A.5.3-3
LOCATION OF SOIL PITS, BORES AND WATER SAMPLES TAKEN IN AMRIS PROJECT AREA

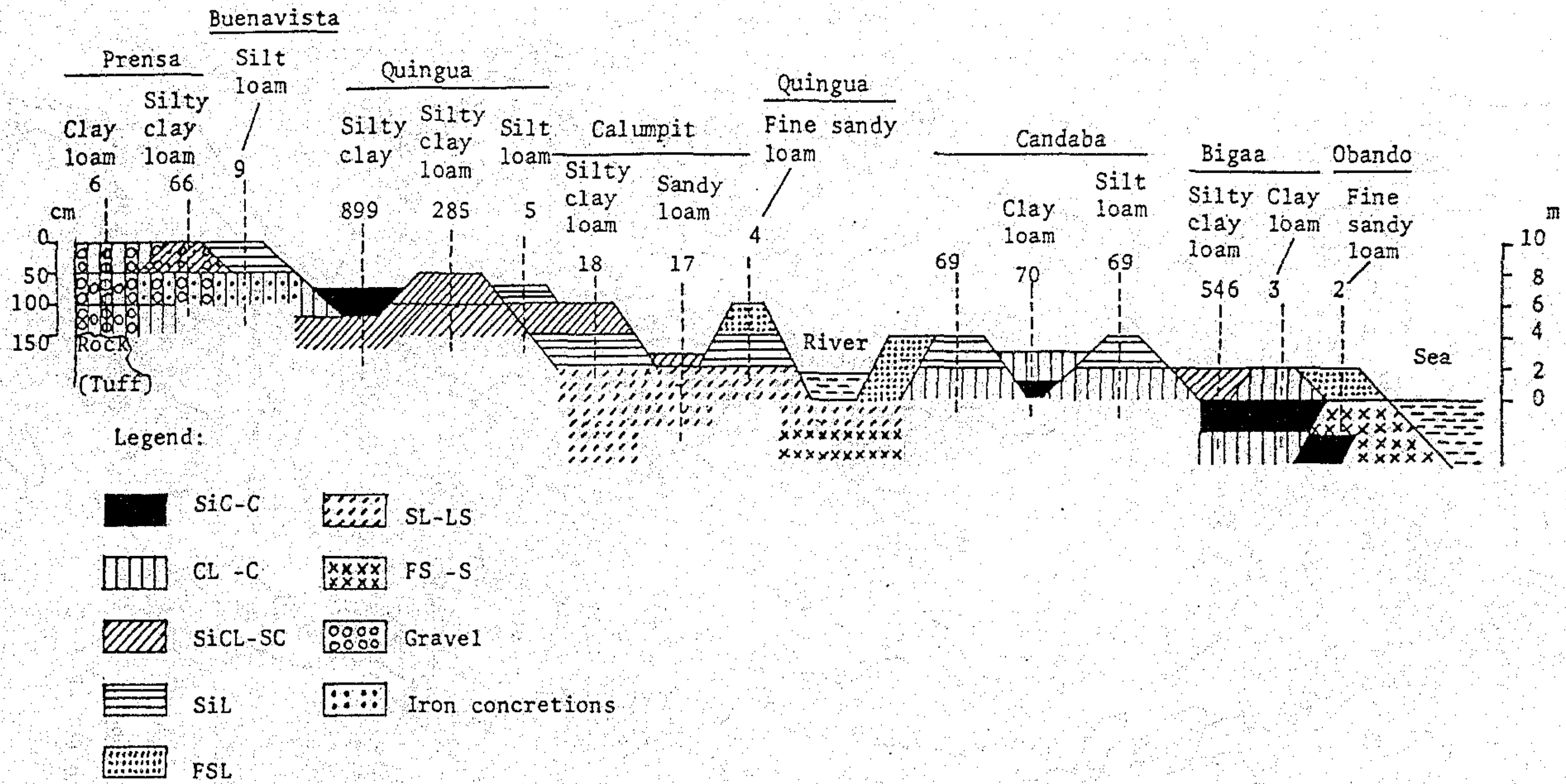


FIGURE A.5.3-4 SCHEMATIC DIAGRAM FOR TEXTURAL SEQUENCES OF SOIL SERIES AND TYPES FOUND IN AMRIS PROJECT AREA

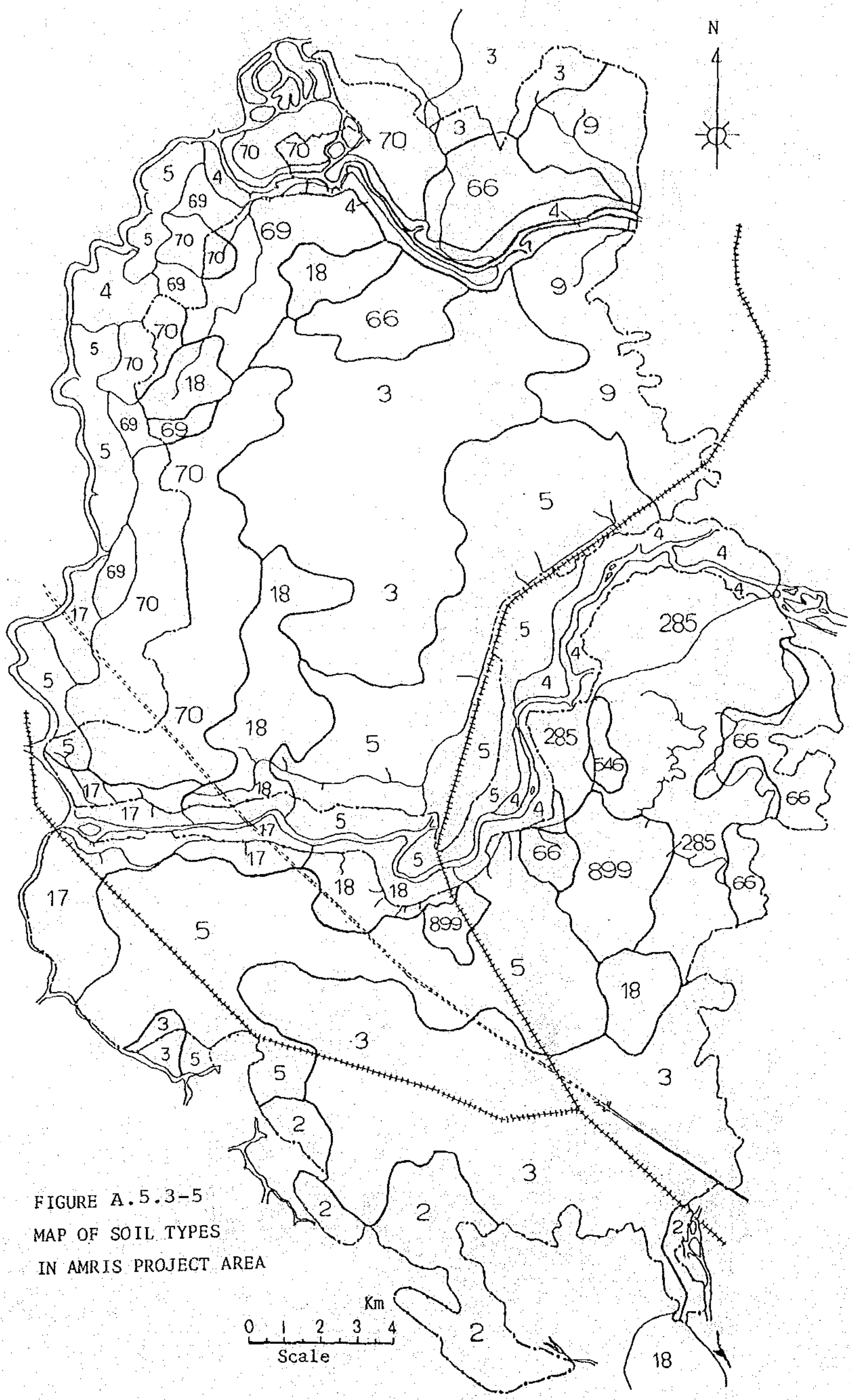


FIGURE A.5.3-5
MAP OF SOIL TYPES
IN AMRIS PROJECT AREA

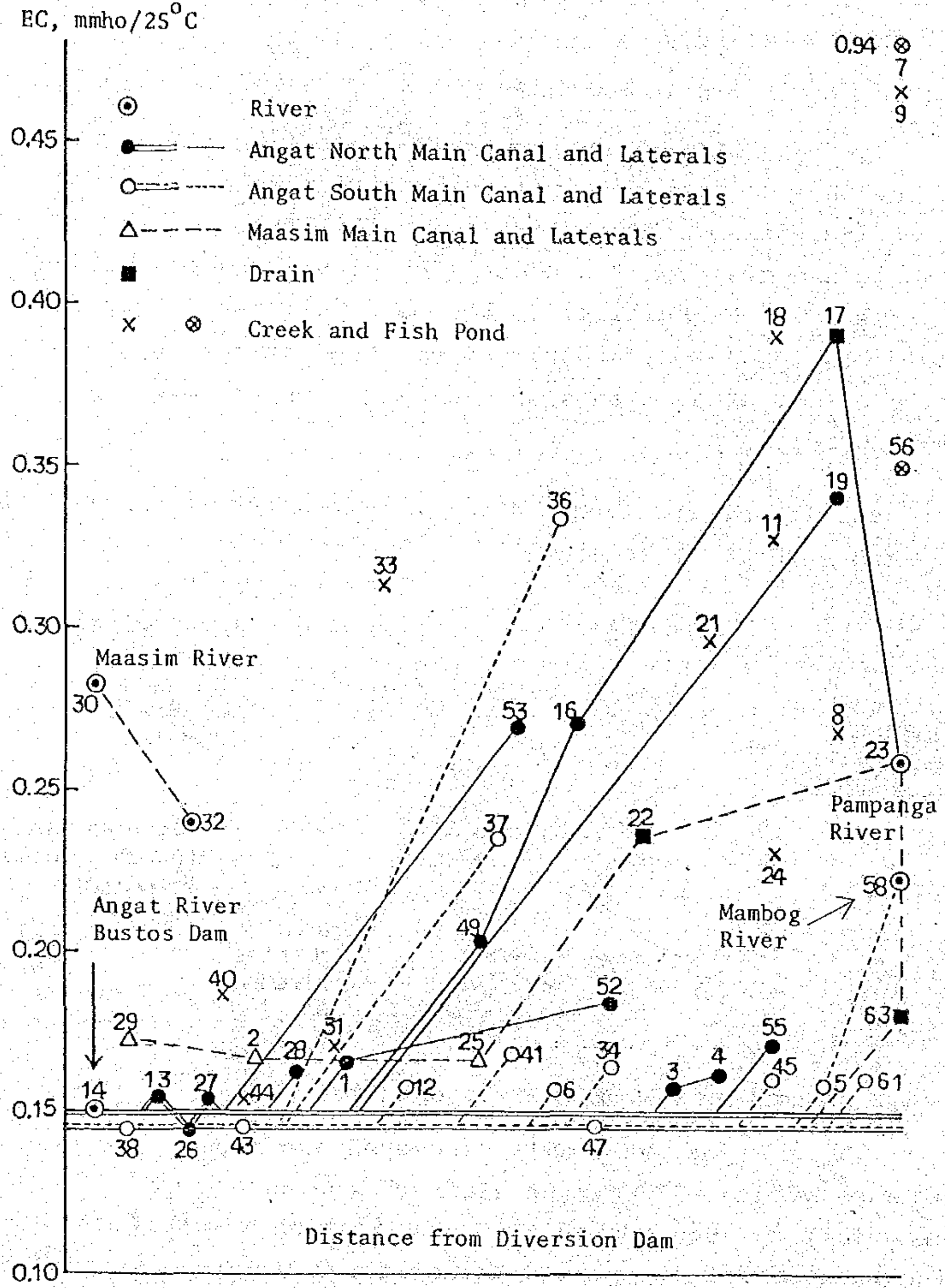


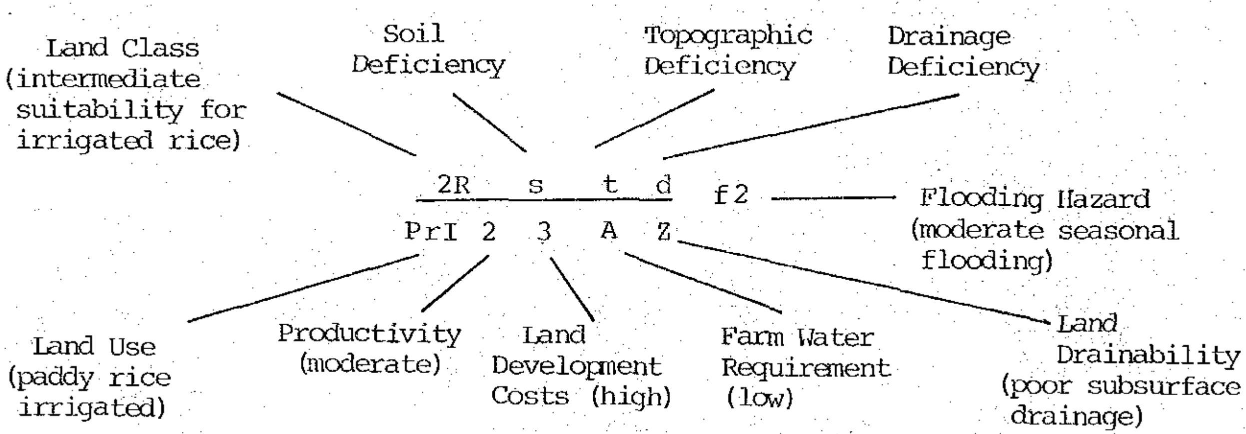
FIGURE A.5.3-6 ELECTRICAL CONDUCTIVITY OF THE WATER SAMPLES TAKEN IN AMRIS PROJECT AREA

5.4 Land Classification

5.4.1 Classification Method

Land classification requires examination and appraisal of the physical and chemical characteristics of the land, which include soil properties and qualities of the topographic and drainage features. The classification method practised in the Philippines has been patterned after the field and laboratory procedures employed at the Bureau of Reclamation, USDA, with some modifications to meet the local conditions.

Results of the land evaluation are mapped with special mapping symbols as follows:



5.4.2 Land Classes of the Project Area

The area was originally surveyed and mapped for land classes before 1973 by the staff of the Bureau of Soils. From 1977 to 1978 upgrading investigation was conducted in the Angat-Magat Integrated Agricultural Development Project to identify and delineate lands capable of sustained high yields of suitable crops when provided with adequate water supply. The results are summarized in Table A.5.4-1. The area distribution is given in Figure A.5.4-1.

Irrigated ricelands occupy 85 percent of the total irrigated areas, of which 66 percent is classified into the highest class (IR). Lands with a potential for production of both paddy and diversified crops under irrigation are classified as 1-2R (2d). These account for 15 percent of the total. This suggests that about 4,200 ha can be subjected to upland crops production in dry season.

Although many survey data were used in this investigation, consideration was not fully made to associate them with the soil classification. Land classes which will be correlated with Soil Series and Types are summarized in Table A.5.4-2. Each Soil Type thus belongs to two or three classes and/or subclasses according to its varying topography. Hence, it will be necessary in the future to delineate the land class areas based on the soil classification system. Detailed information for land specifications and procedures may be referred to in the report of AMIADP, NIA (1978).

