KINGDOM OF THAILAND
MINISTRY OF NATIONAL DEVELOPMENT
DEPARTMENT OF LAND DEVELOPMENT AND
FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS

SOIL SURVEY DIVISION

SEMI-DETAILED SOIL SURVEY OF A PART OF THE CENTRAL PLAIN

PHO PHRAYA, SAM CHUK AND SAM CHUK-EXTENSION IRRIGATION TRACTS.

by W.VAN DER KEVIE and
BANCHONG YENMANAS

REPORT SSR-87, BANGKOK, 1972

KINGDOM OF THAILAND
MINISTRY OF NATIONAL DEVELOPMENT
DEPARTMENT OF LAND DEVELOPMENT AND
FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS

SOIL SURVEY DIVISION

SEMI-DETAILED SOIL SURVEY OF A PART OF THE CENTRAL PLAIN

PHO PHRAYA, SAM CHUK AND SAM CHUK-EXTENSION IRRIGATION TRACTS.

by W.VAN DER KEVIE and
BANCHONG YENMANAS

REPORT SSR-87, BANGKOK, 1972

TABLE OF CONTENTS

Page

List of Figures

List of Tables

List of Maps

INTRODUCTION

A semi-detailed soil survey was made of the Pho Phraya, Sam Chuk and Sam Chuk-extension irrigation tracts. This area, 937,000 rai 1/, is a part of the Northern Bangkok Plain (a subdivision of Central Plain) and adjoins other irrigation tracts which have already been surveyed. The survey is presented on three map sheets printed on semi-controlled, half-tone air photo mosaics. In addition to the basic soil map, a suitability map for irrigated rice was prepared. Interpretations for upland crops were also made and presented in tables.

The survey of the Sam Chuk-extension tract was completed by two parties, directed by Messrs. Phichai Vichaidit and Somchai Lamyai during February to April 1967. The survey in the Sam Chuk and Pho Phraya tracts was completed by four parties under the direction of Messrs. Banchong Yenmanas, Vichit Chongvathana, Snan Keosanan and Rot Theppoonphon during the periods of May-June 1967 and February-May 1968.

The photo mosaics were compiled by the Air Photo Section and reproduced by the Printing Section of the Soil Survey Division at a scale of 1:50,000.

SUMMARY

The semi-detailed soil survey of the Sam Chuk, Sam Chuk-extension and Pho Phraya tracts, covers an area of 937,000 rai (150,000 ha). Two kinds of maps have been produced: - a Soil Map and a Suitability Map for irrigated rice.

Most of the area is used for rice production during the rainy season, with some irrigated rice and upland crops in the dry season. Fruit trees and garden crops are grown on the natural levees of the rivers, especially near the villages.

The production of rice could be considerably increased, if irrigation facilities and water control would be improved. A regular supply of water during the rainy season could help increase yields on the higher soils (Nakhon Pathom series) and, if more water could be made available in the dry season, the area with a second rice crop could be expanded.

A small part, 30,750 rai or 3.4 per cent of the entire area, is suitable to be used for permanent cultivation of upland crops (however, more than half of this is already used for habitation). Small areas, consisting of Nakhon Pathom and Chai Nat soils covering 89,718 rai or 9.5 per cent, which are somewhat poorly drained and have a medium textured surface, could be used for irrigated upland crops in the dry season or for such crops as sugar cane. The poorly drained, clay soils are considered some of the best paddy soils in Thailand and make up the major portion of the area (739,750 rai or 78.0 per cent). These are recommended for irrigated rice in a two-crop per year pattern, when water is available.

1/ 1 rai is 0.16 ha.

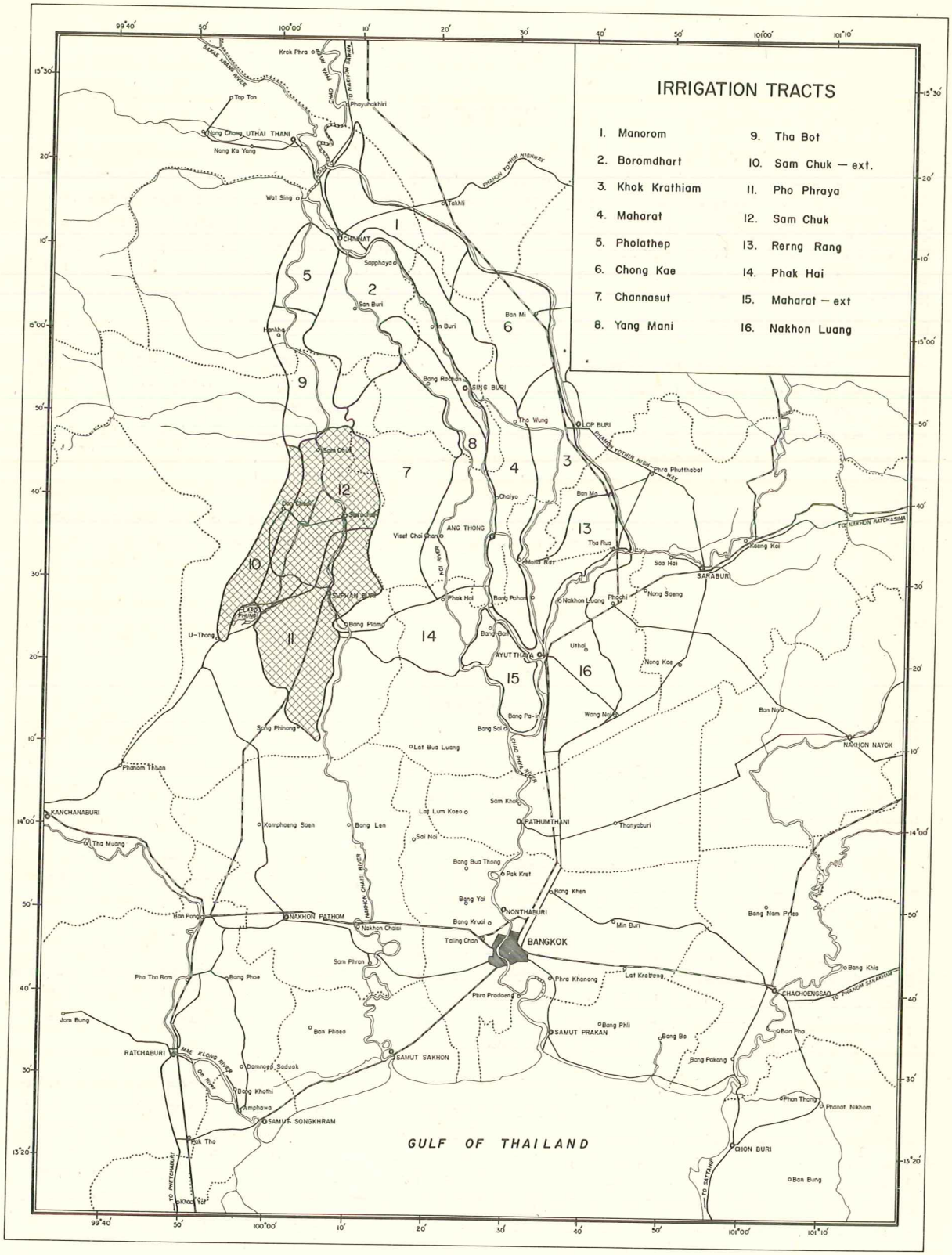


Fig. 1 Location of the survey area in the Central Plain

CHAPTER I

GENERAL DESCRIPTION OF THE AREA

LOCATION AND ACCESSIBILITY

The survey area is situated in the western part of the Central Plain in Suphan Buri province and lies between 14° 10' and 14° 49' north latitudes and 99° 53' and 100° 14' east longitudes. The area is bordered in the north by the Tha Bot and Boromdhart irrigation tracts and in the east by the Channasut irrigation tract (Fig. 1). The Suphan Buri river forms the boundary in the south-east. In the west the boundary is formed by one of the primary irrigation canals, and in the southwest by various small streams.

The total area is irregular in shape and includes 937,000 rai - 354,000 for the Sam Chuk tract, 405,000 for Pho Phraya and 178,000 for the Sam Chuk-extension tract. It makes up about 20 per cent of the Northern Chao Phraya Irrigation Project area.

The largest town is the provincial capital Suphan Buri, with about 18,000 inhabitants. Other towns are the district capitals of U Thong, Sam Chuk, Don Chedi and Si Prachan.

The principal access roads include: (1) the hard-surface Malai Maen highway which joins the Petchkasem highway from Bangkok to South Thailand in Nakhon Pathom, 110 km south of Suphan Buri; (2) a loose-surface road between Suphan Buri and Sing Buri via Sam Chuk which connects the area with the eastern part of the Central Plain and (3) a loose-surface road which connects the area with the northern Central Plain town of Chai Nat.

A railway connects Suphan Buri with the Southern Railway Line in Ban Pong, Ratchaburi province.

The main river, Suphan Buri river (also called Tha Chin river) contains several locks of which two are located near Sam Chuk and Pho Phraya and is navigable by small barges. This river is an important transport route for agricultural produce. The many other natural or man-made waterways, particularly in the south are navigable by small craft and numerous speed-boats provide the main means of public transport during the rainy season.

Many irrigation canals and ditches branch out from the Suphan Buri river, however, most of them are not navigable.

CLIMATE

The survey area is in a tropical savannah climate zone, characterized by high temperatures throughout the year and a pronounced dry season. The average annual temperature for Suphan Buri is 28.2°C and the average temperature range between the hottest month (April) and the coolest month (December) is 6.6°C. The temperature range between summer (June-August) and winter (December-February) is only 3.2°C. Monthly temperature data are given in Table 1.

Table 1. Climatological Data for Suphan Buri (1951-1965)

Temperature (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	25.1	27.6	29.7	31.3	30.4	29.5	28.9	28.6	28.1	27.6	26.3	24.7	28.2
Mean Max.	31.8	34.2	36.4	37.7	35.7	34.3	33.4	32.8	31.8	31.3	30.5	30.3	33.4
Mean Min.	18.3	20.9	23.0	24.9	25.0	24.7	24.4	24.5	24.4	24.3	22.2	19.1	23.0
Ext. Max.	37.0	37.5	39.8	40.7	40.4	39.8	35.5	35.2	35.2	35.2	35.6	35.8	40.7
Ext. Min.	10.2	15.5	14.6	19.8	21.6	21.0	20.6	21.6	21.4	20.0	13.8	10.8	10.2
Relative Humidity (%)													
Mean	63.4	64.3	62.4	61.4	68.8	70.3	73.1	75.6	80.1	80.3	75.1	67.5	70.2
Mean Max.	88.1	92.1	91.8	88.7	89.6	88.2	89.8	90.5	93.3	93.2	91.7	88.6	90.5
Mean Min.	45.0	44.7	43.0	42.5	53.0	56.9	59.1	62.4	68.9	70.2	63.0	52.1	55.1
Ext. Min.	23.0	21.0	20.0	21.0	24.0	36.0	41.0	45.0	51.0	50.0	38.0	36.0	20.0
Rainfall (mm)													
Mean	4.2	13.4	51.4	63.1	175.0	108.8	130.7	151.6	304.9	251.3	48.2	3.0	1305.6
Mean rainy days	0.7	1.6	3.0	4.7	12.5	12.6	14.8	16.4	18.5	14.1	4.0	0.8	103.7
Greatest in 24 hours	24.1	39.1	117.6	102.7	132.2	86.7	71.6	58.7	120.0	111.1	77.9	19.2	132.2
Potential Evapo-transpiration (mm) Turc.	124.1	129.5	128.2	146.2	149.8	132.6	116.4	117.4	116.3	119.3	121.7	119.9	1517.4

The average annual precipitation is 1305.6 mm of which 86 per cent falls during the south-west monsoon from May through October. Most of the rain falls in cloud-bursts in the late afternoon or evening, and a rainfall intensity of more than 50 mm/24 hours is quite common.

During the rainy season precipitation exceeds potential evapotranspiration resulting in a large water surplus. In the dry season, during the northeast monsoon, a considerable water deficiency makes cultivation of most crops impossible, unless irrigation is provided. Fig. 2 shows the monthly variation in rainfall, potential evapotranspiration and periods of water surplus and water deficiency. The evapotranspiration has been calculated with the formula of Turc:

$$E = 0.4 \frac{t}{t + 15} (I + 50)$$

In this formula E is the monthly potential evapotranspiration in mm, t the mean monthly temperature in °C, and I is the average insolation (solar radiation) of the month in cal/cm^2/day. For the short month of February the formula is:

$$E = 0.37 \frac{t}{t + 15} (I + 50)$$

Assuming that soil water storage is about 100 mm for most kinds of soils (THORNTHWAITE 1948), water deficiency and surplus can be calculated for the various seasons. In the transition periods between the dry and rainy season the soil is either filling up (soil moisture recharge) or loosing moisture (soil moisture loss). It appears from the graphs in Fig. 2 that there should be sufficient soil moisture

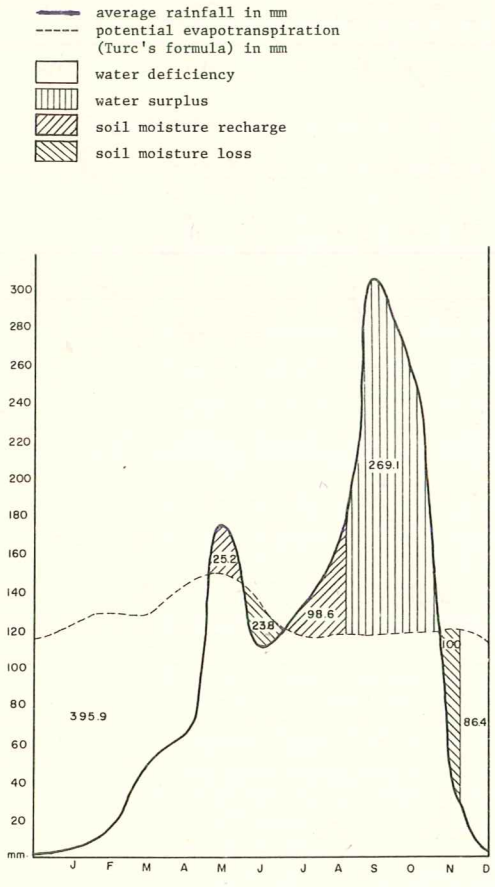


Fig. 2 Diagram showing average monthly rainfall, potential evaporation and soil moisture conditions at Suphan Buri (1951-1965)