TABLE A.5.4-1 HECTARAGE OF LAND CLASSES (UPGRADING) IN AMRIS AREA (1978)

Land	Class	Subclass	Area (ha)	Ratio (%)	
Irrigated	1	-	230	0.8	
Diversified	2	df	378	1.4	
Cropland	3	df	49	0.2	
	Total (1-3)		657	2.4	1.8
	1R	-	18,281	65.9	
	2R	tj	839	3.0	
Irrigated	2R	df	3,272	11.8	
	Sub-total (2R)		4,111	14.8	
Riceland	3R	tj	185	0.7	
	3R	df	325	1.2	
	3R	st	28	0.1	
	Sub-total (3R)		538	1.9	
	Total (1R-3R)		22,930	82.6	64.4
Irrigated	1R (2)	(do, d/A)	3,839	13.8	
Dual Class Land	2R (2)	(df, dt)	327	1.2	
	Total		4,166	15.0	
Total Irrigated Lands			27,753	100.0	11.7
Non-Arable	6	df, std	1,846		5.2
Lands*	M		3,920		11.0
	ROW		2,081		5.8
	Total		7,847		22.0
Grand Total			35,600		100.0

Source: AMIADP Land Classification Upgrading, ADD-UPRP, NIA (1978)

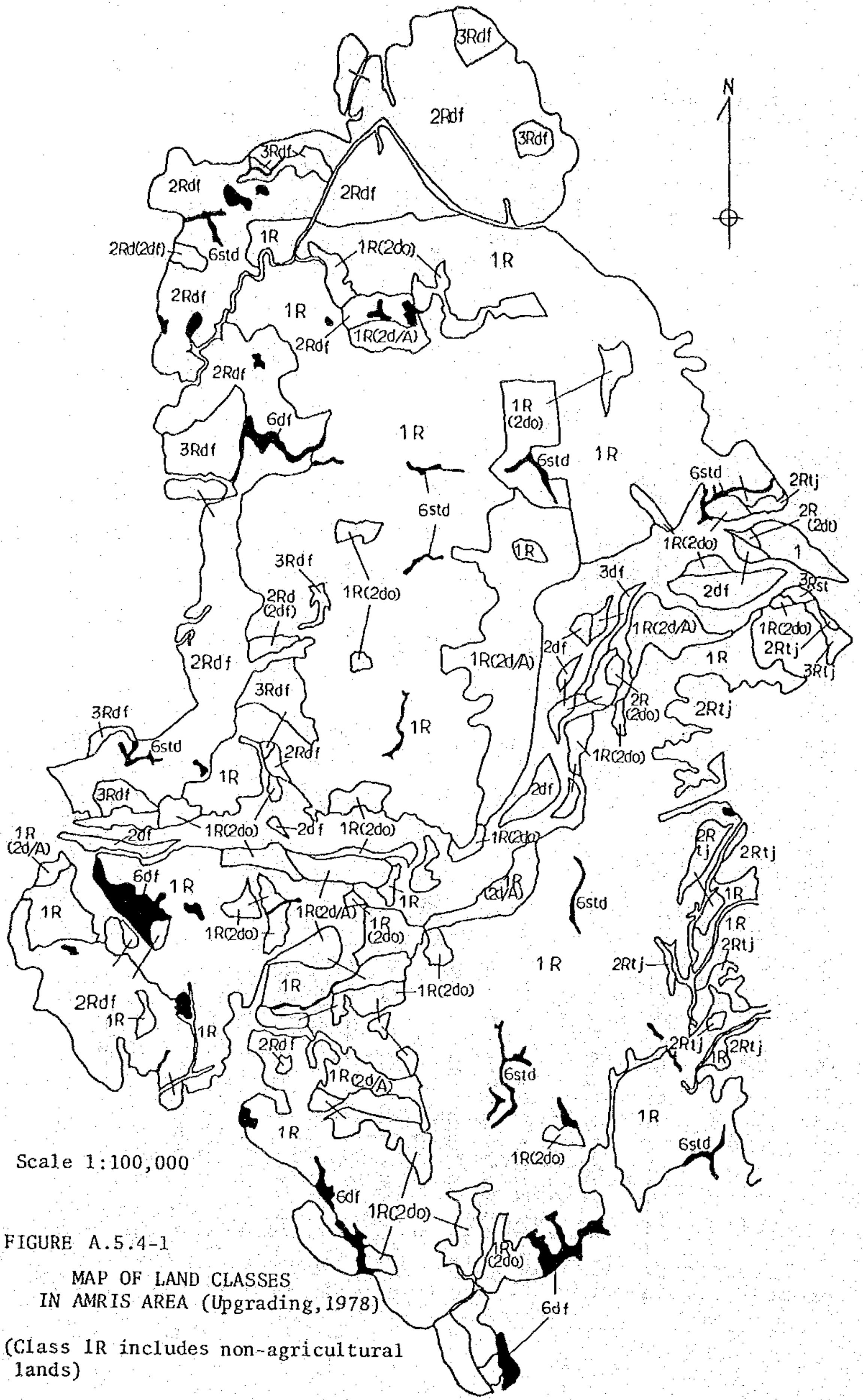
Note : Subclass Symbols:
- S - Soil Deficiency, A - Low Irrigation Water Requirement
- t - Topography Deficiency (j - Irregular Topography)
- d - Drainage Deficiency (o - Subsurface Drainage Construction Required; f - Subject to flooding)

*:
- 6 - Undulating lands with shallow soils, stream channels, swamps, etc.
- M - Towns, villages, residential or industrial areas.
- ROW - Right of way, including public roads, canals, drains and farm roads.

TABLE A.5.4-2 AREA AND LAND CLASS OF SOIL SERIES AND TYPES IN AMRIS PROJECT AREA

Soil Series and Types	Symbol No.	Area (ha)	Area (%)	Land Classes
1. Obando Fine Sandy Loam	2	1,725	4.0	2Rdf, 3Rdf
2. Bigaa Clay Loam	3	11,995	28.1	1R, 1R(2do), 2Rdf
3. Bigaa Silty Clay Loam	546	175	0.4	1R(2do), 2Rdf
4. Quingua Fine Sandy Loam	4	810	1.9	2Rst, 3Rst, 3df
5. Quingua Silt Loam	5	9,015	21.1	1R, 1R(2d/A)
6. Quingua Silty Clay Loam	285	3,950	9.2	1R, 1R(2d/A)
7. Quingua Silty Clay	899	1,150	2.7	1R, 2Rdf
8. Calumpit Sandy Loam	17	1,435	3.4	1R, 2Rdf, 2Rs
9. Calumpit Silty Clay Loam	18	2,530	5.9	1R, 1R(2do)
10. Candaba Silt Loam	69	1,280	3.0	1R, 1R(2do), 2-3Rdf
11. Candaba Clay Loam	70	3,405	8.0	2Rdf, 3Rdf
12. Prensa Silty Clay Loam	66	2,780	6.5	1R, 2Rtj, 3Rtj
13. Buenavista Silt Loam	9	2,485	5.8	1R, 2Rd
Total	(13)	42,735	100.0	

Note: Refer to the note in Table A.5.4-1 for land class symbols.



Scale 1:100,000

FIGURE A.5.4-1

MAP OF LAND CLASSES
IN AMRIS AREA (Upgrading, 1978)

(Class 1R includes non-agricultural lands)

5.5 Soils of New Expansion Area

5.5.1 Soil Series and Types

The exploitable areas which are scheduled to be expanded are located at the lowest elevation of less than five meters above sea level. An exception is the Caingin area in San Rafael (WS6 Ex-1) where coarse particles are deposited, resulting in an alluvial terrace gently sloping from 18 m to 14 m in elevation.

Location of these areas and their hectarage of classified soil types are shown in Table A.5.5-1 and Figures A.5.5-1 to A.5.5-5. To draw these figures, the following maps were used as well as in the soil survey work:

Area No.	(Municipality)	Map Scale	Producer
WS 6 Ex-1	(San Rafael)	1:10,000	Aurora-Penaranda Project, NIA, 1973
WS 6 Ex-2	(San Rafael)	1:50,000	Authority of the Board of Technical Survey and Mapping, 1952-1970
WS 6 Ex-3	(Candaba)	1:50,000	Ibid.
WS 7 Ex	(Candaba)	1:50,000	Ibid.
WS 8 Ex-1	(San Luis)	1:25,000	NIA-JICA Cooperation Project, 1981
WS 8 Ex-2	(San Luis)	1:25,000	Ibid.
WS 9 Ex	(Apalit)	1:25,000	Ibid.
WS 12 Ex	(Apalit)	1:25,000	Ibid.
WS 5 Ex	(Malolos)	1:50,000	Same as WS 6 Ex-2
WS 2 Ex	(Bocaue)	1:50,000	Ibid.

Four Soil Series and eight Soil Types are distributed in the expansion areas, and one to three types are observed in one area. The most extensive is Candaba Clay Loam (70) followed by Bigaa Clay Loam (3). Quingua Silt Loam (5) appears frequently over four areas in a small size. Two

Soil Types (17 and 18) of the newly established Calumpit Series where silt clay loam surface soil is underlaid by coarse textural subsoil are shown in WS9 Ex, 12 Ex and WS2 Ex area, respectively.

5.5.2 Land Classes

Most of the areas proposed to be expanded have been used mainly as paddy fields by farmers; WS6 Ex-1 area has been cultivated for upland crops such as vegetables and beans. These areas divert irrigation water from the nearby rivers and creeks since the farmers are not yet served by AMRIS. Grasslands, marshes and fish ponds, however, are located in a greater portion in WS6 Ex-3, and around WS5 Ex and 2 Ex areas because these areas are submerged frequently in wet season.

Land classes for irrigation suitability are evaluated following the same method as described in paragraph 5.4 and are presented in Table A.5.5-2. The soils are classified mostly into second classes with drainage deficiency, flooding hazard and/or topography deficiency. Only Soil Type (4) belongs to third class because of its lower productivity. Digits in the denominator illustrate lands use, productivity rating (1-2), irrigation water requirement and land drainability, referring to soil characteristics which are summarized in the same Table.

Non-arable lands such as marshes and fish ponds in each area belong to sixth class (6) although their extent has not yet been fully surveyed. It is necessary during the planning stage of the Project to decide to what extent these lands can be reclaimed for cultivation or should be left as they are now.

Conversely, some portion of the 2R class lands can be upgraded to 1R class, when irrigation and drainage facilities are provided through the Project implementation.

5.5.3 Soil Characteristics

Soil characteristics examined in the present survey are summarized in Table A.5.5-2. The figures represent averages from the results of the profile observation and soil analysis.

Soil fertility is, in general, moderately high; the soils are rich in exchangeable bases with a slight accumulation of organic matter throughout the profile. Despite submergence of the lands in wet season, structural development is moderately good enough to allow internal drainage during the irrigation period of rice crop.

Common soil deficiencies are compactness and a high pH of the subsoil. Higher salinity values are found in the soils of Candaba area, WS6 Ex-3 and 7 Ex (3, 70) and Malolos area, WS5 Ex (3), where evapotranspiration seems to dominate during the dry season. In those areas more intense drainage facilities are needed to keep saline soil water from upward movement. Frequent deep plowing and increased nitrogen application are also recommended for most of the expansion areas. Precaution against zinc deficiency of rice plants must be taken especially in the alkaline soil areas as will be pointed out in the next paragraph.

TABLE A.5.5-1 CLASSIFIED SOILS AND AREA OF DISTRIBUTION IN THE EXPANSION AREAS OF AMRIS PROJECT

Soil Series	Soil Type	Type No.	Area of Distribution (ha): Existing Gross Area	Expansion Area: 6 Ex-1	6 Ex-2	6 Ex-3	7 Ex	8 Ex-1	8 Ex-2	9 Ex	12 Ex	5 Ex	2 Ex	Total	Grand Total	Distribution Ratio (%)
I. Soil of the Low-lands																
1. Obando	Fine Sandy Loam	2	1,725	-	-	-	-	-	-	-	-	-	-	-	1,725	3.7
2. Bigaa	Clay Loam	3	11,995	-	-	838	-	-	-	-	-	47	-	885	12,880	27.5
	Silty Clay Loam	546	175	-	-	-	-	-	-	-	-	-	-	-	175	0.4
3. Quingua	Fine Sandy Loam	4	810	167	-	-	47	-	144	-	-	-	-	358	1,168	2.5
	Silt Loam	5	9,015	-	-	-	-	33	69	-	174	28	-	304	9,319	19.9
	Silty Clay Loam	285	3,950	-	-	-	-	-	-	-	-	-	-	-	3,950	8.4
	Silty Clay	899	1,150	-	-	-	-	-	-	-	-	-	-	-	1,150	2.5
4. Calumpit*	Sandy Loam*	17	1,435	-	-	-	-	-	-	34	29	-	-	63	1,498	3.2
	Silty Clay Loam*	18	2,530	-	-	-	-	-	-	-	-	-	103	103	2,633	5.6
5. Candaba	Silt Loam	69	1,280	-	-	-	-	19	50	-	-	-	-	69	1,349	2.9
	Clay Loam	70	3,405	-	-	121	741	149	205	482	220	-	-	1,918	5,323	11.4
II. Soils of the Up-lands and Hills																
6. Prensa	Silty Clay Loam	66	2,780	-	-	-	-	-	-	-	-	-	-	-	2,780	6.0
7. Buenavista	Silt Loam	9	2,485	-	300	-	-	-	-	-	-	-	-	300	2,785	6.0
Total		(13)	42,735	167	300	959	788	201	468	516	423	75	103	4,000	46,735	100.0

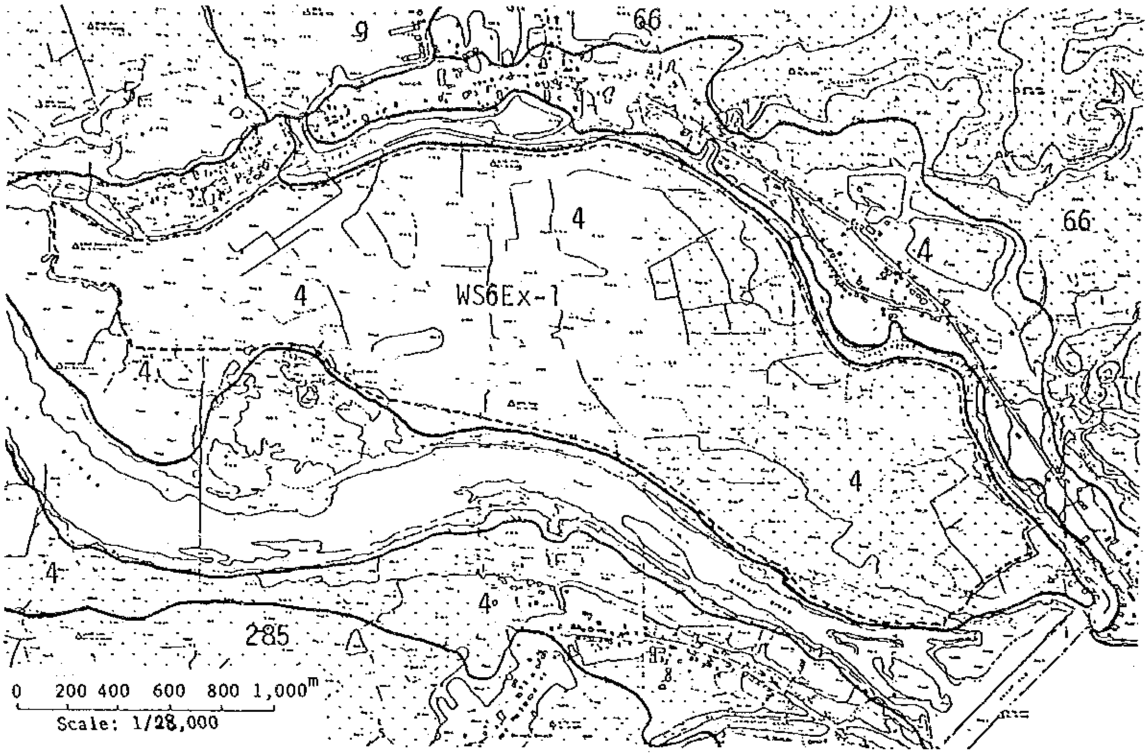
Note: Service area of AMRIS is 31,485 ha for the existing gross area and 3,480 ha estimated for the expansion area.
Each expansion area is marked with number of the existing Working Station through which irrigation will be conducted.
*; Newly established by the present soil survey.