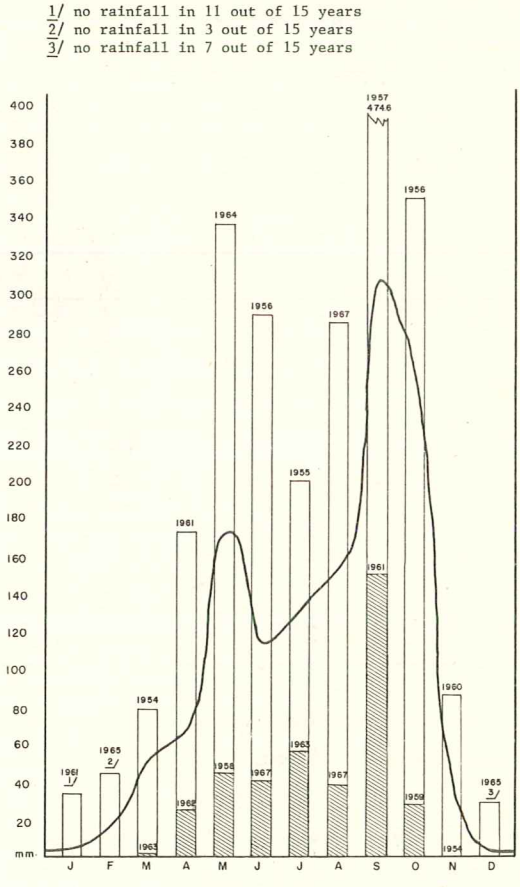
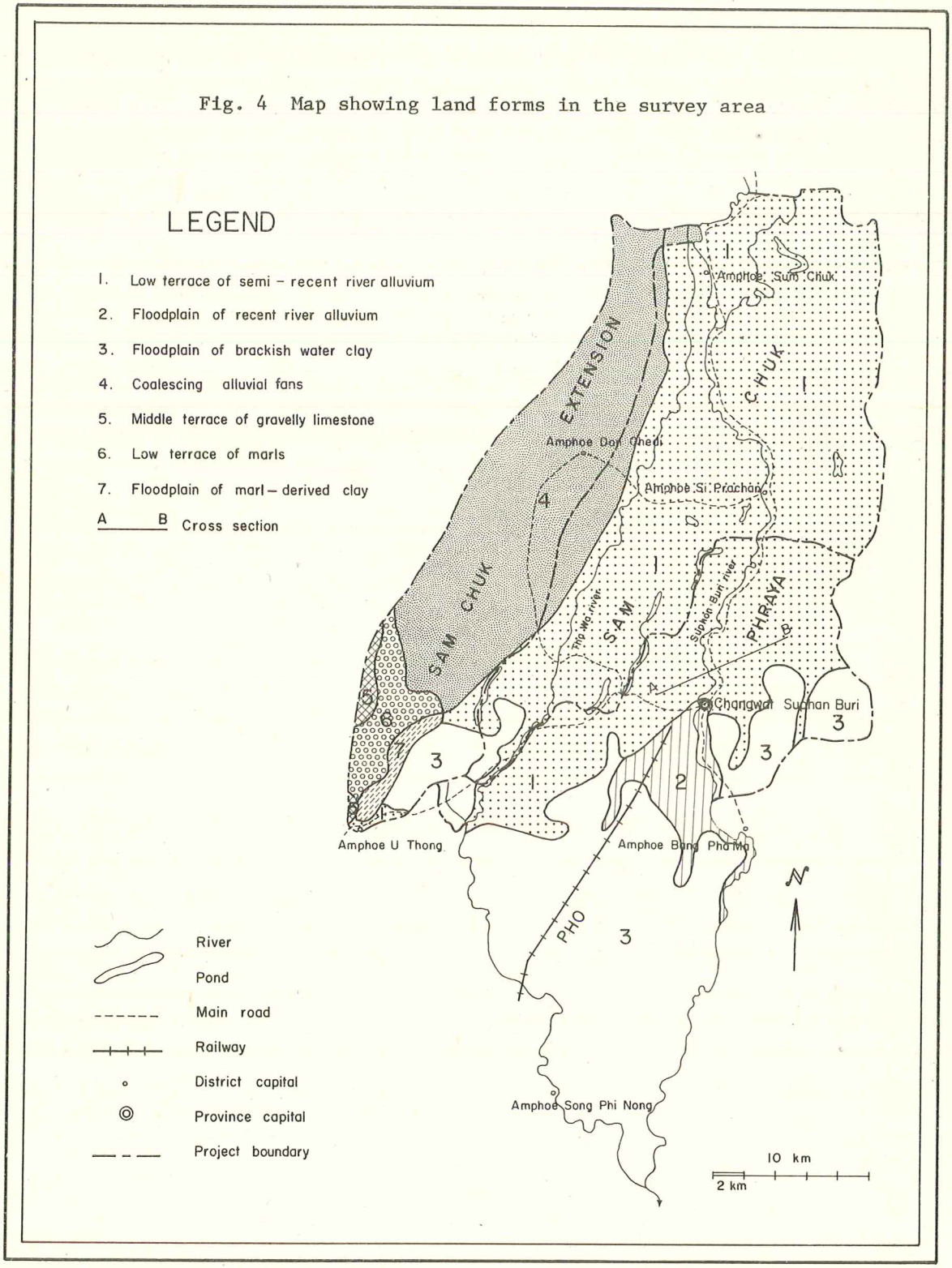


Fig. 3 Rainfall variability for Suphan Buri showing years of maximum and minimum rainfall for every month, compared with average monthly rainfall (1954-1968)

Fig. 4 Map showing land forms in the survey area



for plant growth from May to early December, but not enough for the five month period from December through April. This is usually true for well drained soils at higher elevations, but where soils are somewhat poorly or poorly drained with a shallow groundwater table, the period during which the soils are dry, is much shorter and usually does not exceed 3 months. In June the potential evapotranspiration exceeds rainfall, but soil moisture supply in May (25.2 mm) is normally sufficient to offset soil moisture loss (23.8 mm) in this month. This is a very important factor, because in some years there is not enough rainfall in June or July, which may cause serious damage to crops, particularly to the rice.

The annual variability of the rainfall is not very high. In the 15 year period 1954-1968, for instance, the maximum rainfall was 1590.1 mm in 1957 and the minimum was 979.6 mm in 1963. The monthly variability, however, is considerable, particularly at the turn of the seasons in the months of May, June and November. Fig. 3 shows the rainfall variability by months over the period 1954-1968. In some years the rainy season may start in April and in other years as late as June. Also the end of the rainy season may vary but is usually by the middle of November.

LAND FORMS

With the exception of one very small quartzite hill in the north, the project area consists of alluvial deposits. These are river deposits in the north and brackish water sediments in the south. The survey area can be divided into seven land forms reflecting parent material, elevation, relief, age and drainage (Fig. 4). The various land forms occur on flood plains, terraces and alluvial fans as indicated below.

1. Low terrace of semi-recent river alluvium

This low terrace occurs mainly at elevations above present flooding. The soils are older and more developed than those on the recent alluvium, and usually have a weak Bt-horizon.

A large number of geomorphologic features, like river levees, backswamps, point bars and breach deposits cause the area to be somewhat undulating, though slopes are seldom more than one per cent. A slightly undulating micro-relief may occur on the river levees and breach deposits while the point bar deposits have a rather strongly undulating micro-relief, where short slopes of 1-3 per cent are common.

Many of the backswamps are dissected and connected with each other by channels, that have no natural levees. These channels run through the lowest parts of the former floodplain and are natural drainage channels, which join the main river system further downstream.

A very characteristic feature of the area with semi-recent river deposits is the occurrence of a large number of termite mounds. They can be more than 2 m high and have a ground surface of 5 to 15 sq.m. The mounds are found over extensive areas, where soils are well to somewhat poorly drained, but do not occur on

poorly drained soils.

The many levees, accompanying partly or completely silted up stream channels, indicate important rivers of the past. The Lam Tha Manao, Khlong Ban Huai and Huai Phlot are a few of these old rivers to be named. The channels are often dry during the hot months and carry only some water in the rainy season.

The sediments are derived from acid rocks, such as quartzites and sandstones as well as limestones, shales, basalts, andesites and mica schists. The latter form the origin of the large content of muscovite micas in the sand fraction of the sediments. Along the river channels where the velocity and turbulence of the overflowing water was greatest, medium and moderately fine textured sediments were deposited, while aggradation in the areas further from the rivers, called backswamps or basins, was caused by clay deposition. There is a difference in elevation between the levees and backswamps of 2 to 3 m. The sediments in the survey area are finer than in the irrigation tracts situated more to the north in the upper parts of the delta, where loamy deposits occur more extensively. In the southern part of the area the semi-recent river clays are underlain by older soils formed on brackish water deposits.

2. Flood plain of recent river alluvium

In the transition zone from the terrace with semi-recent alluvium to the area with brackish water alluvium, recent river deposits occur on both sides of the Suphan Buri river. The river overflows its banks annually and fresh sediments are deposited over brackish water deposits. The river sediments are clays in the backswamps and clay loam on the narrow levees. The sediments have a high content of micas and other weatherable minerals. Profile development is very weak and the soils lack a Bt-horizon.

Many geomorphologic features of the semi-recent area, such as levees, backswamps and breach deposits are present but termite mounds do not occur.

3. Flood plain of brackish water clay

The flood plain of the southern part of the project area consists almost entirely of very fine textured brackish water sediments. These were deposited more than 3,000 years ago in a large mangrove swamp where sea water and fresh river water mixed freely. Under these conditions, which are still being found along some parts of Thailand's coasts, sulphides were accumulated in the reduced clay. Most of the sulphides are present in the form of pyrites (FeS_2) and in the reduced subsoils a content of more than 1 per cent sulphur is normal. The surface may consist of a thin layer of fresh water sediments containing sulphates transported from the subsoil upward.

The flood plain with brackish water deposits is nearly level with elevations varying from 3 to 5 m. The rivers flowing through the northern part of the area have very low and narrow levees, while in the south the levees are practically non-existent. A common feature is the large number of wallows, which are shallow, mostly rounded depressions of about 50 cm deep and with a diameter of 10 to 50 m. Some of them hold water throughout the year, but most dry out for a few months in the hot season. There are also many narrow streams, former tidal channels, some of which are dry for a short period every year.

4. Coalescing alluvial fans

The northwestern fringe of the survey area is a part of an extensive area consisting of coalescing alluvial fans which have been built up by deposits of numerous small streams, draining the Tanowsri mountain range. These fans are nearly level with slopes eastward of less than 1/4 per cent. Most of the material deposited is clay, with some medium to coarse sand, and becomes finer toward the Suphan Buri (Tha Chin) river.

The small streams have frequently shifted their course and most of the old channels have been filled. Scattered Remnants of narrow levees that accompanied the streams appear as small elongated or oval shaped knolls, only slightly higher than their environment. Soils on these levees are somewhat coarser textured and better drained than the associated soils. The sediments of the coalescing alluvial fans are mainly derived from acid rocks, such as quartzites and phyllites, but with some influence of the limestone occurring in the western hills. Large numbers of termite hills occur, particularly in the western part of the area.

5. Middle terrace of gravelly limestone

A small extension of a large terrace underlain with gravelly limestone extends into the southeastern fringe of the survey area. The deposit consists of limestone colluvium derived from the nearby limestone hills. The gravels are small and irregular in shape. The relief is undulating with slopes of more than two per cent. The terrace elevation is 16 to 20 m and form the highest parts in the area, excluding Khao Din, the little quartzite hill in the north, which is 29 m high.

6. Low terrace of marls

Surrounding the terraces which contain limestone gravels is a low nearly flat terrace at an elevation of 12-14 m, consisting of marl and marl-derived clay. The marls are similar to those occurring in a much more extensive area in the east of the Bangkok Plain in the provinces of Nakhon Sawan, Lop Buri and Sara Buri. These marls are probably deposited during the Pleistocene in a lake surrounding the limestone hills occurring in the western part of U Thong district. A few termite hills occur on this terrace, but the development of a granular structure on the surface of the mounds causes them to flatten, due to erosion.

7. Flood plain of marl-derived clay

The flood plain, bordering the marl terrace is small and consists of clay sediments, with a high content of montmorillonite derived from the marl and limestone area in the west and is underlain with marl. The area is flat and has an elevation of 8 to 9 m. It is flooded by river water as well as water draining the limestone hills and the marl terrace.

VEGETATION AND LAND USE

Most of the survey area has been cleared for cultivation. The river levees are still covered with trees, but only a few species of the original forest remain. Most trees are either fruit trees or species that are useful as a source of charcoal, building material, etc. Isolated trees occur throughout the northern and western part of the area of which many are on termite mounds. The original vegetation was probably a mixed deciduous forest on the higher parts with fresh water swamp forest in the backswamps and flood plains.

Rice is the principal crop with transplanted rice predominating on the semi-recent alluvium, alluvial fans and marl terrace, whereas broadcasted rice is grown on most of the recent alluvium and the flood plains with brackish water deposits and marl derived clay.

In the northern part of the semi-recent alluvium in Sam Chuk and Si Prachan districts sugar cane is grown and processed by the Sam Chuk sugar factory. Small amounts of soybeans, mungbeans, peanuts, sesame, and maize are produced. In addition, vegetables are grown on the levee soils close to the villages, even in the dry season when they have to be handwatered.

At the time of the soil survey (1967 and 1968) very little double cropping was practiced and the water level in the irrigation canals was always very low. However, a recent trip through the area in April 1970 showed that a second rice crop and on some fields, upland crops, particularly water melons, were grown with irrigation. SMALL (1971) estimated that about 10,000 rai is now planted with a dry season rice crop. The irrigated fields are mainly along the canals and most of the second cropping is confined to the semi-recent alluvium and the alluvial fans.

Yields of rice are related to the kind of soils and are relatively high on the semi-recent alluvium - 40 to 50 tang/rai (2,400 to 3,000 kg/ha). Much higher yields may be obtained with better management including the use of more fertilizer. The yields on the alluvial fans and acid sulphate soils are lower, but 30 tang/rai (1,800 kg/ha) is normally obtained.

CHAPTER II

SOILS

SURVEY METHODS

In planning the soil survey of the area, the field aspect was divided into three parts. These include office study and preparation, field studies and mapping, and laboratory studies. The preparation of the report and cartographic work followed.

Vertical air photos of good quality taken in 1952 and 1953 (approximate scale 1:43,000) were used as a base map for the soil survey. Alternate photos were enlarged to a scale of 1:20,000 for position-finding, plotting of observation points, reporting of field data and drawing of soil boundaries. These were supplemented for further orientation by topographic maps (scale of 1:50,000). Copies of the original photos were used for stereoscopic air photo interpretation, where necessary.

During the dry season the roads and many tracks are passable by vehicles, and Land Rovers were used for transportation wherever possible. In areas that were not accessible for cars the surveyors walked and made borings at predetermined spots.

The density of observations varied depending on the soil patterns. In the southern part of the survey area where the landscape is flat and identical soils occur over extensive surfaces, approximately two borings per sq.km. were made, and in the north, where more intricate patterns occur, 4 to 8 borings.

Screw augers were used in the first year of survey (1967) but these were later replaced by open blade augers (Edelman type) for the moist clay soils and bucket augers for dry, medium textured soils. The depth of the borings with the screw augers was 100 cm, and with the other augers 120 cm. Some deep borings of 2 m or more were made, using extension pieces.

Short soil descriptions were made of most borings to indicate the main soil characteristics. Information concerning land use, flooding conditions and, when possible, rice yields was collected. Soil colour notations were based upon the Munsell Color charts. The field pH was determined with a Truog-Hellige test kit. It was found, however, that determinations with the glass electrode pH-meter on dried samples gives a pH that is 0.5 to 1 unit lower, particularly in the low pH ranges (pH 4 to 5.5).

Detailed profile descriptions were made and samples taken of all major soils for chemical analyses. These descriptions and analyses results are given in appendices I and II. Appendix II lists the kind of analyses made, methods used and gives an interpretation of the data. All chemical and physical analyses plus observed soil properties are used as a basis or aid in the identification of the various soils and in the interpretations made for use and management of each soil.

The soil boundaries were transferred by hand from the large photos used in the field to the 1:43,000 scale air photos. The boundaries were then studied with

a mirror stereoscope for more exact plotting. From the small scale photos the soil boundaries were transferred by the free-hand method to the semi-controlled airphoto mosaic compiled on a scale of 1:50,000.

GENERAL PROPERTIES OF THE SOILS

The soils of the project area can be grouped according to the seven land forms described previously. These units, shown on Fig. 4, coincide with broad soil associations and are described as follows:

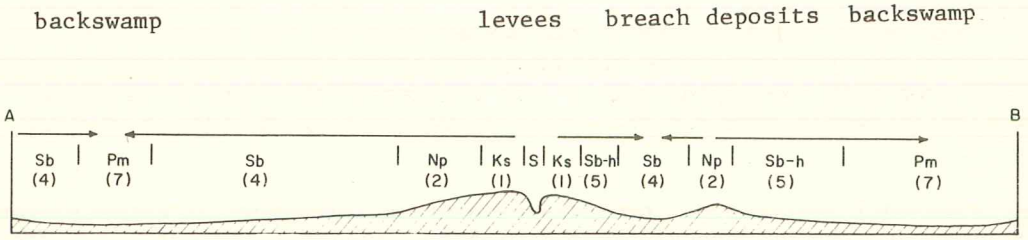
Soils on low terrace of semi-recent river alluvium

With the exception of the soils in the lowest parts of the backswamps (Phimai series), all other soils of the association have weak to moderately developed profiles with textural B-horizons. These horizons are best developed in the soils occuring in an intermediate position between the river levees and the backswamps (Nakhon Pathom series), while the medium textured soils on the levees (Kamphaeng Saen series) and the clay soils of the higher parts of the backswamps have only a weakly developed Bt-horizon. Soil development varies also with the age of the sediments. Some of the older areas, where river channels have been silted up, have more strongly developed soils than the areas along present-day rivers, such as the Suphan Buri river. The Bt-horizon is characterized by the occurrence of thin, patchy or broken clay coatings in pores and on soil aggregate faces and is finer textured than the A-horizon. The thickness of the Bt-horizon is variable but is usually more than one meter.

The soils on semi-recent alluvium differ in characteristics such as texture, drainage, physiographic position and flooding conditions. All are moderately fertile, but the clay soils of the backswamps are more fertile than the coarser textured soils of the levees. There is a toposequence of soils in the direction from the levees toward the backswamps (Fig. 5). The soils on the levees are never flooded and the soils of the backswamps are deeply inundated with rainwater and drainage water from surrounding higher areas. The Phimai soils in the lowest parts of the backswamps may be inundated for more than a meter. Most backswamps have very poor drainage and water may be standing on the surface for as many as 9 months - from mid-May to mid-February.

The soils have moderate to moderately high fertility. They are moderately to slightly acid in the surface and slightly acid to alkaline in the subsoil. The soil structure is weakly developed, particularly in the surface layers. This is partly due to puddling practices in the rice fields before transplanting. The organic matter content is low in all the soils, but is higher in the basins than on the levees.

Fig. 5. Cross section AB (north of Suphan Buri) showing position of the various soils on semi-recent alluvium 1/.



⟶ Direction of increasing fine texture and poor drainage.
S Suphan Buri river.
Horizontal scale 1:45,000. Vertical scale appr. 1:800

1/ Letter symbols are abbreviations of soil names and numbers in parenthesis are symbols used on soil map.

Soils on flood plain of recent river alluvium

The recent river alluvium occupies only a small area which is a transition zone between the semi-recent deposits and the brackish water sediments. A topo-sequence occurs from river to backswamps which is characterized by increasing fineness of texture and poorer drainage. The soils of this sequence are Tha Muang, Chai Nat, Ratchaburi and Phimai series. These soils have an A-C or A-B-C horizon sequence and are somewhat similar to those on the semi-recent alluvium, but lack a Bt-horizon. They often consist of stratified deposits of mainly fine textured materials. The sand fraction contains a considerable amount of mica.

The natural soil fertility is quite high due to the annual deposition of fresh sediments. The soils are moderately acid to neutral in the surface layer and slightly acid to mildly alkaline in the subsoil. The backswamp areas are flooded with river water to depths of more than a meter. The backswamps on the recent alluvium are slightly better drained than in the basins of the semi-recent alluvium and the Phimai series, in the lowest parts, may have water standing on the surface for a period of 7 to 8 months.

All the recent alluvial soils are mottled and the drainage is somewhat poor to poor, except on the levees where they are moderately well drained. Soil structure is weakly developed even though areas used mainly for broadcasted rice are seldom puddled. The organic matter content is low, varying from less than one per cent in the surface layers of the levee soil (Tha Muang and Chai Nat series) to 2 or 3 per cent in the basin (Phimai series).

Soils on brackish water clay

The soils developed on brackish water deposits usually have a thick black to very dark grey A-horizon that is probably mainly a river deposit.

They occur in the south of the survey area and are mainly acid sulphate soils. The acidity varies with the septh of the so-called "cat clay" horizon, which is a horizon containing pale yellow mottles of the mineral jarosite. This horizon is extremely acid and the upper boundary occurs at a depth varying from 40 to 150 cm.

The soil reaction of the surface layer is influenced by acids rising from the subsoil and the pH ranges from 4.5 to 5.5. The lower part of the A-horizon and upper part of the B-horizon contains varying quantities of gypsum, mostly occurring in nests with fine crystals. The gypsum was formed by the reaction of sulphates in the soils with calcium dissolved in the floodwater. The C-horizon consisting of completely reduced, very soft mud clay has a very high content of sulphur, mainly present in the form of pyrites (FeS_2). It is the oxidation of this mineral that causes the formation of the mineral jarosite ($KFe_3(OH)_6(SO_4)_2$) and the high acidity of the soil. It was found that by drying this mud clay, the pH dropped from 6 to below 3.5 (PONS and VAN DER KEVIE 1969).

The fertility of these soils is moderately low, particularly since phosphorus is unavailable to plants due to strong fixation. The soils are deeply flooded with water from the Suphan Buri river and water drained from the terraces to the west. This water probably has a fairly high lime content, compared with the floodwater in the eastern part of the Bangkok Plain. Flood levels vary from 1 to 1.50 m. Flooding starts in August and the fields have water on the surface for 6 to 7 months every year.

Two acid soil series were distinguished on the brackish water deposits, the Ayutthaya and the Sena series. Both soils have formerly been included in Bang Khen series and Rangsit series respectively. The Ayutthaya series has been mapped and published as Bang Khen in three reports (VAN DER KEVIE et al. 1966, 1967, 1968). However, they differ in that the Bang Khen soils, as they are now defined, does not have a cat clay horizon. The Bang Khen soils are most extensive in the southern part of the Bangkok Plain in the transition zone between the areas with acid sulphate soils and non-acid marine soils. The definition of the Rangsit series has been changed in such way that only soils without gypsum are included. In two reports (VAN DER KEVIE et al. 1967, 1968) small areas of Sena soils were mapped as Rangsit. The Rangsit soils occur primarily in the eastern part of the Bangkok Plain.

Small areas of non-acid soils on brackish water deposits occur in the transition zone toward the area with river sediments. These soils (Bang Len series) have a very thick black to very dark grey A-horizon and an olive yellow mottled subsoil. The soils contain varying quantities of gypsum and are neutral to mildly alkaline (pH 6.5 to 8). The fertility of these soils is higher than of the acid sulphate soils.

Soils on coalescing alluvial fans

The soils occurring on coalescing alluvial fans include Low Humic Gley and Grey Podzolic soils with an A-Bt-C horizon sequence. They contain medium angular quartz sand which indicates that the soil material is of local origin. Most are paddy soils (Deum Bang series) with sandy clay loam to sandy clay surface textures and sandy clay to clay subsoils. These soils are strongly mottled with red or brown colours and drainage is somewhat poor. The fertility is moderate and soil reaction ranges from strongly to medium acid (pH 5 to 6) in the surface to medium acid to neutral (pH 5.5 to 7) in the subsoil. The deeper subsoil (below 150 cm), however, contains lime concretions and has a high pH.

The soils in this physiographic position are not flooded by river water, though, in small areas, flash floods may damage the rice in some years. Cultivation is based upon available rainwater and the rice fields usually have 5 to 40 cm of surface water throughout the rainy season.

Grey Podzolic soils (Don Chedi series) occur on the higher parts in the area. These are well drained soils with sandy clay loam to sandy clay textures.

Soils on the middle terrace of gravelly limestone

The soils on this slightly undulating terrace are shallow Rendzinas (Takhli series) with an A-C profile. The A-horizon is black and generally thin. The parent rock occurs close to the surface where the A-horizon has been eroded.

These soils are mildly alkaline. Fertility is quite high, but the shallowness of the soils is a major limitation for agriculture.

Soils on the low terrace of marls

The soils of the low marl terrace are Grumusols with clay textures, a self mulching surface and deep cracks in the dry season. Most of the soils have a very thick (80-140 cm), black A-horizon underlain by white marl. The clay is mainly of the montmorillonitic type that swells or shrunks with changes in moisture and has many pressure faces and slickensides throughout the profile. Three series occur on this terrace, the Lop Buri containing lime concretions throughout the Ban Mi series, and the Chong Kae series.

A serious salinity problem developed after the construction of irrigation canals in the area, about 8 years ago, particularly in the Lop Buri soils. On the higher spots salt efflorescence appears in the dry season. In other places, where salinity is less serious, the granular structure, normally occurring on the surface, is destroyed by rain-showers causing the formation of crusts.

The natural fertility of the soils is moderately high under normal conditions, but productivity on the Lop Buri soils is considerably reduced by salinity. The soils are generally deficient in phosphorus and iron deficiency may be serious in the calcareous Lop Buri soils.

Soils in the flood plain of marl derived clay

The alluvium from marl derived clay is a local deposit of very limited extent.

The only series in this unit is the Khok Krathiam which includes soils that are somewhat similar to the Ban Mi, but differ in physiographic position and are not underlain by marl. They are deeply flooded by river water in the rainy season. No termite mounds and no trees occur in this area. These soils are slightly acid in the surface layer and alkaline in the subsoil. The natural fertility is high.

SOIL LEGEND

The basic mapping units, used in this soil survey, are soil series, but soil variants, soil types, soil phases, soil associations, soil complexes and one unnamed soil unit are also identified. A soil series is a group of soils that are similar in most characteristics such as parent material, horizon development, texture of the subsurface horizons, colour, drainage conditions, etc. (USDA 1951). A few soil areas are identified as variants 1/. These are taxonomic units having characteristics of a new soil series but because of limited extent are temporarily identified as a variant of a closely related soil. If, in future surveys they are found to be more extensive they will be given series names. The soil phases are based on features that are of importance for land use and soil management, such as slight differences in physiographic position related with different drainage and flooding conditions (high phase of Saraburi series) or high salinity (saline phase of Lop Buri series). Another phase was recognized based upon a thin clay loam layer of recent river deposits over acid sulphate soils (clay loam overwash phase of Ayutthaya series). A few soil types were distinguished on the basis of texture in the surface layer (types of Deum Bang series and variants).

The soil associations are composed of several soil series, variants or types, occurring in such an intricate pattern, that they cannot be separated at the mapping scale used. In some areas on the coalescing alluvial fans in the Sam Chuk-extension tract, several variants and types of Don Chedi and Deum Bang series could not be separated and were mapped as complexes. Two complexes have been mapped in the Pho Phraya tract; an Alluvial Complex and a Slope Complex, of which the latter is only of minor extent. These complexes are mixtures of soils that either cannot be defined in terms of its composing soil series or variants, or the composing series cannot be mapped separately, even at very large scale.

One small soil area was indicated on the map as an "unnamed" unit (No. 5). This is a variant or new series but is so limited in extent and not related to any known series so no attempt was made to give it a name during the present survey.

1/ called phases in former soil survey reports.

Each mapping unit having the same name as the taxonomic unit it is supposed to cover, may include up to 25 per cent of other taxonomic units 1/. This percentage depends on the scale of mapping and could be decreased by working on larger scale maps and by increasing the number of observations.

A total of 34 mapping units have been distinguished consisting of 17 series, 1 unnamed unit, 4 soil associations and 2 soil complexes, the remainder being variants, soil phases and soil types. All mapping units of the survey area plus the acreage and proportionate extent of each in the three irrigation tracts are listed in Table 2.

In accordance with normal soil survey procedures, each series has been named for a town or village near the place, where the series was first recognized and described. Thus many of the soils found in this survey have been established during other surveys in the Central Plain and the names derived from localities outside the survey area. Only the Don Chedi series has been named for a town in the Sam Chuk-extension tract.

DESCRIPTION OF MAPPING UNITS

A short description of the mapping units is given for the non-technical user of this survey report, indicating the main distinctive characteristics of each of the soils. Ranges in texture, colour and acidity are described together with information on other characteristics significant for the use of the soils. In addition brief statements are given on their physiographic position, drainage, flooding conditions, fertility status and land use. The rice yields mentioned are average yields obtained by the farmers with traditional methods of cultivation and varieties.

Technical descriptions of the main soil series, giving the central concept of each and ranges in profile characteristics, can be found in Appendix I. Analytical data are given in Appendix II.

In the descriptions below, the soils are grouped according to the land forms which are shown in Fig. 4.

Soils on semi-recent river alluvium

1. Kamphaeng Saen series

The Kamphaeng Saen series consists of well to moderately well drained soils on river levees. They are moist in the rainy season but dry out, at least in the surface, for 3 to 4 months during the dry season. The parent material contains mica.

1/ units of soil classification.

Table 2. List of Mapping Units with Area in Rais and Percentage of Total Area for the Pho Phraya, Sam Chuk and Sam Chuk-extension Irrigation Tracts

Soil symbol	Name of soil mapping unit	Pho Phraya		Sam Chuk		Sam Chuk-ext.		Total survey area	
		rai	%	rai	%	rai	%	rai	%
1	Kamphaeng Saen series	5,906	1.2	11,781	3.4			17,687	1.9
2	Nakhon Pathom series	21,594	5.2	50,594	14.3	1,562	0.9	73,750	7.9
3	Nakhon Pathom, variant			10,375	2.9			10,375	1.1
4	Saraburi series	38,375	9.5	83,782	23.7			122,157	13.0
5	Saraburi, high phase	30,281	7.4	88,000	23.5	875	0.5	114,156	12.2
6	Saraburi, variant with medium sand fraction			6,531	1.6	4,156	2.4	10,687	1.1
7	Phimai series	42,469	10.8	35,313	10.0			77,782	8.3
8	Phimai, variant with medium sand fraction			1,250	0.4			1,250	0.1
9	Alluvial Complex			38,344	10.8			38,344	4.1
10	Tha Muang, mottled variant	6,500	1.4					6,500	0.7
11	Chai Nat series	5,281	1.0					5,281	0.6
12	Ratchaburi series	14,812	3.5					14,812	1.6
13	Bang Len series	19,313	4.6					19,313	2.1
14	Ayutthaya series	123,281	31.1	3,312	0.9	10,907	6.1	137,500	14.7
15	Ayutthaya, clay loam overwash phase	8,875	2.0					8,875	1.0
16	Sena series	88,563	22.3			5,812	3.3	94,375	10.1
17	Don Chedi series			531	0.2	12,532	7.1	13,063	1.4
18	Don Chedi, mottled variant						0.2	312	0.03
19	Deum Bang sandy clay loam			2,531	0.7	4,718	2.7	7,249	0.8
20	Deum Bang clay			20,094	5.7	10,937	6.2	31,031	3.3
21	Deum Bang sandy clay loam, red mottled variant			5,062	1.4	31,000	17.4	45,157	4.8
22	Deum Bang clay, red mottled variant			1,250	0.4	43,907	24.6	36,062	3.9
23	Association of Don Chedi and Deum Bang sandy clay loam					1,500	0.8	1,500	0.16
24	Association of Deum Bang sandy clay loam, red mottled variant and Don Chedi series					12,969	7.3	12,969	1.4
25	Association of Deum Bang clay, red mottled variant and Don Chedi series					4,625	2.6	4,625	0.5
26	Association of Don Chedi series and its mottled variant					2,375	1.3	2,375	0.2
27	Takhli series					3,156	1.8	3,156	0.3
28	Lop Buri series, saline phase					6,938	3.9	6,938	0.7
29	Ban Mi series, dark variant					7,843	4.4	7,843	0.8
30	Unnamed unit no. 5					1,188	0.7	1,188	0.1
31	Chong Kae series					2,656	1.5	2,656	0.3
32	Khok Krathiam series					7,657	4.3	7,657	0.8
33	Slope Complex			62	0.1			62	0.01
	Total	405,250	100	353,812	100	177,625	100	936,687	100

These soils have a brown to dark brown or dark greyish brown loam surface, 15 to 25 cm thick. Some clay loam soils are included. Organic matter content is less than one and a half per cent. The soil is friable, but aggregate stability is low. The soil reaction is moderately to slightly acid (pH 5.5 to 6.5).