TABLE A.5.5-2 LAND CLASSES AND SOIL CHARACTERISTICS OF NEW EXPANSION AREAS

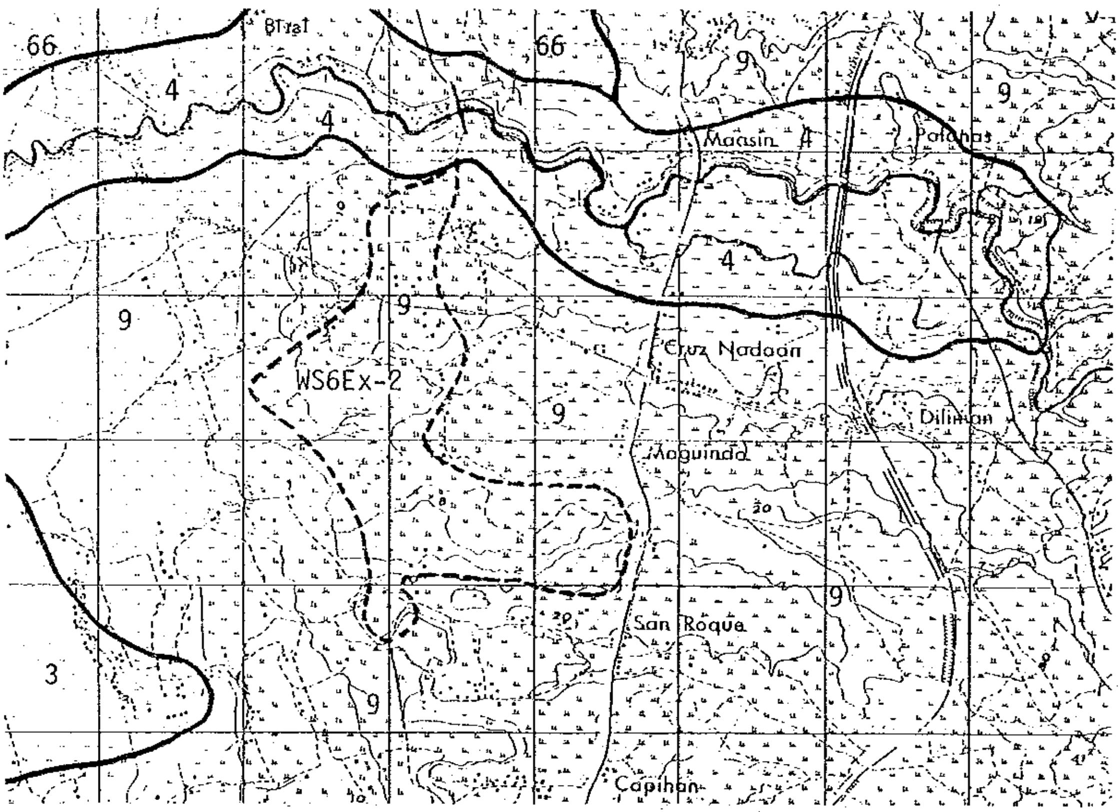
Area No.	Soil Type No.	Elevation (m)	Present Land Use	Land Class	Soil Characteristics (surface - subsoil) Texture	Color (dry)	Compactness	pH (1:2)	EC (1:2) (mmhos)
SW 6 Ex-1	4	14 - 18	Upland, Paddy	$2sf_0$/C22BX $2Rstf_0$/PrI22BX	Sil-SL	ybr-lybr	vh-vh	7.3 - 7.9	0.1 - 0.1
SW 6 Ex-2	9	8 - 9	Paddy	1R/PrIllAx $2Rdf_{1-2}$/PrI22AY	CL-SiC	br-lybr	vh-vh	7.5 - 8.9	0.1 - 0.1
SW 6 Ex-3 and	3	3.5 - 4.5	Paddy, Grassland,	$2Rdf_{2-3}$/PrI12AZ	CL-SiC	grbr-dgrbr	h-sh	6.3 - 7.8	1.2 - 1.4
SW 7 Ex	70	3.0 - 4.0	Fish Pond	$2Rdf_3$/PrI22AZ	CL-SiC	gr-dgr	h-h	7.8 - 8.0	0.3 - 1.1
SW 8 Ex-1	5	2.5 - 3.5	Paddy	$2Rdf_1$/PrI22AZ	- -	- -	- -	- -	- -
	70	2.0 - 3.0		$2Rdf_3$/PrI12AZ	SiC-CL	lybr-grbr	vh-h	6.2 - 8.0	0.1 - 0.0
SW 8 EX-2	4	1.5 - 3.0	Paddy, Marsh	$3Rsdf_2$/PrI32BX	FSL-SiL	lybr-ybr	vh-h	8.4 - 8.5	0.1 - 0.1
	70	1.5 - 2.0		$2Rdf_3$/PrI22AZ	CL-SiCL	pbr-grbr	vh-h	7.8 - 8.2	0.1 - 0.0
SW 9 Ex	5	2.5 - 3.5	Paddy, Marsh	$2Rdf_2$/PrI22AZ	- -	- -	- -	- -	- -
and	17	2.0 - 3.0		$2Rdf_2$/PrI22AY	SiCL-SiL	br-ybr	h-vh	8.1 - 8.6	0.1 - 0.1
SW 12 Ex	70	1.5 - 2.5		$2Rdf_3$/PrI22AZ	CL-SiCL	ybr-dybr	sh-h	7.7 - 8.6	0.4 - 0.2
SW 5 Ex	3	2.0 - 3.0	Paddy, Marsh,	$2Rdf_{2-3}$/PrI12AZ	SiCL-CL	gbr-gbr	h-h	7.4 - 7.9	0.4 - 0.8
	5	2.5 - 3.5	Fish Pond	$2Rdf_{2-3}$/PrI22AZ	SiL-CL	gbr-gbr	h-sh	7.6 - 9.0	0.1 - 0.2
SW 2Ex	18	2.0 - 3.5	Paddy, Fish Pond	$2Rdf_2$/PrI22AY	SiCL-SL	ybr-ybr	vh-vh	6.7 - 8.1	0.1 - 0.2

Note: For land classification, refer to Paragraph 5.4.
Some symbols are illustrated as follows:

1. Flooding hazard : f_1 Slight seasonal flooding
   f_2 Moderate seasonal flooding
   f_3 Severe deep annual flooding
2. Present Land Use : PrI Paddy rice irrigated
   C Diversified crops, irrigated
3. Farm water requirement: A Low
   B Medium
4. Land drainability: X Good
   Y Restricted
   Z Poor