The subsoil (Bt-horizon) is a brown, dark yellowish brown or strong brown clay loam to light clay. In some profiles faint mottles occur in the lower part. The reaction is slightly acid to neutral (pH 6 to 7).

These soils have an undulating micro-relief, partly due to the occurrence of termite mounds, many of which have been somewhat flattened by the farmers.

The larger part of the area is used for habitation. The remaining land is used for bamboo, fruit trees, garden crops and some upland crops. Soil fertility is moderate with a considerable nitrogen deficiency. Crops should respond to fertilizers. (Capability subclass U-IIm, suitability subgroup for irrigated rice P-IIIp, land use planning class for irrigated double cropping 1).

2. Nakhon Pathom series

The Nakhon Pathom series consists of somewhat poorly drained soils on the lower slopes of the river levees. When used for rice they are submerged during the rainy season but otherwise only saturated with water for most of the rainy period. Unless irrigated, the soils dry out in the surface for about 3 months during the dry season.

The Nakhon Pathom soils have a brown or dark greyish brown clay loam surface with many, fine strong brown mottles, if used for rice. A thin, weakly developed plough pan is normally present at 15 cm depth. The organic matter content is rather low (less than one and a half per cent). This horizon is moderately to slightly acid (pH 5.5 to 6.5).

The subsoil is a brown, or dark yellowish brown clay with many yellowish brown mottles. The soil reaction is slightly acid to mildly alkaline (pH 6 to 8). The subsoil usually contains few, fine iron-manganese concretions and occasionally lime concretions, particularly in the northeastern part of the survey area.

These soils are almost flat with slopes of less than one half per cent. There are many large termite mounds. The soils are used for transplanted paddy. Second crops, either rice or upland crops, are grown in the dry season on some irrigated fields. Soil fertility is moderate. Rice yields of nearly 40 tang/rai (2,400 kg/ha) are common but much higher yields can be achieved by application of NP fertilizers (FAO 1968b and 1969). The mapping unit contains small inclusions of the high phase of Saraburi series. Capability subclass U-IIId, suitability group for irrigated rice P-I, land use planning class for irrigated double cropping 3).

3. Nakhon Pathom series, variant without surface gley

This variant is very similar in appearance to the normal Nakhon Pathom series, but due to the cultivation of sugar cane for many years (more than 12 years in some cases), no mottles or plough pan occur in the surface layer. The tilth of

the plough layer is slightly better in these soils.

Yields of 6 to 8 ton/rai of sugar cane are common, if not irrigated. Irrigation and application of fertilizers may double the yields. (Capability subclass U-IIId, suitability group for irrigated rice P-I, land use planning class for irrigated double cropping 3).

4. Saraburi series

The Saraburi series cover a very large part of the semi-recent alluvium, occurring in the backswamps (basins). During the rainy season the soils are inundated by rain water and run-off water from the surrounding land for 7 to 8 months. When dry the soil develops wide cracks of 20 to 40 cm deep. The soils are somewhat poorly to poorly drained.

These soils have a dark greyish brown or dark brown clay surface horizon with many fine strong brown or reddish yellow mottles (rice root rust). Structure is weak subangular blocky. The reaction is moderately acid to slightly acid (pH 5.5-6.5). The organic matter content is about two per cent.

The subsoil is a brown, olive brown or dark greyish brown clay with many yellowish brown mottles. The soil reaction is slightly acid to mildly alkaline (pH 6 to 8). Most soils contain some round iron-manganese concretions and occasionally lime concretions. Slickensides are common in these soils.

The soils are flat. Only few trees and no termite hills occur on them. Most of the soils are used for transplanted rice, but in some areas broadcasted rice is grown. The natural fertility is moderately high. Rice yields of 50 tang/rai (3,000 kg/ha) are common on these soils, yet a substantial yield increase can be obtained by application of NP fertilizers. (Capability subclass U-IVf, suitability group for irrigated rice P-I, land use planning class for irrigated double cropping 4).

5. Saraburi series, high phase

The high phase of the Saraburi soils are similar in appearance to the normal Saraburi, but are slightly better drained. Trees and termite mounds are common and the landscape is similar to that of the Nakhon Pathom series. Only transplanted rice is grown, producing high yields. (Capability subclass U-IVd, suitability group for irrigated rice P-I), land use planning class for irrigated double cropping 4).

6. Saraburi series, variant with medium sand fraction

These soil occur in the transition zone between the coalescing alluvial fans and the semi-recent alluvium. The texture is clay throughout but angular sand of medium and coarse grain size has been washed in during deposition. (Capability subclass U-IVf, suitability group for irrigated rice P-I, land use planning class for irrigated double cropping 4).

7. Phimai series

The Phimai series consists of poorly drained, clay soils, that are wet for most of the year. They occur in backswamps of the semi-recent and recent alluvium and are inundated for a long period. Due to better surface drainage the inundation period in the recent alluvial backswamps is shorter (7 to 8 months) than on the semi-recent alluvium (8 to 9 months). The surface soils dry out and cracks of 20 to 30 cm depth develop. These are open for only a few months.

The surface soil is dark grey to dark greyish brown with many fine, strong brown or reddish yellow mottles along rice root channels. The organic matter content is 2 to 3 per cent. The structure is weak blocky. The soil reaction is slightly acid to moderately acid (pH 5.5 to 6.5).

The subsoil is dark grey to grey with many brown and yellowish brown mottles. The pH ranges from 6 to 8. Most profiles contain some round iron-manganese concretions and occasionally some lime concretions. Slickensides are common in these soils.

The Phimai soils occur in almost flat areas on the bottom of the backswamps. No trees or termite hills occur. The soils are used for broadcasted rice. Soil fertility is moderately high. Rice yields are 40 to 50 tang/rai (2,400 to 3,000 kg/ha), but would be much higher, if transplanted rice could be grown. (Capability subclass U-IVf, suitability group for irrigated rice P-I, land use planning class for irrigated double cropping 4).

8. Phimai series, variant with medium sand fraction

These soils occur in the transition zone between the coalescing alluvial fans and the semi-recent alluvium. They are similar in appearance to the normal Phimai series, but contain angular grains sand of medium and coarse size, washed in from the west during deposition. (Capability subclass U-IVf, suitability group for irrigated rice P-I, land use planning class for irrigated double cropping 4).

9. Alluvial complex

The alluvial complex occurs in an extensive area of alluvium consisting of a large number of parallel narrow ridges and elongated depressions with considerable differences in elevation at very short distances. Several soil series occur in this unit in such an intricate pattern that the individual series could not be separated. The main soils include the Nakhon Pathom and Saraburi series, but also some Kamphaeng Saen and Phimai series occur to a limited extent.

These soils are fertile and rice yields in most areas are high, however, due to the pronounced relief they are not suitable for irrigation. (Capability subclass U-IIId/IVf, suitability group for irrigated rice P-IV, land use planning class for irrigated double cropping 5).

Soils on recent river alluvium

10. Tha Muang series, mottled variant

This variant of the Tha Muang series occurs on the low levees of the Suphan Buri river. The soils are moderately well drained and are distinguished from the normal Tha Muang series, not occurring in the survey area, by the occurrence of strong mottling in all subsurface layers. The soil material contains mica.

These soils have a dark greyish brown or brown loam or clay loam surface layer, which may have weak mottling along root channels. Organic matter content is less than one per cent. The soil is friable but aggregate stability is low. The soil reaction is moderately to slightly acid (pH 5.5 to 6.5).

The subsoil is a brown or yellowish brown clay loam with many strong brown or dark brown mottles. Loam or light clay layers may occur. The soil reaction is slightly acid to neutral (pH 6 to 6.5).

The soils are almost flat and most areas are used for habitation. Around farm houses, fruit trees, bamboo and garden crops are grown. The soils have moderately high fertility, but are deficient in nitrogen. (Capability subclass U-IIf, suitability subgroup for irrigated rice P-IIIt, land use planning class for irrigated double cropping 2).

11. Chai Nat series

The Chai Nat series consists of somewhat poorly drained soils on the slopes of the river levees. The soils dry during the dry season for 3 to 4 months and are flooded with river water in the rainy season.

These soils have a dark greyish brown to greyish brown clay loam surface layer with strong mottling in pores (rice rust). Organic matter content is low. The structure is weak blocky. Aggregate stability is low. The soil reaction is moderately to slightly acid (pH 5.5 to 6.5).

The subsoil is a greyish brown or brown, light clay with many yellowish brown and dark brown mottles. Layers of coarser and finer texture may alternate. The soil reaction is slightly acid to neutral (pH 6 to 7).

The soil are almost flat, but may have a slightly undulating micro-relief. Some trees normally occur. The soils are used for rice during the rainy season. Both transplanted and broadcasted rice is grown. In the dry season, beans and vegetables are grown in places where water is available. Soil fertility is moderately high. Rice yields of 40 tang/rai (2,400 kg/ha) are common on these soils. Response to fertilizers is probably low. (Capability subclass IIId, suitability group for irrigated rice P-I, land use planning class for irrigated double cropping 3).

12. Ratchaburi series

The Ratchaburi series are somewhat poorly to poorly drained clay soils occurring in the backswamps. The soils are dry for 2 to 3 months, at least in the surface, and wide cracks of 30 to 40 cm deep develop. The soils are inundated by river water for a period of 6 months. Flood levels are 30 cm to 1 m.

The soils have a dark greyish brown surface layer with many fine strong brown mottles. Organic matter content is moderately low (one and a half to two per cent). The structure is weak blocky. Agregate stability is moderate. The soil reaction is moderately to slightly acid.

The subsoil is dark greyish brown with very many strong brown and dark brown mottles. Also some grey spots occur. The soil reaction is slightly acid. The deeper subsoil, below 80 cm to 150 cm, consists of brackish water deposits having red and yellow mottles and an extremely low pH. Slickensides are common in these soils.

The soils are flat to nearly flat. Almost no trees occur. The soils are only used for broadcasted rice. Soil fertility is moderately high. Yields of rice are normally 40 to 50 tang/rai (2,400 to 3,000 kg/ha). Response to fertilizers is probably low. (Capability subclass U-IVf, suitability group for irrigated use P-I, land use planning class for irrigated double cropping 4).

Soils on brackish water clay

13. Bang Len series

The Bang Len series is limited in extent and borders areas with river alluvium. The soils are poorly drained clays. They are flooded annually for a period of 6 to 7 months. Flood levels are often more than a meter. The soils dry out in the surface for 2 to 3 months. Wide cracks 30-40 cm deep will develop during this period.

The soils have a black to very dark grey surface horizon of 30 to 80 cm thickness. Organic matter content is moderate (2 to 3 per cent). The structure is often moderate blocky with granular structure on the surface. Soil aggregate stability is high. The soil reaction is moderately to slightly acid. The lower part of this horizon contains some gypsum.

The subsoil is grey to light grey with many yellow, olive yellow and light olive brown mottles. The upper part of this horizon has a variable gypsum content, mostly concentrated in nests of fine crystals. The soil reaction is slightly acid to mildly alkaline. The deeper subsoil (at least below 2 m) is a grey or greenish grey, soft mud-clay, with a low to moderate sulphur content.

The soils are flat. They have no trees and are used only for broadcasted rice. Soil fertility is moderately high. Rice yields of 40 to 50 tang/rai (2,400 to 3,000 kg/ha) are common. (Capability subclass U-IVf, suitability group for irrigated rice P-I, land use planning class for irrigated double cropping 4).

14. Ayutthaya series 1/

The Ayutthaya soils are poorly drained, very strongly acid, clays. They are flooded annually for a period of 6 to 7 months with highest flood levels of over 100 cm. The soils dry out in the surface for about 2 to 3 months and develop wide cracks 30 to 40 cm deep.

The soils have a very dark grey surface horizon 30 to 80 cm thick. The 15 to 20 cm thick plough layer has many fine, strong brown or yellowish red mottles while the lower part has red mottles. Organic matter content is moderate; two to four per cent. The structure is weakly to moderately blocky with high aggregate stability. The soil reaction is very strongly acid to moderately acid. The lower part of the horizon may contain fine gypsum crystals.

The subsoil consists of three main horizons; a greyish brown, to light brownish grey, red mottled horizon, containing gypsum; a greyish brown, brownish yellow and pale yellow mottled horizon (cat clay), starting below 100 cm; and a dark grey, reduced mud-clay in the deeper subsoil. The soil reaction is extremely acid (pH below 4.5) in the two mottled horizons but increases to moderately acid (pH 5.5 to 6) in the reduced subsoil. The lower part of the yellow mottled horizon is most acid and may have a pH of 3.5. The reduced subsoil has a very high sulphur content mainly in the form of pyrites (FeS_2).

The soils are flat. There are no trees and broadcasted rice is the only crop grown. Soil fertility is moderately low. Rice yields of 30 tang/rai (1,800 kg/ha) are common on these soils. Response to fertilizers without substantial applications of lime is low. (Capability subclass U-IVf, suitability subgroup for irrigated rice P-IIs, land use planning class for irrigated double cropping 4).

15. Ayutthaya clay loam, overwash phase

This phase of the Ayutthaya series occurs along certain small streams draining the area with river deposits and is characterized by a layer of 20 to 30 cm of greyish brown clay loam overlying a normal Ayutthaya soil. Areas are flooded annually and thus receive a thin layer of fresh sediments. The drainage is somewhat poor to poor.

The organic matter content of the surface soils is low. The soil reaction is strongly acid. Soil fertility is slightly higher than in the normal Ayutthaya series. (Capability subclass U-IVf, suitability subgroup for irrigated rice P-IIs, land use planning class for irrigated double cropping 4).

16. Sena series, (Se) 2/

The Sena series consists of poorly drained, very strongly acid, clay soils. They are flooded annually for a period of 6 to 7 months, with flood levels of more than 150 cm. The soils dry out in the surface for about 2 to 3 months and develop wide cracks of 30 to 40 cm deep.

1/ Formerly included in Bang Khen series (see page 14).
2/ Formerly included in Rangsit series (see page 14).

The soils have a very dark grey to black surface horizon, 20 to 40 cm thick. There are many fine, strong brown or yellowish red mottles in the plough layer. Organic matter content is moderate (2 to 4 per cent). The structure is weakly to moderately blocky with high aggregate stability. The reaction is very strongly acid. The lower part of this dark horizon may contain some gypsum.

The subsoil consists of three main horizons; a greyish brown to brown, red and brownish yellow mottled horizon, containing fine gypsum crystals; a greyish brown to brown horizon with brownish yellow and pale yellow mottles (cat clay), starting at some depth between 40 and 100 cm; and a very soft, dark grey, reduced subsoil, mostly starting below 150 cm. The soil reaction is extremely acid (pH lower than 4.5) in the mottled horizons and increases to moderately acid in the reduced subsoils. The most acid layer in the soil is the lower part of the pale yellow mottled horizon with a pH around 3.5. The reduced subsoil has a very high sulphur content, mainly in the form of pyrites (FeS_2).