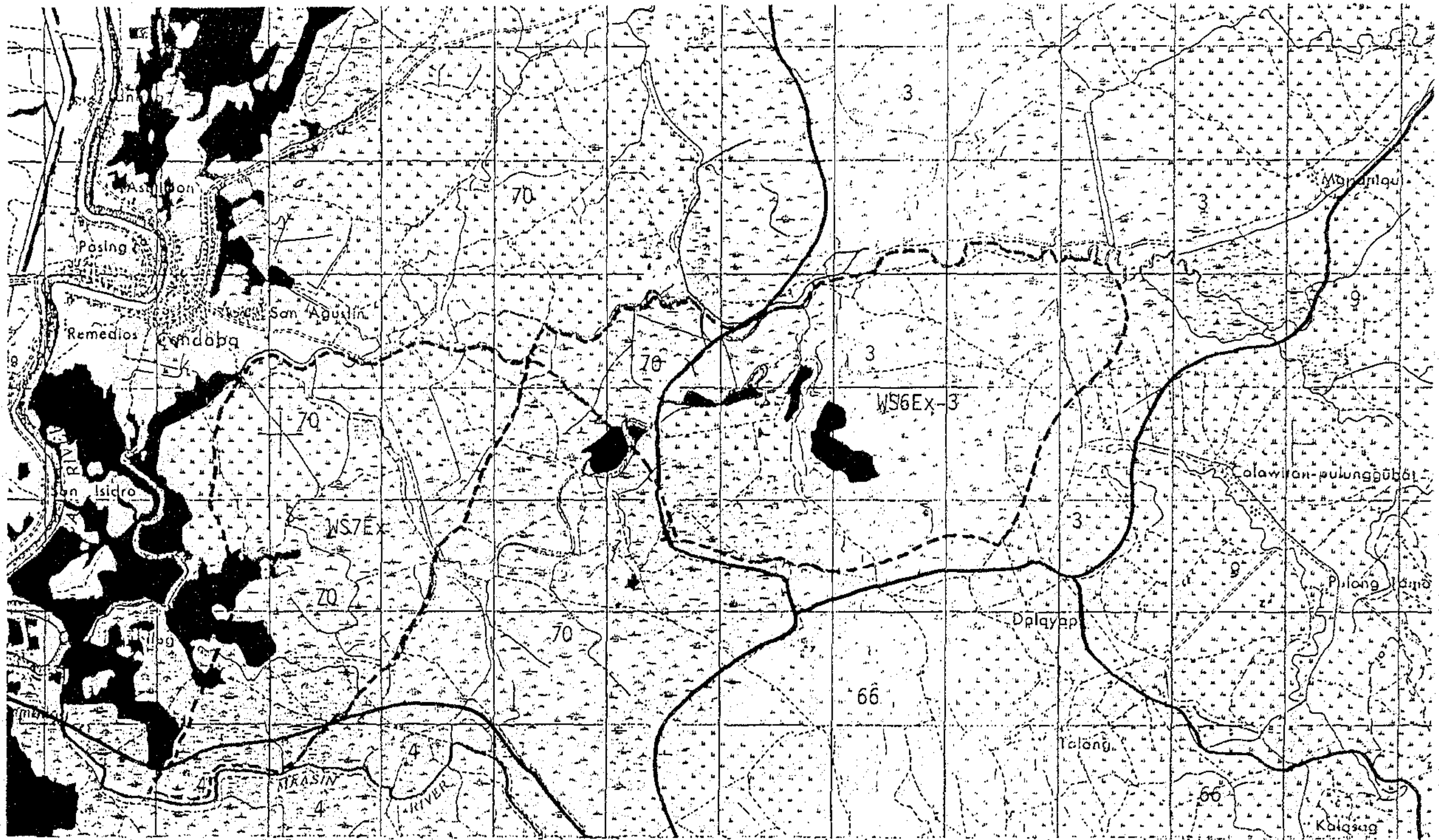


WS 6 Ex-1 (Caingin-San Rafael)



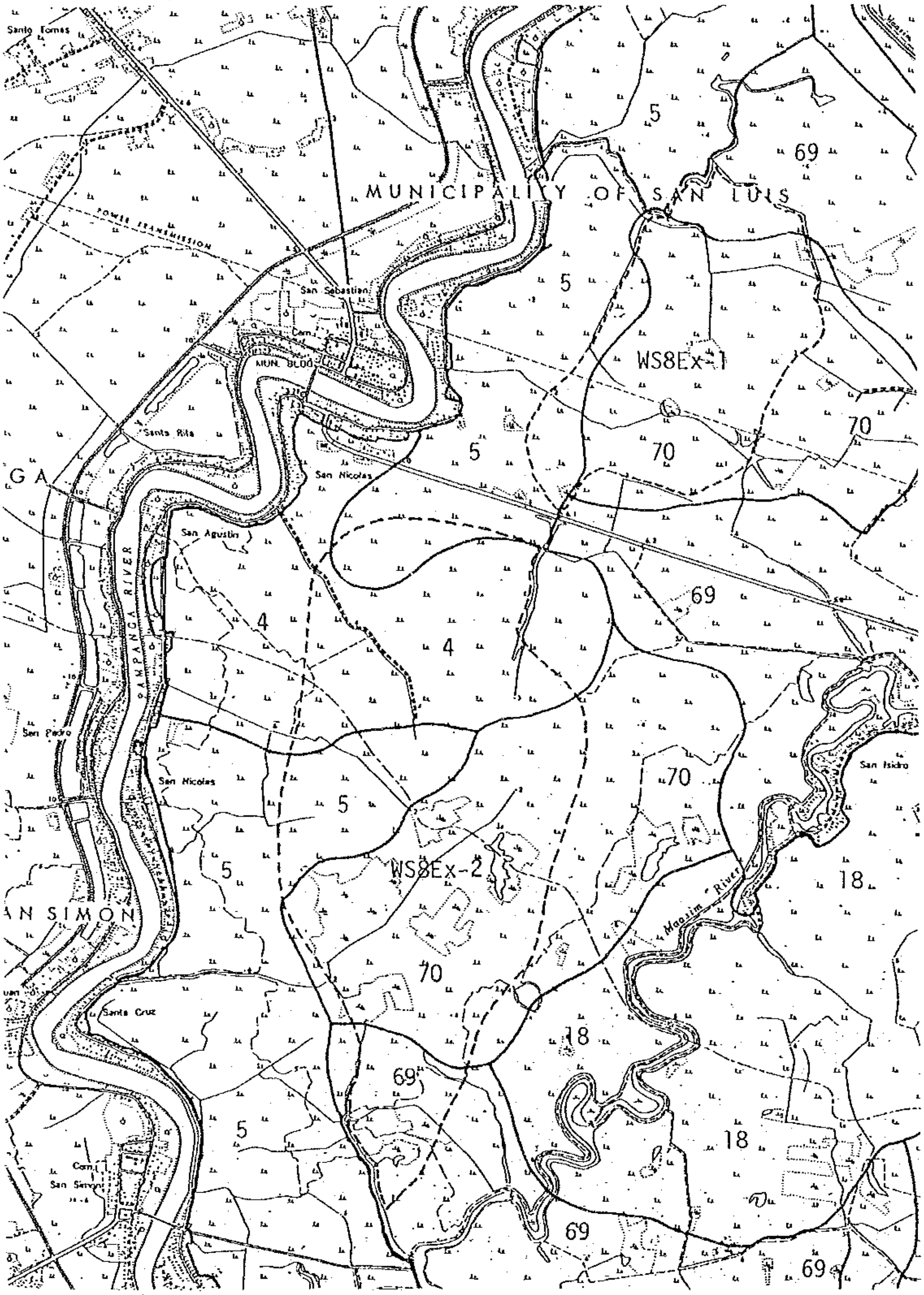
Scale: 1/50,000 WS 6 Ex-2 (San Rafael)

FIGURE A.5.5-1 SOIL MAP OF EXPANSION AREA - 1
(WS 6Ex-1 and WS 6Ex-2)



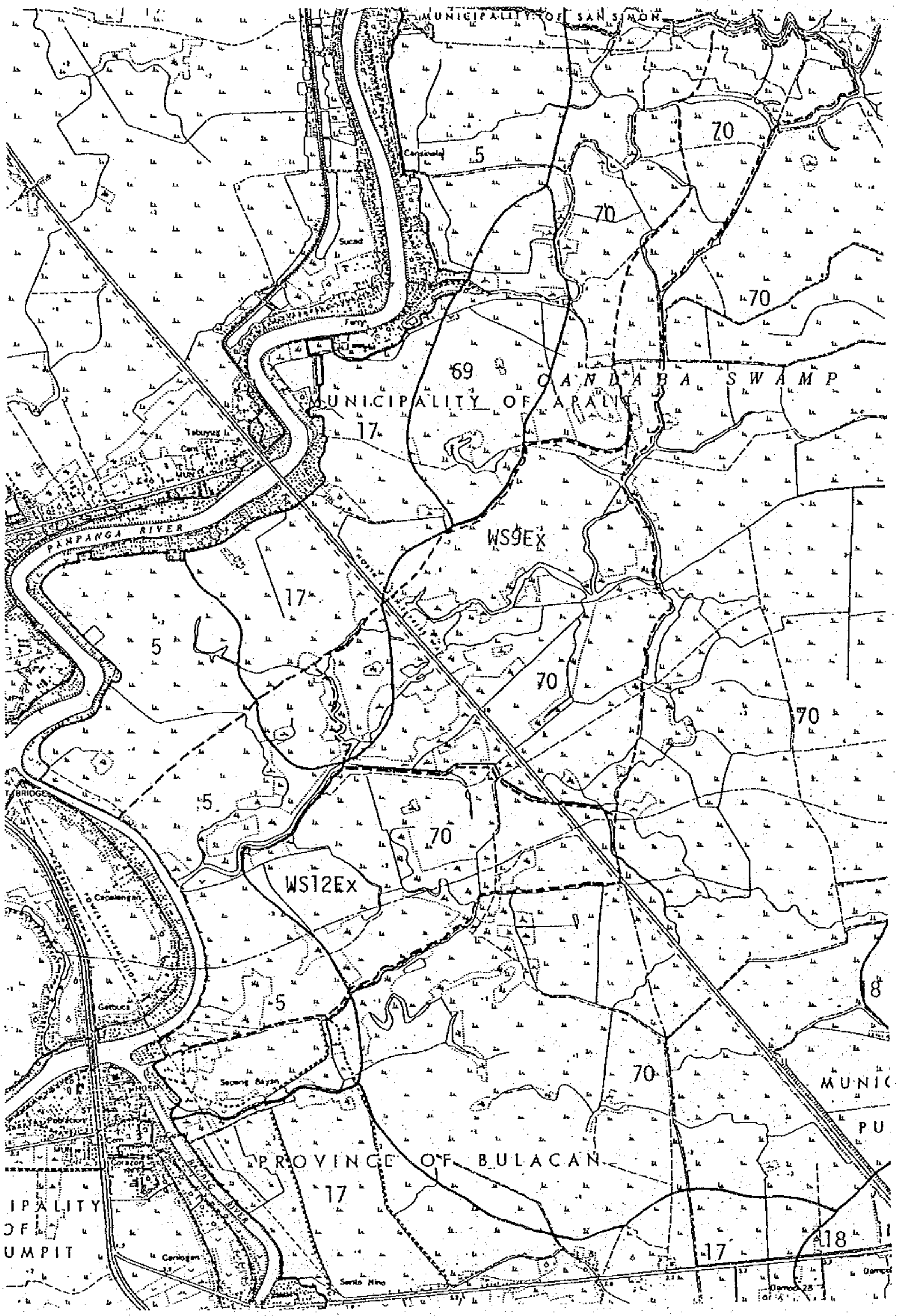
Scale: 1/50,000

FIGURE A.5.5-2 SOIL MAP OF EXPANSION AREA - 2
(WS 6Ex-3 and WS 7Ex) (CANDABA)



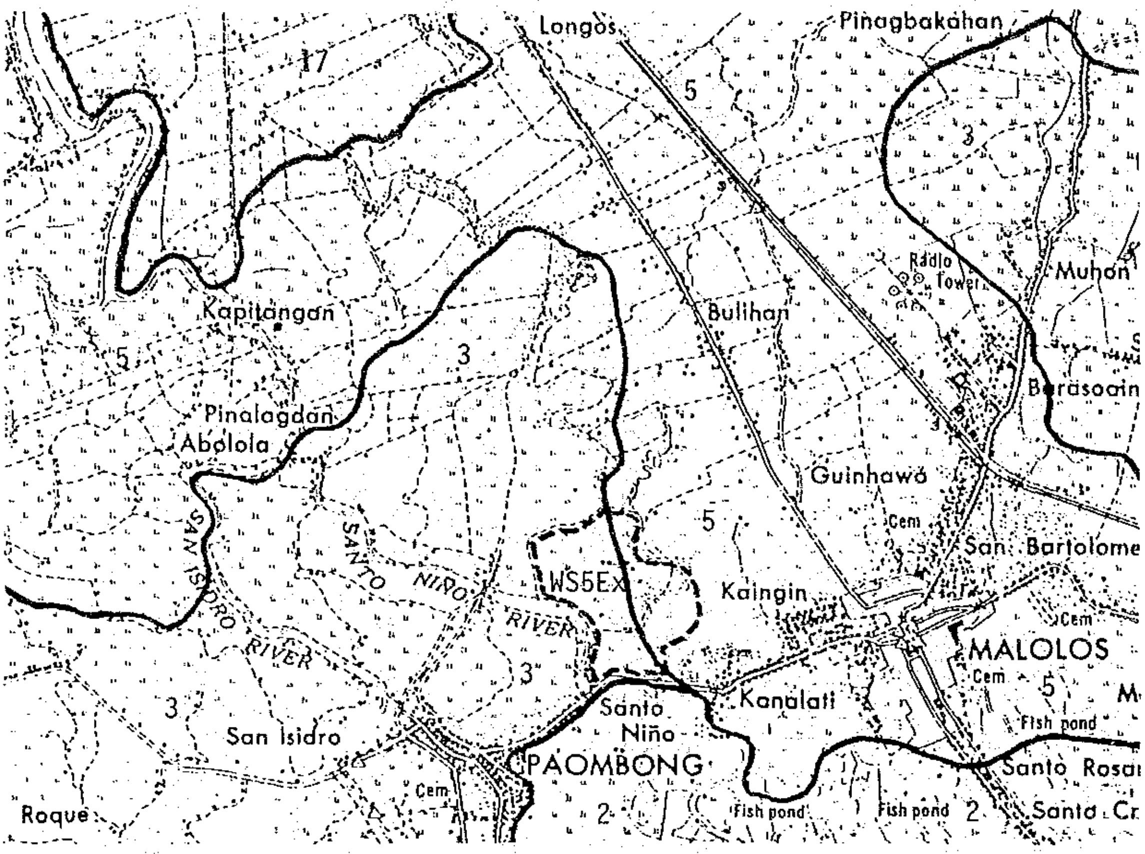
Scale: 1/36,000

FIGURE A.5.5-3 SOIL MAP OF EXPANSION AREA- 3
(WS 8Ex-1 and WS 8Ex-2)
(San Luis and San Simon)