The soils are flat. There are no trees and the only crop grown is broadcasted rice. Soil fertility is moderately low. Rice yields of 20 to 30 tang/rai (1,200 to 1,800 kg/ha) are common. Response to fertilizers without substantial applications of lime is low. (Capability subclass U-IVf, suitability subgroup for irrigated rice P-IIs, land capability class for irrigated double cropping 4).

Soils on coalescing alluvial fans

17. Don Chedi series

The Don Chedi series consists of well to moderately well drained, medium textured soils on the highest parts of the alluvial fans. The sand fraction is medium to coarse and the grains are angular. The soils are never flooded and are dry for 4 to 5 months.

These soils have a dark greyish brown to dark brown sandy loam surface horizon 20 to 30 cm thick. The soils have a crumb structure with moderate stability. The soil reaction is strongly to moderately acid (pH 5 to 6).

The subsoils are brown to strong brown sandy clay laom to sandy clay and may have very faint reddish brown or yellowish red mottles in the lower part. The soil reaction is variable and ranges from very strongly acid to slightly acid (pH 4.5 to 6.5). In the northern part of the area the soils are more acid than in the south.

These soils have an undulating micro-relief and some termite hills. The larger part of the soil areas are used for habitation. The remaining land is used for bamboo, fruit trees, garden crops and some upland crops. Soil fertility is moderately low. Crops should response to fertilizers. (Capability subclass U-IIIs, suitability subgroup for irrigated rice P-IIIs, land use planning class for irrigated double cropping 1).

18. Don Chedi series, mottled variant

This variant occurs in many places in the transition zone between the Don Chedi and Deum Bang series soils but only in a few places do they cover areas large enough to be mapped.

The soils are moderately well drained and have sandy loam to sandy clay textures. The sand fraction is medium. The soils are never flooded and dry out for about 4 months during the dry season.

The surface soil is a greyish brown to brown sandy loam. The colour turns light grey, after drying. The organic matter content is very low. The structure is very weak blocky with low aggregate stability. The soil reaction is strongly to moderately acid.

The subsoil is a brown, pale brown or yellowish brown sandy clay with many distinct brown mottles. The soil reaction is slightly acid to mildly alkaline (pH 6.0 to 8.0).

The soils have an undulating micro-relief and are used for both paddy and upland crops. Soil fertility is probably moderately low. (Capability subclass U-IIIs, suitability subgroup for irrigated rice P-IIIs, land use planning class for irrigated double cropping 3).

19. Deum Bang sandy clay loam

The sandy clay loam type of the Deum Bang series consists of somewhat poorly drained soils with a medium to coarse sand fraction. The soils dry out at least in the surface for 3 to 4 months. They are not flooded by river water, but rice fields are submerged during the growing season.

The soils have a dark greyish brown to brown sandy clay loam surface that becomes light grey after drying. Soils with a sandy loam texture in the surface are included in this unit. There are many fine strong brown or yellowish brown mottles. The organic matter content is less than one per cent. The structure is very weak blocky and aggregate stability is low. The soil reaction is strongly or moderately acid.

The subsoil is a brown to light brownish grey clay with many strong brown, yellowish brown or brown mottles. The soil has a very firm consistence. The reaction is slightly acid to mildly alkaline. The deeper subsoil, below 150 cm, may contain lime concretions.

The soils are flat with a very gentle slope. There are many large termite mounds. The soils are only used for transplanted rice. Soil fertility is moderate with a considerable nitrogen deficiency. Yields of 30 tang/rai (1,800 kg/ha) are common on these soils, but much higher yields can be obtained by application of NPK fertilizers. (Capability subclass U-IVd, suitability subgroup for irrigated rice P-IIs, land use planning class for irrigated double cropping 4).

20. Deum Bang clay

The clay type of the Deum Bang series is a somewhat poorly drained soil on the lowest parts of the alluvial fans. The soils usually have a clay texture throughout, but in places may be sandy clay. The sand fraction is medium, which is characteristic of this series. Though rather similar to the sandy clay loam type of the Deum Bang series, the colours may be slightly greyer and the soils dry out during a shorter period.

The fertility of these soils is somewhat higher than of the Deum Bang sandy clay loam soils and rice yields of 40 tang/rai (2,400 kg/ha) are common. (Capability subclass U-IVd, suitability group for irrigated rice P-I, land use planning class for irrigated double cropping 4).

21. Deum Bang sandy clay loam, red mottled variant

This variant is very similar in appearance to the Deum Bang sandy clay loam soils, except for the red mottles in the subsoil. (Capability subclass U-IVd, suitability subgroup for irrigated rice P-IIs, land use planning class for irrigated double cropping 4).

22. Deum Bang clay, red mottled variant

This variant is similar in appearance to the clay type of the Deum Bang series, except for the red mottles in the subsoil. (Capability subclass U-IVd, suitability group for irrigated rice P-I, land use planning class for irrigated double cropping 4).

23. Association of Don Chedi series and Deum Bang sandy clay loam

This mapping unit consists of an intricated soil pattern of Don Chedi and sandy clay loam type of Deum Bang series with approximately equal surfaces of both series. The topography is slightly undulating. (Capability subclass U-IVd/IIIs, suitability group for irrigated rice P-IV, land use planning class for irrigated double cropping 5).

24. Association of Deum Bang sandy clay loam, red mottled variant and Don Chedi series

This unit consists of an intricated soil pattern of the red mottled variant of Deum Bang sandy clay loam and Don Chedi series with about equal surfaces of both soils in addition to smaller surfaces of other variants of Deum Bang series. The topography is slightly undulating. (Capability subclass U-IVd/IIIs, suitability group for irrigated rice P-IV, land use planning class for irrigated double cropping 5).

25. Association of Deum Bang clay, red mottled variant and Don Chedi series

This unit consist of an intricated soil pattern of the red mottled clay variant of the Deum Bang series and Don Chedi series, with about equal surfaces of both soils in addition to smaller surfaces of other variants of Deum Bang series. The topography is slightly undulating. (Capability subclass U-IVd/IIIs, suitability group for irrigated rice P-IV, land use planning class for irrigated double cropping 5).

26. Association of Don Chedi series and its mottled variant

This mapping unit consists of Don Chedi series and the mottled variant of this series, covering about equal surfaces. The topography is slightly undulating. (Capability subclass U-IIIs, suitability group for irrigated rice P-IV, land use planning class for irrigated double cropping 5).

Soils on terrace of gravelly limestone

27. Takhli series

This series consists of shallow, black, well drained clay loam to light clay soils. The parent material is a partially cemented, white limestong gravel. The soil is calcareous, the pH being about 8. The structure is granular on the surface and strong blocky in the subsurface layers. Agregate stability is very high.

The soils are slightly undulating, having slopes of more than 2 per cent. In some places the soil has been eroded and the limestone occurs on the surface. In other places the soils may be 60 to 80 cm deep.

Only in a few places upland crops or rice are grown on these soils, but most of the land is covered by grass, bamboo and shrubs. (Capability subclass U-IVs, suitability group for irrigated rice P-IV, land use planning class for irrigated double cropping 5).

Soils on low terrace of marls

28. Lop Buri series, saline phase

The Lop Buri series consists of somewhat poorly drained, black, fine clay soils. The clay is very sticky when wet and shrinks strongly during drying. The soils are dry in the surface for about 4 months and develop wide cracks of more than 50 cm deep. The surface layer has a granular structure with a very high aggregate stability. The structure in the subsurface layers is moderately blocky. The soil is very calcareous and fine lime concretions occur in all the subsurface layers. Very fine, round iron-manganese concretions occur throughout the soil. The organic matter content is about 2 per cent.

The parent material, occurring below 100 to 150 cm is a white, soft marl

with many hard lime concretions.

The soils are saline, having a very high salinity in those spots with slightly higher elevations. Here the structure in the surface is not granular, but a hard crust is formed in the dry season.

The surface is nearly flat with slopes of less than 1/4 per cent. There are few low termite mounds and few trees. The soils are used for transplanted rice. Yields, which used to be more than 30 tang/rai (1,800 kg/ha) before the salinization of the soils, have dropped to 15 or 10 tang/rai (900 or 600 kg/ha). In many places the land has been abandoned. (Capability subclass U-IVx, suitability group for irrigated rice P-IV, land use planning class for irrigated double cropping 5).

29. Ban Mi series, dark variant

The dark variant of the Ban Mi series is a somewhat poorly drained, black to very dark grey, clay soil, and is distinguished from the normal Ban Mi series by its darker colour. The clay is very sticky when wet and shrinks when dry. The soils are dry in the surface for more than 3 months and are never flooded in the rainy season, though rice is cultivated on submerged fields. In the dry season the soil has wide cracks of more than 50 cm deep.

These soils have a black surface with some fine strong brown mottles. The structure is granular in the plough layer and weak to moderate blocky below. The stability of the soil aggregates is high. The soil reaction is slightly acid to neutral.

The subsurface horizons to a depth of more than 100 cm are very dark grey and not mottled. The soil contains fine iron-manganese concretions. The reaction is neutral. The deeper subsoil is a light grey, mottled clay with few lime concretions and an alkaline reaction.

The soils are flat with few termite hills and trees and are used for transplanted rice. The soils have moderately high fertility and yields of 50 tang/rai (3,000 kg/ha) are common. Yields could probably be increased with NPK fertilizers. (Capability subclass U-IVd, suitability group for irrigated rice P-I, land use planning class for irrigated upland crops 4).

30. Unnamed unit No. 5

The unit No. 5 consists of somewhat poorly drained, dark brown soils. The soils are never flooded and dry out for 3 to 4 months during the dry season. The soils are slightly to moderately saline.

The surface soil has a clay loam to clay texture and is very dark greyish brown with fine strong brown mottles. The soil reaction is slightly acid.

The subsoil is a dark brown clay with few yellowish brown and red mottles and many fine found iron-manganese concretions. The reaction is neutral.

The soils are nearly flat with many termite hills and few trees. They are

used for transplanted rice only. The soils have moderate fertility with yields of 30 tang/rai (1,800 kg/ha) or lower. (Capability subclass U-IVd, suitability subgroup for irrigated rice P-IIs, land use planning class for irrigated double cropping 4).

31. Chong Kae series

The Chong Kae series consists of somewhat poorly drained clay soils that are very sticky when wet and shrink when dry. The soils are dry in the surface for more than 3 months and are never flooded in the rainy season, though rice is cultivated on submerged fields. In the dry season the soils have wide cracks of less than 50 cm deep.

The surface soil is dark greyish brown with fine strong brown mottles. Structure is weak to moderately blocky with high aggregate stability. The reaction is strongly to moderately acid.

The subsoil is greyish brown with many fine yellowish red and red mottles. The soil reaction is moderately acid.

The soils are flat with many termite mounds and few trees. Transplanted rice is the only crop grown on them. Soil fertility is moderate and yields of 40 tang/rai (2,400 kg/ha) are common on these soils. (Capability subclass U-IVd, suitability group for irrigated rice P-I, land use planning class for irrigated double cropping 4).

Soils on floodplains of marl-derived clay

32. Khok Krathiam series

The Khok Krathiam series consists of very dark grey, poorly drained, clay soils that are very sticky when wet and shrink when dry. The soils are dry in the surface for 2 to 3 months and are flooded for a period of 7 months during the rainy season. Maximum flood levels are 50 to 100 cm. Wide cracks develop in the surface during the dry season.

The surface horizon is black with few fine, strong brown mottles. The structure is weak granular on the surface and weak to moderate blocky below. Aggregate stability is high. The reaction is moderately acid.

The subsurface horizon to a depth of more than 100 cm is very dark grey with few brown mottles. The reaction is slightly acid to neutral. The deeper subsoil is a light grey mottled clay with lime concretions.

The soils are flat. There are no termite hills and no trees. Broadcasted rice is the only crop that is grown. The soils have moderately high fertility and yields of 50 tang/rai (3,000 kg/ha) are common. The yields could probably be increased with NPK fertilizers. (Capability subclass U-IVf, suitability group for irrigated rice P-I, land use planning class for irrigated double cropping 4).

Soils on hill

33. Slope complex

The slope comples consists of very shallow, stony soils on steep slopes. A thin brown surface horizon is present at some places with reddish brown soil below.

This unit occurs only on a very small quartzite hill in the north of the area. The hill is covered with low trees and shrubs. (Capability subclass U-VIIe, suitability group for irrigated rice P-I, land capability class for irrigated double cropping 5).

CLASSIFICATION OF SOILS

For the purpose of international soil correlation the soil series of the area are classified at Great Soil Group or Sub Group levels according to two systems; the one generally used in Thailand (DUDAL and MOORMANN 1964), the USDA system (1960 and 1970) and in addition identified with appropriate Units of the FAO/UNESCO Soil Map of the World (Table 3).

Table 3. Placement of the Soils in Great Soil Groups as used in Thailand, in the USDA System of Soil Classification and Units of the Soil Map of the World

	Great Soil Group by Specified Systems		
Soil Series	Dudal/Moormann 1/	USDA 2/	FAO/UNESCO 3/
Kamphaeng Saen	Non Calcic Brown	Udic Haplustalfs	Chromic Luvisols
Nakhon Pathom	Low Humic Gley	Aeric Tropaqualfs	Gleyic Luvisols
Saraburi	Alluvial Soil	Aeric Tropaquepts	Gleyic Cambisols
Phimai	Alluvial Soil	Typic Tropaquepts	Eutric Gleysols
Tha Muang	Alluvial Soil	Typic Ustifluvents	Eutric Fluvisols
Chai Nat	Alluvial Soil	Aeric Tropaquepts	Gleyic Cambisols
Ratchaburi	Alluvial Soil	Aeric Tropaquepts	Gleyic Cambisols
Bang Len	Alluvial Soil	Typic Haplaquolls	Mollic Gleysols
Ayutthaya	Alluvial Soil	Sulfic Tropaquepts	Humic Gleysols
Sena	Alluvial Soil	Sulfic Tropaquepts	Humic Gleysols
Don Chedi	Grey Podzolic	Ustoxic Dystropepts	Ferralic Cambisols
Deum Bang	Low Humic Gley	Aeric Tropaqualfs	Gleyic Luvisols
Tha Khli	Rendzina	Typic Rendolls	Rendzinas
Lop Buri	Grumusol	Typic Pelluderts	Pellic Vertisols
Ban Mi, dark variant	Grumusol	Typic Pelluderts	Pellic Vertisols
U5	Low Humic Gley	Aquic Haplustalfs	Gleyic Luvisols
Chong Kae	Grumusol	Aquentic Chromuderts	Chromic Vertisols
Khok Krathiam	Grumusol	Typic Pelluderts	Pellic Vertisols

1/ R. Dudal and F.R. Moormann (1964). 2/ Soil Taxonomy of the National Cooperative Soil Survey (1970).
3/ FAO/UNESCO Soil Map of the World (FAO 1970b).

CHAPTER III

SOIL SURVEY INTERPRETATION

The soil survey provides basic information about the soils of the area. It describes and classifies them and shows the extent and location of each on the soil map. The value of the survey is, to a large extent, in its application to the practical use of the soil, whether for farming or some other purpose.

In order to make maximum use of the soil survey, interpretation (usually by a soil scientist) of the data is required in terms that apply to the specific uses and treatments under consideration. This part of the report presents some of the important interpretations of the survey data for the area. Many other kinds of interpretations can be made.

The kinds of interpretation 1/ presented and described are: (1) land capability classification for upland crops; (2) suitability grouping for irrigated rice; (3) suitability of soils for specific upland crops; (4) land use planning classes for irrigated double cropping.

LAND CAPABILITY CLASSIFICATION FOR UPLAND CROPS

The method chosen for general agricultural interpretation or evaluation of soils in Thailand is designated as land capability classification for upland crops 2/. The method used is based upon (with slight modifications) the principles presented in the Soil Survey Interpretation Handbook of Northeast Thailand, part II, Soil Survey Report No. 60, 1967. It is a practical grading or grouping of soils based upon their limitations (management requirements and risk of damage) when used for crop production.

The capability of each mapping unit has been evaluated by interpretation of the various characteristics and properties of the soils. In addition to land and soil properties, observations in the field, cultivation experiences and yield data obtained from farmers and other workers in agriculture (Department of Agriculture, Department of Rice, UNDP Soil Fertility Project, Dutch and Australian experts working in various development and research projects in the Central Plain) have been used to establish the specifications necessary for grouping the soils (Table 4).

1/ At the time of the survey the main irrigation canals had been built but it is not known how much water will be available. Therefore soil interpretations are given for both irrigated and non-irrigated cropping systems.

2/ This system is similar to the land capability classification system used by the United States Department of Agriculture, Soil Conservation Service.

Table 4. Specifications for Land Capability Classes for Upland Crops

Soil and Land Characteristics	Class U-I	Class U-II	Class U-III	Class U-IV	Class U-V	Class U-VI	Class U-VII	Class U-VIII
Texture of surface soil	loam to clay loam	sandy loam to friable clay	loamy sand to clay	sand to fine clay				
Texture of subsurface soil	sandy loam to friable clay	loamy sand to clay	loamy sand to fine clay	sand to fine clay				
Depth to rock or impermeable zone	>125	>100	>75	>50		>25		
Coarse fragments	none	slightly gravelly	gravelly or slightly stony or slightly rocky	very gravelly, stony or rocky		very gravelly, very stony or very rocky	very gravelly, very stony or very rocky	rocky land
Soil reaction	$5.0<pH<8.0$	$4.5<pH<8.0$	$4.5<pH<8.5$	$4<pH<8.5$				
Salinity Ece x 10^6	$<2,000$	$<4,000$	$<6,000$	$<8,000$				
CEC of surface soil	>10	>8	>5	>2				
Slope	$<1\%$	$<3\%$	$<8\%$	$<12\%$	$<1\%$			
Drainage	well drained	moderately well drained	somewhat poorly to somewhat excessively drained	poorly to somewhat excessively drained	very poorly drained	excessively drained	excessively drained	excessively drained
Period that soil is too dry for growing crops	<2 months	<4 months	<5 months	<8 months				
Flooding	never flooded	never flooded or occasionally flooded for short periods in rainy season	never flooded to flooded for prolonged periods in the rainy season	never flooded to flooded for prolonged periods in the rainy season				

There are two levels of generalization used in this classification system: the land capability class and subclass (a third level called "management group" could be used in detailed surveys). The land capability class is the broadest level of generalization. The soils in each class have the same general level of capability for agriculture and approximately the same degree of limitations. The classes are indicated by Roman numerals I to VIII in decreasing order of capability. The soils of classes U-II to U-VIII have a combination of limitations of about the same degree; however, the kind of limitations may vary 1/.

The soils of the survey area are placed in land classes based upon the present conditions and primarily for upland crops. If the irrigation system could be improved so as to make water available at all times the choice of crops would be wider and cartain soils might be placed in a higher class.

The subclass is the second degree of generalization. The soils in each class are subdivided into subclasses according to the dominant kind of limitation. The dominant limitation is indicated by a small case letter following the class number, e.g. U-IIId.

A suitability grouping for irrigated rice is set apart, and described later, from the land capability classification for upland crops as the soil and water requirements for upland crops and wetland rice are very different.

A number of assumptions have to be made if soils are to be grouped consistently within the land capability classification and suitability grouping for irrigated rice. These assumptions are:

1. Capability classification and suitability grouping are interpretative groupings of the soils. They are based on the combined effects of many soil characteristics, on risks of crop damage, limitation in use, productive capacity and soil management. Slope, texture, soil depth, effects of past erosion, permeability, water holding capacity, type of clay, etc., are considered permanent soil qualities and characteristics.

2. A level of management that is practical and within the ability of most farmers is assumed. Most farmers use animal power and simple farming equipment and apply manure occasionally plus some fertilizers and pesticides.

3. Land capability classes U-I through U-IV and soil suitability groups for irrigated rice P-I through P-III include soils that can be used to grow cultivated crops. Such crops should give a favourable economic return above costs of production.

4. The capability classification of soils in the area may change when more adequate irrigation and drainage is provided.

5. Distance to markets, lack of good roads, etc. are not criteria for capability and suitability grouping.

1/ A prefix "U" is used to distinguish land capability classes from rice suitability groups that are indicated by the prefix "P".

6. Soils suited to cultivation may also be suited to other uses such as pasture or forest. When soils are grouped in classes U-I through U-IV, it does not imply that all soils so grouped should be farmed.

7. Capability and suitability groupings may be changed as new information about the behaviour of the soils becomes available. Also, groupings may change as agricultural technology changes and new uses for soils are found.

Eight land capability classes for upland crops are distinguished. Soils placed in class U-I have no significant limitations for growing upland crops, and relatively little effort is required to produce satisfactory yields of a wide range of crops. However, no soils in the area are placed in class U-I. In classes U-II and U-III there are increasingly severe limitations for agricultural use; relatively greater effort is required to produce satisfactory crop yields and the choice of crops may be narrower. These problems are still more severe in soils in class U-IV, which, though capable of marginal production of a few crops, do not offer good possibilities for improvement. Soils in classes U-V, U-VI, U-VII and U-VIII are not generally suited for cultivated crops. Those placed in classes U-V, U-VI and U-VII can, however, be used for grassland or woodland. Soils placed in class U-VIII do not produce economic returns in agriculture or forestry. No soils in the area are placed in classes U-I, U-V, U-VI and U-VIII.

At the lower level, land capability subclasses group soils within a class according to kinds of limitations. There are eight subclasses and also eight kinds of limitations. The kinds of limitations, are designated by the following symbols:

1. e - erosion
   Soils with an erosion hazard or past erosion damage.

2. s - soil limitation in the root zone
   Soils with problems such as shallowness, unfavourable texture, stoniness or low fertility that is difficult to correct.

3. m - lack of moisture for plant growth
   Soils on which growth of crops with a long growing season is severely reduced by lack of moisture.

4. t - unfavourable topography
   Soils whose relative position or relief (macro or micro) limits use for paddy and irrigated upland crops.

5. f - flooding
   Soils that are susceptible to flash floods or in the case of upland crops, prolonged deep flooding, or both, which damage the crops or limit choice of crops.

6. d - impeded drainage
   Soils whose use for upland crops is limited by excess water due to high water table, slow permeability or slow surface drainage or a combination of all three.

7. x - salinity or alkalinity
   Soils for which the major limitation is salinity or alkalinity.

8. a - soil acidity
   Soils for which strong acidity, difficult to correct, is the major limitation for crop production.

The dominant kind of limitation that limits use determines the assignment of the mapping units to capability subclasses. For example, in a classification for lowlands a mapping unit for which flood is the main problem or hazard, even though it also may have poor drainage, a low fertility or lack of moisture in the dry season, would be assigned to subclass U-IVf. The land capability classes are summarized as follows:

Class U-I	Soils very well suited for upland crops, having no significant limitations that restrict their use.
Class U-II	Soils well suited for upland crops, having slight limitations that restrict their use.
Class U-III	Soils moderately suited for upland crops, having moderate limitations that reduce the choice of crops and/or require special management.
Class U-IV	Soils poorly suited for upland crops, having severe limitations that restrict the choice of crops and/or require very careful management.
Class U-V	Soils having little or no erosion hazard, but having other limitations that are impractical to remove, making them unsuited for upland crops.
Class U-VI	Soils having severe limitations that make them generally unsuited for cultivation and limit their use to pasture, woodland, wildlife food cand cover and water supply.
Class U-VII	Soils having very severe limitations that make them unsuited for cultivated crops and that restrict their use largely to woodland, wildlife food and cover, water supply and recreation.
Class U-VIII	Soils and land types having limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife food and cover, and water supply.

These eight classes were established for use in all Thailand. However, soils in the classes U-I, U-V, U-VI and U-VIII do not occur in the Sam Chuk and Pho Phrya irrigation tracts.

The capability subclasses occurring in the survey area are described in the following pages. The soils in each subclass are listed, and the principal uses and management problems are given. Table 5 lists the subclasses and gives the approximate extent of each in rais by irrigation districts as well as for the total area. In those cases where the class or subclass may be changed in the future because of improved drainage or irrigation, this is indicated in the discussion of the various soil units.

Table 5. Total Area in Rais and Percentage of Total Area of Subclasses for upland crops

Subclass	Pho Phraya		Sam Chuk		Sam Chuk-ext.		Total survey area	
	rai	%	rai	%	rai	%	rai	%
U-IIm	5,906	1.2	11,781	3.4	-	-	17,687	1.9
U-IIf	6,500	1.4	-	-	-	-	6,500	0.7
U-IIId	26,875	6.2	60,969	17.2	1,562	0.9	89,406	9.6
U-IIIs	-	-	531	0.2	15,219	8.6	15,750	1.63
U-IVd	30,281	7.4	111,937	31.7	103,124	58.0	245,342	26.2
U-IVf	335,688	83.8	130,188	36.6	28,532	16.1	494,408	52.8
U-IVs	-	-	-	-	3,156	1.8	3,156	0.3
U-IVx	-	-	-	-	6,938	3.9	6,938	0.7
U-VIIe	-	-	62	0.1	-	-	62	0.01
U-IIId/IVf	-	-	38,344	10.8	-	-	38,344	4.1
U-IVd/IIIs	-	-	-	-	19,094	10.7	19,094	2.06
Total	405,250	100	353,812	100	177,625	100	963,687	100

Land capability classes and subclasses of the survey area

Class U-II: Soils well suited for upland crops having slight limitations that restrict their use. Total area 24,187 rai.

Capability subclass U-IIm, having moisture limitations

Subclass U-IIm includes very deep, nearly level to slightly undulating, well to moderately well drained soils with loam to clay texture. The soils have a moderate fertility and are well suited for upland crops if and when sufficient water is available for plant growth. The soils are dry for 3 to 4 months during the dry season and moisture deficiency is their major limitation.

These soils could be used for permanent farming under irrigation, though due to their undulating micro-relief and high position in regard to water delivery levels in the irrigation canals, they would have a topographic limitation for irrigated agriculture (U-IIt).

Under good management these soils can produce high yields of many crops, including maize, sugar cane, cotton, beans, vegetables and fruits. At present, most of the land of this subclass is used for village sites, fruit trees, vegetables and some sugar cane.

Only the Kamphaeng Saen series (map unit 1) of the semi-recent river levees is included in this subclass. Total area 17,687 rai.

Capability subclass U-IIf, having flooding limitations

Subclass U-IIf includes very deep, nearly level to slightly undulating, moderately well drained soils with loam to clay loam textures. The soils have moderately high fertility and are well suited for upland crops if and when sufficient water is available for plant growth. The soils are dry for 3 to 4 months during the dry season and in addition to flooding hazard during the rainy season moisture deficiency is an important limitation. During and after the peak of the rainy season the soils are subject to shallow floods from the river for short periods.

The soils could be used for permanent farming under conditions of irrigation and water control, though due to their undulating micro-relief and high position in regard to water delivery levels in the irrigation canals, they would have topographic limitations for irrigated agriculture (U-IIf).

The soils, included in this subclass belong to the Tha Muang mottled variant (map unit 10) occurring on narrow river levees. They are mainly used for village sites and fruit trees and only little land is available for cultivated crops. Total area 6,500 rai.

Class U-III: Soils moderately suited for upland crops, having moderate limitations that reduce the choice of crops and/or require special management. Total area 105,156 rai.

Capability subclass U-IId, having drainage limitations

This subclass includes very deep, almost level, somewhat poorly drained, clay loam soils with slowly permeable clayey subsoils. The soils have moderately high fertility and soil reaction ranges from slightly acid to mildly alkaline.

The soils could be used for continuous cultivation under conditions of irrigation and water control. They are not very well suited for upland crops in the peak of the rainy season, due to waterlogging, except for sugar cane which is grown quite successfully on these soils. In the dry season various upland crops, such as maize, soya beans, mung beans and sesame can be grown when properly irrigated. Under such conditions the soils should be classified in subclass U-IId.

The soils included in this class are the Nakhon Pathom series and its variant without surface gley (map units 2 and 3) and the Chai Nat series (map unit 11) on the recent alluvium. Total area 89,406 rai.

Capability subclass U-IIIs, having soil limitations

Subclass U-IIIs includes very deep, well to moderately well drained, slightly undulating, fine loamy soils. The soil fertility is low, and the soil reaction very strongly to slightly acid.

The soils are used for village sites, fruit trees, vegetables and few upland crops, such as cassava. These soils would respond well to irrigation, however, they have a somewhat undulating micro-relief and are generally situated above the water delivery level of the present irrigation laterals.

Included in this subclass are the Don Chedi series, its mottled variant and the association of both units (map units 17, 18 and 26). Total area 15,750 rai.

Class U-IV: Soils poorly suited for upland crops, having severe limitations that restrict the choice of crops and/or require very careful management. Total area 749,844 rai.

Capability subclass U-IVd, having severe drainage limitations

Subclass U-IVd includes very deep, level or nearly level, somewhat poorly to poorly drained, clay to clay loam soils with slowly permeable clayey subsoils. The soils have moderate to moderately high fertility. Their soil reaction ranges from strongly to slightly acid.

The soils are too wet for upland crops during the rainy season due to a high groundwater level and surface flooding by rainwater. Some of the soils are difficult to work because of their clay texture. All of these soils dry out in the dry season and upland crops can only be grown under irrigated conditions. If irrigation and water control could be provided during the dry season the soils should be placed in subclass U-IIId.

Included in this class are soils of the terraces; the high phases of the Saraburi series (map unit 5), the Deum Bang soils (map units 19, 20, 21 and 22), the dark variant of Ban Mi series (map unit 29), Chong Kae series (map unit 31) and the unnamed soil no. 5 (map unit 30). Total area 245,342 rai.

Capability subclass U-IVf, having severe flooding limitations

The soils in this subclass are poorly drained clay soils that are deeply flooded by river water for a prolonged period every year. The fertility of these soils ranges from moderately high in the non-acid soils of the river alluvium to moderately low in the acid sulphate soils. The soil reaction ranges accordingly from neutral to very strongly acid.

The soils are too wet for upland crops in the rainy season because of flooding from rivers, causing the soils to be wet until well into the dry season. Most of these soils dry out for only 3 months per year. Some vegetables can be grown in the dry season if water is available, however, extreme waterlogging

causes most to be unsuited for irrigated upland crops.

This subclass includes all soils of the river backswamps, all soils developed on brackish water deposits and the low lying soils on marl derived clay; the Ratchaburi series (map unit 12), Phimai series and its variant with medium sand fraction (map units 7 and 8), Saraburi series and its variant with medium sand fraction (map units 4 and 6), Bang Len series (map unit 13), Ayutthaya series and its clay loam overwash phase (map units 14 and 15), Sena series (map unit 16) and Khok Krathiam series (map unit 32). Total area 494,844 rai.