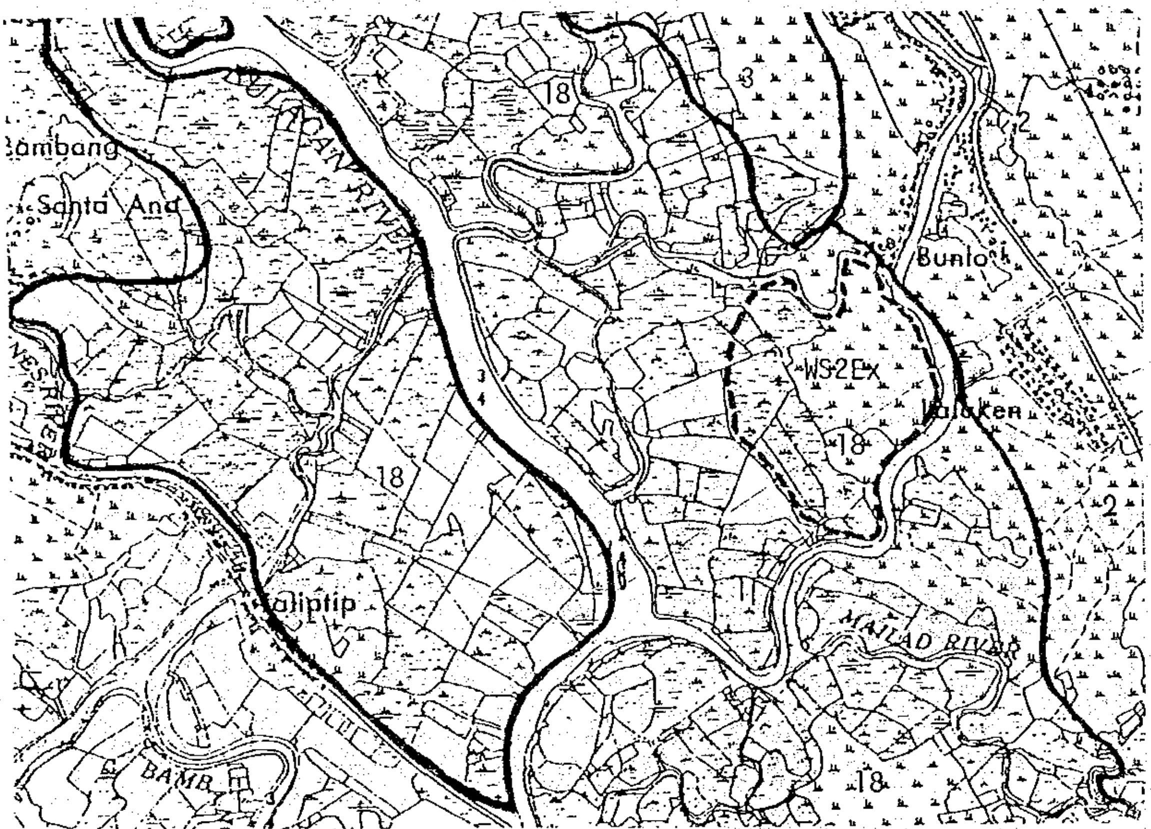


Scale: 1/36,000

FIGURE A.5.5-4 SOIL MAP OF EXPANSION AREA - 4
(WS 9Ex and WS 12Ex)
(Apalit and Calumpit)



Scale: 1/43,000 (Anilao-Malolos)



Scale: 1/40,000 (Bocaue)

FIGURE A.5.5-5 SOIL MAP OF EXPANSION AREA - 5
(WS 5Ex and WS 2Ex)

5.6 Problems and Recommendation

No serious problem has been noted as requiring special attention in the soils of Project Area except in the low-land areas where poor drainage conditions cause frequent flood damage in the wet season. Because of the clayey texture under alluvial sedimentation, the soils are, in general, rich in nutrient bases derived from the geologically calcareous and lateritic origins. Meanwhile, nitrogen and phosphorus are the fertilizer elements needed in the Project Area.

5.6.1 Soil Classification

In previous soil maps (1939, 1956 and 1964), areas occupied by silt loam types of Quingua and Candaba Soil Series (5 and 69) are fairly large. In the present soil survey, however, many of the soil profiles examined have shown the finer-textured surface layer (SiCL or Sic).

Moreover, some areas with coarse-textured subsoil (SL or SiL) are found to be overlaid by the SiCL Surface soil. These are distributed along river levees and poorly drained lowlands. Since these profiles have been described for the first time, they are classified into a new Soil Series named Calumpit which is further divided into two Soil Types of sandy loam (17) and silty clay loam (18). Their extent is not broad, being about 4,000 ha or nine (9) percent of the total gross area. (Refer to Table A.5.3-8).

Based on these results and combined with the existing soil maps, a new AMRIS soil map has been developed. It is composed of seven Soil Series and thirteen (13) Soil Types. Because of the fairly low density of the survey sites, each boundary of the Types should be rechecked by a more detailed survey. Re-survey of the Bulacan Province that has been initiated recently by the Bureau of Soils is expected to establish a new soil classification map which includes the AMRIS Area.

5.6.2 Land Classification

As already pointed out, land classification must be conducted for lands which have been classified into the lowest order such as soil type or soil phase. According to the land classification mapping system used by NIA, soils are evaluated to include distinct soil phases which are identified within one soil type.

However, the existing two land class maps of the AMRIS Area (1973 and 1978) do not present any correlation between soil unit and land class. To make full use of the results of the soil survey, it is necessary to establish this relationship not only for proper land use but also for progressive agricultural management.

5.6.3 Soil Characteristics

As far as the physical and chemical properties of the soils analysed are concerned, no weak point has been identified for their use as arable lands. Soil pH and Eh values measured present no special hazard in growing rice crop.

(1) Soil Compactness

Soil of clayey texture is generally very compact. Subsoils are sometimes too hard for the crop roots to penetrate into the solum although this is favored by the moderately well developed structure. Accordingly, the field must be deep plowed once every three years to allow vigorous growth of the root system.

(2) Soil Salinity

As described in the foregoing chapter, a high subsoil salinity has been observed in two areas, the Canadaba Swamp and the southernmost part near the sea. Most of them belong to the proposed expansion area. The salinity is not so severe, slightly exceeding 4 mmhos. Hence, if sufficient irrigation water is supplied and later drained without any upward movement of soil water into the rhizosphere, the crops can grow normally. To convert these lands into the crop fields, however, more detailed soil salinity determination should be made. Salt-tolerant varieties of local or newly bred lines will grow well on these saline soils. Since younger seedlings are more susceptible, it is best to transplant 4 to 6-week-old seedlings instead of the ordinary practise of using 3-week-old seedlings. Direct sowing is not recommended because of the susceptibleness of young seedlings and also because of the occurrence of frequent floods in the fields.

(3) Zinc Deficiency

Of the minor elements that affect plant growth, no other element has received as much attention as the problem of zinc deficiency in the wetland rice areas in this country. It was first diagnosed in calcareous soils with alkaline reaction. Regardless of pH it is now known to occur in several kinds of soils. For example, soils high in magnesium carbonates or those with organic acid evolution after submerging the field tend to make zinc less available to rice.

No apparent observation has been recorded on zinc deficiency in soils of the Project Area. This may not deny the possibility of its existence considering the extensive areas of alkaline soils in the Candaba Swamp and other lowland areas.

These soils are rich in exchangeable calcium and magnesium and have been left undrained for a long time. An intensive monitoring is thus essential in the expansion areas. Once the deficiency symptom has been diagnosed, the method of fertilization, including organic manure aqplication, must be changed in forms of quality and quantity of nitrogen and phosphorus fertilizer elements.

5.6.4. Irrigation Water Quality

In the present study, the quality of water samples taken from many sources has been satisfactory in terms of their reaction (pH) and electrical conductivity (EC values). All river, canal and creek water analyzed given EC values less than 0.3 mmhos on the average, denoting that they are safe for irrigation purposes.

Even the drain water which shows a very slight increase in EC as compared with its original irrigation water does not exceed 0.4 mmhos. This suggests a high possibility in reuse of the water during times when irrigation water is scarce.

5.6.5 Recommendations

From the viewpoint of pedology and soil conservation, the following is recommended for agricultural development in the Project Area:

(1) conduct a more detailed soil survey in the area to establish the boundaries between Soil Series and types;

(2) conduct a correlation study between classified soil units and their land classes to include soil management aspects;

(3) plow soils deep during land preparation with increased dose of nitrogen fertilizer to attain higher productivity;

(4) conduct an intensive survey on soil salinity in the proposed expansion areas, and monitor observation on the zinc deficiency problem, and

(5) conduct a study on irrigation water use or its repeated use.

Items (1) and (2) should be conducted by the staff of the Bureau of Soils.

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