Capability subclass U-IVs, having severe soil limitations

This subclass consists of shallow, slightly undulating, well drained clay loam to clay soils overlying partially cemented white limestone gravel. Soil fertility is moderately high, though their high content of calcium carbonate limits the choice of crops. The shallowness of these soils and the moisture deficiency during the dry season are the main limiting factors for farming.

Only the Takhli series (map unit 27) has been included in this subclass. Total area 3,156 rai.

Capability subclass U-IVx, having salinity limitations

This subclass consists of deep, somewhat poorly drained, black, clay soils overlying soft, white marls. Soil fertility is moderately high. Their workability is somewhat difficult due to the very sticky consistence when wet and waterlogging is a problem during the rainy season or under irrigated conditions. The major limitation, however, is the strong salinity of these soils that was caused by the rising groundwater table after irrigation of the area.

It will be very difficult to grow upland crops under present conditions, however, if the salt problem could be solved, these soils might be placed in capability subclass IId.

Only the saline phase of the Lop Buri series is included in this subclass. Total area 6,938 rai.

Class U-VII: Soils having very severe limitations that make them unsuited for cultivated crops and that restrict their use largely to woodland, wildlife food and cover, water supply and recreation.

Capability subclass U-VIIe, having severe erosion limitations

This subclass consists of very shallow, stony soils on steep slopes. They are moderately low in fertility and excessively drained, however, the major limitation is high susceptibility to erosion. Only the soils on a little hill in the north of the survey area are included in this subclass. These soils are mapped in a Slope Complex (map unit 33). Total area 62 rai.

In addition to the subclasses described above, some combinations of sub-

classes have been given to areas that were mapped as associations of soil series and soil types or as an alluvial complex. The various soils in these mapping units occur in a very intricate pattern and could not be mapped separately at a scale of 1:50,000. These combinations are described below.

Capability subclasses IIId/IVf

This combination of subclasses includes various soils of different classes, however, the main constituents are subclasses U-IIId and U-IVf, already described in the foregoing. Due to the undulating relief of ridges and swales these soils are unsuited for irrigation.

This combination of subclasses was given to the soils of the Alluvial Complex (map unit 9). Total area 383,344 rai.

Capability subclasses U-IVd/IIIs

The kind of soils and limitations and management problems are similar to those discussed under the separate subclasses U-IVd and U-IIIs. In addition to the limitations mentioned there, the somewhat undulating relief renders these areas unsuited for irrigated farming.

Included in this unit of combined subclasses are various associations of Don Chedi series and types and variants of Deum Bang series (map units 23, 24 and 25). Total area 19,094 rai.

SUITABILITY OF SOILS FOR IRRIGATED RICE

Because of the very different soil and water requirements for rice, which is by far the most important crop in Central Thailand, and in regard to the irrigation project being almost completed, the soils have been grouped according to their suitability for irrigated rice 1/.

In addition to the assumptions made, that were necessary to group the soils in the land capability classes for upland crops, the following assumptions were made for the soil suitability grouping for irrigated rice:

1. The irrigation project is completed and sufficient irrigation water is provided to all parts of the area. Flooding will be sufficiently controlled to prevent damage to the crop by rapidly rising flood water.

1/ This system of soil suitability grouping was also used in other soil surveys of the Land Development Department in the Chao Phraya Irrigation Project area.

2. The possible extensive use of new high yielding varieties has not been taken into account. In that case yields and profits would be very much enhanced eventually and a regrouping of certain soils would be necessary.

The following 4 suitability groups have been recognized:

Group P-I Good land for irrigated rice, having no limitation.

Group P-II Moderately good land for irrigated rice, having moderate limitations.

Group P-III Marginal land for irrigated rice, having severe limitations.

Group P-IV Unsuitable land for irrigated rice.

Specifications for the suitability groups for irrigated rice are given in Table 6. All soils that cannot be placed in any of the first 3 groups according to these specifications are placed in group P-IV.

Table 6. Specifications for Soil Suitability Groups for Irrigated Rice

Soil and land characteristics	Class I	Class II	Class III
Texture of surface soil	clay loam, silty clay loam, silty clay, sandy clay, clay	sandy loam, loam, silt loam and finer textures	loamy sand to clay
Texture of subsurface soil	clay, silty clay	clay, silty clay, sandy clay, clay loam, silty clay loam	loam, silt loam, sandy clay loam and finer textures
Depth to subsurface horizon	< 30	< 50	< 50
Soil reaction	$5 < pH < 7.5$	$4.5 < pH < 8$	$3.5 < pH < 8$
Salinity EC x 10^6	$< 4{,}000$	$< 6{,}000$	$< 10{,}000$
Slope	$< \frac{1}{2}\%$	$< 1\%$	$< 2\%$
CEC of surface soil	> 8	> 3	
Micro-relief	$> 80\%$ of land is smooth; little levelling required	$> 80\%$ of land is smooth; little levelling required	$> 50\%$ of land is smooth; moderate levelling required
Drainage	somewhat poor to poor	somewhat poor to poor	moderately well to poor

Groups P-II and P-III have been subdivided in subgroups, grouping soils that have similar kinds of limitations affecting the suitability of the soils for irrigated rice. No subdivision was made for group P-I, having no limitations and for group P-IV, including soils with very severe limitations that prevent their use for irrigated rice.

The following limitations were used in the suitability rating for irrigated rice:

1. s - soil limitations in the root zone
   Soils with unfavourable texture, low fertility, high acidity, alkalinity of salinity, shallowness and stoniness.

2. p - moisture deficiencies
   Soils with permeable subsoils, hampering impounding of water on the ricefields.

3. t - topographic limitations
   Soils with undulating micro-relief, sloping soils or soils that are situated at relatively high elevations.

A separate map showing the suitability groups and subgroups for irrigated rice is included in this report. Only the major limitation of the soils within the subgroup is indicated.

The total acreage of the subgroups for the three irrigation tracts is shown in Table 7. In Table 10 the suitability subgroups are listed to show their relation to the soil mapping units, land capability classes for upland crops and land use planning classes.

Table 7. Total Area in Rais and Percentage of Total Area of Soil Suitability Groups and Subgroups for Irrigated Rice

Subclass	Pho Phraya		Sam Chuk		Sam Chuk-ext.		Total survey area	
	rai	%	rai	%	rai	%	rai	%
P-I	172,125	42.5	292,189	82.5	79,593	44.8	543,907	57.1
P-IIs	220,719	54.9	10,905	3.1	53,625	30.2	285,249	31.5
P-IIIt	6,500	1.5	-	-	-	-	6,500	0.7
P-IIIp	5,906	1.2	11,781	3.4	-	-	17,687	1.9
P-IIIs	-	-	531	0.2	12,844	7.3	13,375	1.5
P-IV	-	-	38,406	10.8	31,563	17.7	69,969	7.3
Total	405,250	100	353,812	100	177,625	100	936,687	100

Suitability groups and subgroups for irrigated rice in the survey area

Suitability Group P-I: Good land for irrigated rice, having no serious limitations

The soils in this group have no limitations that restrict their suitability for irrigated rice. This class consists of low and moderately low lying soils with more or less flat topography. The texture is predominantly clay, but clay loam surface layers occur in some soils. The drainage of the soils ranges from somewhat poor to poor. Water is easily impounded on these soils.

The soils in this group are the Nakhon Pathom, Saraburi, Phimai, Chai Nat, Ratchaburi, Bang Len, Ban Mi, Chong Kae and Khok Krathiam series (map units 2-8, 11-13, 20, 22, 29, 31 and 32), and the clay types of Deum Bang series. Present rice yields range from 35 to 50 tang/rai (2,100 to 3,000 kg/ha). Potential yields under good management and with application of fertilizers are much higher and could be 60 to 70 tang/rai (3,600 to 4,800 kg/ha) on respectively Nakhon Pathom and Saraburi soils (FAO 1968b). On most soils two transplanted rice crops could be grown annually, if irrigation water is provided. The very low lying Phimai, Ratchaburi, Bang Len and Khok Krathiam soils, however, are deeply flooded in the rainy season and a broadcasted rice crop should be alternated with a transplanted crop in the dry season. Total area 543,907 rai.

Suitability Group P-II: Moderately good land for irrigated rice

Suitability Subgroup P-IIs, having soil limitations

The soils in this subgroup have moderate limitations that restrict their suitability for irrigated rice. They are fine or medium textured with flat topography and slow internal drainage, but have moderately low or low fertility. The soils are either extremely acid or have low cation exchange capacities or both, or have slight salinity hazards. The drainage ranges from somewhat poor to poor and water is easily impounded on these soils.

The soils in this subgroup are the Ayutthaya and Sena series (map units 14-16), the Deum Bang sandy clay loam types (map units 19 and 21) and the unnamed soil unit no. 5 (map unit 30). Rice yields range from 25 to 35 tang/rai (1,500 to 2,100 kg/ha) being lowest on the Sena soils and highest on the Deum Bang soils. The use of fertilizers would increase the yields somewhat, though responses will be much lower than on the soils of group P-I. The Deum Bang soils have good possibilities for the cultivation of two transplanted crops per year under irrigation. The Ayutthaya and Sena soils are deeply flooded in the rainy season and here a broadcasted crop could be alternated with a transplanted crop. Total area 285,249 rai.

Suitability Group P-III: Marginal land for irrigated rice

Suitability Subgroup P-IIIt, having topographic limitations

This subgroup includes only the mottled variant of the Tha Muang series (map unit 10), having severe topographic limitations, that restrict their suitability for irrigated rice. The soils are situated on the natural levees of the Suphan Buri river. They have a rough surface and large parts are situated above the water delivery level of the irrigation canals. Total area 6,500 rai.

Suitability Subgroup P-IIIp, having moisture deficiencies and some topographic limitations

The subgroup includes only the Kamphaeng Saen series (map unit 1) on the natural levees of the semi-recent alluvium. The soils are moderately well drained and it is difficult to impound water on the fields causing a moisture deficiency for paddy. In addition, there is a topographic limitation, the soils have a slight micro-relief and are often situated above the water delivery levels of the present irrigation canals. Total area 17,687 rai.

Suitability Subgroup P-IIIs, having soil limitations

This subgroup includes the Don Chedi series and its mottled variant on the higher parts of the coalescing alluvial fans (map units 17-18 and 26). The soils have a moderately low fertility and are well to moderately well drained, thus it is difficult to impound water on the fields. In addition, most of the Don Chedi series has slight topographic limitations and occurs at relative high elevation relative to the water delivery level of the present irrigation laterals. Total area 13,375 rai.

Suitability Group P-IV: Unsuitable land for irrigated rice

The soils in this group have severe limitations that restrict their use for irrigated rice. Included are the soil complexes and associations (map units 9, 23-26 and 33), where the pronounced micro-relief is the main limitation. They consist of soils covering small areas at different elevations. Some of the associations, such as the association of Don Chedi series and its mottled variant, have also low fertility and are too well drained.

The Alluvial complex is used for rain fed rice and high yields may be obtained. However, due to the pronounced micro-relief irrigation would be very difficult.

Also included in this group is the saline phase of the Lop Buri series, and the Takhli series (map units 27 and 28). The rice yields on the saline Lop Buri soils are low, only 10 to 20 tang/rai (600 to 1,200 kg/ha), and it seems that more land will have to be abandoned due to increasing salinity. The Takhli series soils have undulating topography and are too well drained for irrigated rice. Total area 69,969.

SUITABILITY OF SOILS FOR SPECIFIC UPLAND CROPS

In view of the potential of the survey area for crop diversification, suitability ratings of the soils have been made for various upland crops. Only agronomic aspects of the soil-crop relationships have been considered and the different evaluations of the soils for specific upland crops are designed to give an indication of where some of the most common upland crops could be grown, with and without irrigation. It is not the purpose of this section to recommend the expansion of certain upland crops as this would depend on many factors other than those discussed in this report.

The ratings of the soils for specific upland crops are based for a large part on the experience obtained on the Central Region Agricultural Centre in Chai Nat, the Land Consolidation Project area in Channasut and the Thai-Chinese Land Cooperation Project in Sanphaya, where soils are similar to those in the survey area.

In Table 8 four suitability ratings are given for the soils of the survey area, both for irrigated and non-irrigated production of specific crops. Four degrees of suitability have been distinguished in rating the soils for each crop and these are defined as:

1. Suitable. Given to soils with favourable properties for the production of the crop. Plantgrowth is good and economic returns are at least sufficiently high to make a profit in most years.

2. Moderately suitable. Given to soils with properties that are only moderately favourable for the production of the crop. While the crop can be grown on these soils, yields are not high. Management requirements may be costly and returns are low.

3. Poorly suitable. Given to soils with properties that are unfavourable for the production of the crop. The crop may be lost in some years and yields are low. Management requirements are very costly and economic returns are mostly below costs.

4. Unsuitable. Given to soils that are not suited for the production of the crop. No yields can be obtained on these soils due to very severe hazards.

The suitability ratings of the soils for the non-irrigated crops are made on the assumption of traditional management. Animal power and simple farming equipment is used and some fertilizers are applied. With more advanced management, including control of plant diseases, use of adapted crop varieties, liming in some cases, proper tillage and the provision of drainage, the productivity of some soils for a wide range of upland crops could be raised. The ratings of the soils for irrigated crops are made on the assumption that sufficient irrigation water is provided throughout the year and that damaging floods are controlled. Also a higher level of management of soil and water is assumed. For instance planting on widely spaced ridges is necessary for most crops on the fine textured soils to avoid water-logging.

The main limiting factor for the production of all upland crops under irrigated and non-irrigated conditions is the deep flooding of most of the area

Table 8. Suitability Rating of the Soils for Specific Upland Crops

Soils \ Crops	Non-irrigated							Irrigated						
	Maize	Sorghum	Peanut	Soy bean	Mung bean	Sesame	Sugar cane	Maize	Sorghum	Peanut	Soy bean	Mung bean	Sesame	Sugar cane
1. Kamphaeng Saen series	1	1	1	1	1	1	1	1 1/	1	1	1	1	1	1
2. Nakhon Pathom series	4	3	4	3	3	3	2	3	2	3	2	2	3	1
3. Nakhon Pathom, variant without surface gley	4	3	4	3	3	3	2	3	2	3	2	2	3	1
4. Saraburi series	4	4	4	3	3	4	4	4	4	4	3	3	4	4
5. Saraburi, high phase	4	4	4	3	3	4	4	4	3	4	3	3	4	2
6. Saraburi, variant with medium sand fraction	4	4	4	3	3	3	4	4	4	4	3	3	4	4
7. Phimai series	4	4	4	4	4	4	4	4	4	4	4	4	4	4
8. Phimai, variant with medium sand fraction	4	4	4	4	4	4	4	4	4	4	4	4	4	4
9. Alluvial Complex	4	3/4	4	3/4	3/4	3/4	2/3	- 2/	-	-	-	-	-	-
10. Tha Muang, mottled variant	2	2	2	2	2	2	2	1 1/	1	1	1	1	1	1
11. Chai Nat series	2	3	4	3	3	3	4	2	2	3	2	2	3	4
12. Ratchaburi series	3	4	4	3	3	3	4	3	3	4	3	3	4	4
13. Bang Len series	4	4	4	4	4	4	4	4	4	4	4	4	4	4
14. Ayutthaya series	4	4	4	4	4	4	4	4	4	4	4	4	4	4
15. Ayutthaya, clay loam overwash phase	4	4	4	3	3	3	4	4	3	4	3	3	4	4
16. Sena series	4	4	4	4	4	4	4	4	4	4	4	4	4	4
17. Don Chedi series	3	3	2	2	2	2	3	2 1/	2	2	2	2	1	1
18. Don Chedi, mottled variant	3	3	2	2	2	2	2	2	2	2	2	2	1	1
19. Deum Bang sandy clay loam	4	4	4	3	3	3	3	4	3	3	3	3	3	2
20. Deum Bang clay	4	4	4	3	3	3	4	4	4	4	3	3	4	4
21. Deum Bang sandy clay loam, red mottled variant	4	4	4	3	3	3	4	4	3	3	3	3	3	2
22. Deum Bang clay, red mottled variant	4	4	4	3	3	3	4	4	4	4	3	3	4	4
23. Association of Don Chedi and Deum Bang sandy clay loam	3/4	3/4	2/4	2/3	2/3	2/3	3/4	- 2/	-	-	-	-	-	-
24. Association of Deum Bang sandy clay loam, red mottled variant and Don Chedi series	4/3	4/3	4/2	3/2	3/2	3/2	4/3	- 2/	-	-	-	-	-	-
25. Association of Deum Bang clay, red mottled variant and Don Chedi series	4/3	4/3	4/2	4/3	4/3	4/3	4/3	- 2/	-	-	-	-	-	-
26. Association of Don Chedi series and its mottled variant	3	3	2/3	2/3	2/3	2/3	3/2	- 2/	-	-	-	-	-	-
27. Takhli series	3	3	3	3	3	3	4	- 2/	-	-	-	-	-	-
28. Lop Buri, saline phase	4	4	4	4	4	4	4	4	4	4	4	4	4	4
29. Ban Mi, dark variant	4	4	4	3	3	3	4	4	3	3	3	3	3	3
30. Unnamed unit No. 5	4	4	4	3	3	3	3	4	3	3	3	3	3	2
31. Chong Kae series	4	4	4	3	3	3	4	4	3	3	3	3	3	3
32. Khok Khratiam series	4	4	4	4	4	4	4	4	4	4	4	4	4	4
33. Slope Complex	4	4	4	4	4	4	4	4	4	4	4	4	4	4

1/ It has to be noted that most of these soils are situated somewhat above water delivery levels of the irrigation canals and that high ratings are only given for those areas where irrigation water can be provided.

2/ No rating was given for soils that cannot be irrigated by gravity due to severe topographic limitations.

and water-logging in the remaining parts except for the river levees. For the production of non-irrigated crops, drought in the dry period and early rainy season is an additional major limitation. In rating the soils the length of the growing season of each crop has been taken into consideration and the soil was rated assuming that the crop concerned would be grown in the most favourable period of the year. For instance, on soils with prolonged flooding the most favourable growing period is in the early rainy season (May-July), while on soils that are flooded for a few weeks only, the crops should be harvested before the end of September. For soils that are not subject to flooding the period of August-October is probably most favourable as drought hazards are very limited in this period.

The most promising upland crops for the survey area are soy bean, mung bean, sorghum and sugar cane, which should all be irrigated in order to obtain high returns. Somewhat less possibilities exist for maize, peanut and sesame. Maize is extremely susceptible to water-logging on fine textured soils and for peanuts the fine textured soils give problems in harvesting as the soil sticks to the nuts and has to be washed off.

Except for sugar cane all these crops will mature within 90-120 days, which enable them to be harvested before the onset of the rains in May, if grown under irrigated conditions. Studies on time of planting have shown that planting in January is close to the optimum (JUDD 1971).

Other crops that might be grown in the area eventually, but have been left out of the suitability rating because of limited knowledge on the behaviour of these crops under existing soil and water conditions, are cotton, sunflower, jute and tobacco.

Table 8 shows clearly that the best possibilities for crop diversification in the survey area exist on the Nakhon Pathom soils, which cover a relatively large surface. Sugar cane, sorghum, soy beans and mung beans can be grown on these soils under irrigated conditions, but very good management is necessary. Some other soils (Kamphaeng Saen, Tha Muang and Don Chedi), though more suitable for upland crops, have only limited possibilities due to their small extent, relatively high elevation and use for village sites.

Finally it has to be stated that while some of the upland crops named in the foregoing might be grown successfully on certain soils, rice is still a very good alternative, even at low price levels. With much less labour, rice can be grown at lower costs than any of the upland crops.

LAND USE PLANNING CLASSES FOR IRRIGATED DOUBLE CROPPING

Based upon an interpretation of the soils (including relief and elevation) of the survey area and assuming that irrigation water is available, each soil has been placed into one of five land use planning classes. These classes are in effect defined patterns of irrigated double cropping and not ratings for degrees of production or cropping hazards as with land use capability classes. In defining

the designed cropping patterns the bi-seasonal aspect of agriculture in Central Thailand has been taken into account. For instance, certain soils, having severe drainage or flooding limitations are not suited for the cultivation of upland crops in the rainy season, but may be suited for growing upland crops in the dry season if irrigation water could be provided. Well drained soils are best suited for continuous cultivation of upland crops if the growing season could be extended into the dry season by irrigation.

The five kinds of double cropping patterns have also been used in previously surveyed parts of the northern Bangkok Plain where irrigation and land consolidation projects are being planned or implemented. These are defined as follows:

Class 1. Land to be used for upland crops only.

Class 2. Land to be used for upland crops only, but a rice crop in the rainy season is possible.

Class 3. Land preferably to be used for more than one irrigated rice crop per year, but irrigated upland crops could be grown during the dry season.

Class 4. Land to be used for two irrigated rice crops per year.

Class 5. Land unsuitable for irrigated crops, which can be used for either rice or upland crops in the rainy season only.

In Table 9 the land use planning classes for irrigated double cropping are listed together with the area covered by each in the three irrigation tracts. Table 10 lists the individual soil units and each class as well as the land capability subclasses for upland crops and the suitability subgroups for irrigated rice. rice.

Table 9. Total Area in Rais and Percentage of Total Area of Land Use Planning Classes for Irrigated Double Cropping

Land use planning classes	Pho Phraya		Sam Chuk		Sam Chuk-ext.		Total	
	rai	%	rai	%	rai	%	rai	%
1	5,906	1.2	12,312	3.6	12,532	7.1	30,750	3.4
2	6,500	1.4	-	-	-	-	6,600	0.7
3	26,875	6.2	60,969	17.2	1,874	1.1	89,718	9.6
4	365,969	91.2	242,125	68.4	131,656	74.1	739,750	78.9
5	-	-	38,406	10.8	31,863	17.7	69,969	7.4
Total	405,280	100.0	353,812	100.0	177,625	100.0	963,687	100.0

Table 10. List of Soil Mapping Units, Land Capability Subclasses for Upland Crops, Subgroups for Irrigated Rice and Land Use Planning Classes for Irrigated Double Cropping.

Soil name	Subclass for upland crops	Subgroup for rice irrigated	Land use planning class for irrigated double cropping
1. Kamphaeng Saen series	U-IIm	P-IIIp	1
2. Nakhon Pathom series	U-IIId	P-I	3
3. Nakhon Pathom, variant without surface gley	U-IIId	P-I	3
4. Saraburi series	U-IVf	P-I	4
5. Saraburi, high phase	U-IVd	P-I	4
6. Saraburi, variant with medium sand fraction	U-IVf	P-I	4
7. Phimai series	U-IVf	P-I	4
8. Phimai, variant with medium sand fraction	U-IVf	P-I	4
9. Alluvial Complex	U-IIId/IVf	P-IV	5
10. Tha Muang, mottled variant	U-IIf	P-IIIt	2
11. Chai Nat series	U-IIId	P-I	3
12. Ratchaburi series	U-IVf	P-I	4
13. Bang Len series	U-IVf	P-I	4
14. Ayutthaya series	U-IVf	P-IIs	4
15. Ayutthaya, clay loam overwash phase	U-IVf	P-IIs	4 4
16. Sena series	U-IVf	P-IIs	4
17. Don Chedi series	U-IIIs	P-IIIs	1
18. Don Chedi, mottled variant	U-IIIs	P-IIIs	3
19. Deum Bang sandy clay loam	U-IVd	P-IIs	4
20. Deum Bang clay	U-IVd	P-I	4
21. Deum Bang sandy clay loam, red mottled variant	U-IVd	P-IIs	4
22. Deum Bang clay, red mottled variant	U-IVd	P-I	4
23. Association of Don Chedi and Deum Bang sandy clay loam	U-IVd/IIIs	P-IV	5
24. Association of Deum Bang sandy clay loam, red mottled variant and Don Chedi series	U-IVd/IIIs	P-IV	5
25. Association of Deum Bang clay, red mottled variant and Don Chedi series	U-IVd/IIIs	P-IV	5
26. Association of Don Chedi series and its mottled variant	U-IIIs	P-IV	5
27. Takhli series	U-IVs	P-IV	5
28. Lop Buri, saline phase	U-IVx	P-IV	5
29. Ban Mi, dark variant	U-IVd	P-I	4
30. Unnamed unit No. 5	U-IVd	P-IIs	4
31. Chong Kae series	U-IVd	P-I	4
32. Khok Krathiam series	U-IVf	P-I	4
33. Slope Complex	U-VIIe	P-IV	5

Each land use planning class contains soils with similar suitability for specified kinds of double cropping under conditions of irrigation and water control. The agricultural planner should refer to the land capability subclasses, suitability subgroups for irrigated rice and suitability ratings for specific upland crops in order to estimate the best use of the individual soils of each group. He would thus be able to choose the cropping pattern best suited to the soils of a given tract of land. For example, map unit 5 is classed as U-IVd and P-I whereas unit 16 is classed as U-IVf and P-IIs, yet both are best suited in a cropping system with two rice crops per year.

The definition of class 3 given in foregoing reports on the soil survey in the northern Bangkok Plain 1/ as "land to be used for rice with irrigated upland crops as a second crop in the dry season" has been redefined. It appeared in experiments with irrigated upland crops in several parts of the Northern Chao Phraya Irrigation Project area, on both Nakhon Pathom and Chai Nat series soils (ILACO 1968 and THAI-AUSTRALIAN RESEARCH PROJECT 1968), that water-logging is a major problem for some soils and rice would be much easier to grow and be more profitable at present price levels than upland crops. Therefore, it seemed appropriate depending upon soil type, to recommend the soils in this class for double rice cropping in the first place, though upland crops can be grown in the dry season. In fact, these soils are best suited for the new high yielding rice varieties.

Class 2, occurring more extensively in the most northern part of the Chao Phraya Irrigation Project area, is very limited in extent in the Pho Phraya tract. The land in classes 1 and 2 is, for a large part, taken up by village and farm houses and little is available for irrigation. Also much of this land may be situated above water delivery levels of the irrigation canals.

From Table 9 it appears that 88.5 per cent or almost 830,000 rai of the total area is suited for double rice cropping (classes 3 and 4). Of this area about two thirds (capability subclass U-IVf) is used for broadcasted rice in the rainy season, but with irrigation water available a transplanted rice crop could be grown in the dry season. Of the remaining one third of this area (capability subclasses U-IIId and IVd), almost 90,000 rai could also be used for some irrigated upland crops in the dry season (class 3 or capability subclass U-IIId).

1/ Soil Survey Reports Nos. 37, 39, 40, 53, 54, 61, 66, 69. Soil Survey Division, Land Development Department, Bangkok.

BIBLIOGRAPHY

DUDAL, R. and F.R. MOORMANN, 1964. Major soils of Southeast Asia. Journal of Trop. Geogr. Vol. 18.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 1967. Soil Survey interpretation and its use. Soils Bulletin No. 8. Rome, Italy.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 1968a. Definitions of soil units for the soil map of the world and Addendum (May 1968). World Soil Resources Report No. 33. Rome, Italy.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 1968b. Technical Report No. 1, UNDP/SF Soil Fertility Research Project, Bangkok, Thailand.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 1969. Technical Report No. 2, UNDP/SF Soil Fertility Research Project, Bangkok, Thailand.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 1970a. Technical Report No. 3, UNDP/SF Soil Fertility Research Project, Bangkok, Thailand.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 1970b. Key to Soil Units for the Soil Map of the World, Soil Resources, Development and Conservation Service, Rome, Italy.

FUKUI, H. and E. TAKAHASHI, 1969. Rice Culture in the Central Plain of Thailand. The Southeast Asian Studies, Vol. 6, No. 4.

GALLUP, D.L. et al., 1967. Land Capability Classification. Soil Survey Report No. 60. Soil Survey Division and Land Classification Division, Department of Land Development, Bangkok, Thailand.

INTERNATIONAL LAND DEVELOPMENT CONSULTANTS (ILACO), 1968. Report on the feasibility of land consolidation, Arnhem, The Netherlands.

JUDD, P., 1971. Irrigated agriculture in the Central Plain of Thailand. Reprint of paper presented at Seminar on Contemporary Thailand, 6-9th September 1971, Canberra, Australia.

MOORMANN, F.R. and S. ROJANASOONTHON, 1968. Soils of Thailand. Soil Survey Division, Department of Land Development, SSR72, Bangkok, Thailand.

SMALL, L., 1971. Agronomic regions of the Northern Greater Chao Phraya Project area; in "An economic evaluation of the development of water control in the northern Chao Phraya region of Thailand". Draft of thesis, Bangkok.

THAI-AUSTRALIAN CHAO PHRAYA RESEARCH PROJECT, 1968. First report to the Ministry of Agriculture, Part A. Summary of results and their practical implications, Canberra 1968.

THORNTHWAITE, C.W., 1948. An approach toward a rational classification of climate. Geogr. Rev.

TURC, L., 1954. Le bilan d'eaux des sols. Sols Africains 3, P. 138-172.

UNITED STATES DEPARTMENT OF AGRICULTURE, 1951. Soil Survey Manual, USDA Handbook No. 18. Washington D.C., U.S.A.

UNITED STATES DEPARTMENT OF AGRICULTURE, 1960 and 1967. Soil Classification, a comprehensive system, 7th Approximation, and Supplement. Washington D.C., U.S.A.

UNITED STATES DEPARTMENT OF AGRICULTURE, 1966. Land-capability classification, Agriculture Handbook No. 210. U.S. Soil Conservation Service, Washington D.C., U.S.A.

UNITED STATES DEPARTMENT OF AGRICULTURE, 1967b. Soil laboratory methods and procedures for collecting soil samples. Soil Survey Investigations Report No. 1. U.S. Soil Conservation Service, Washington D.C., U.S.A.

UNITED STATES DEPARTMENT OF AGRICULTURE, 1970. Soil Taxonomy of the National Cooperative Soil Survey (draft). U.S. Soil Conservation Service, Washington D.C., U.S.A.

VAN DER KEVIE, W. et al, 1966, 1967 and 1968. Reports on the Soil Surveys of the Maharat, Channasut and Yang Manee Irrigation Tracts. Soil Survey, Reports Nos. 53, 61 and 66. Soil Survey Division, Department of Land Development, Bangkok, Thailand.

APPENDIX I

DESCRIPTION OF SOIL SERIES

In this appendix descriptions are given of all soil series, occurring in the project area. They are taxonomic units forming the main elements of the mapping units described in chapter II. One representative profile has been described for each series. The location of the profile has been indicated on the soil map with the last figure of the profile code number. No descriptions are given of the unnamed unit and most variants, types and phases.

In addition to the profile descriptions, tables with laboratory data are given in Appendix II for each profile.

Kamphaeng Saen series

The Kamphaeng Saen series are Non Calcic Brown Soils (Udic Haplustalfs), occurring on semi-recent river levees. They are deep, well to moderately well drained brown, fine loamy soils with an A-Bt-C horizon sequence. The Bt-horizon is weakly developed and is characterized by the occurrence of thin, patchy or broken clay coatings in pores and on ped faces. Soil reaction is slightly acid to neutral.

Typical profile: Kamphaeng Saen loam (Profile SW 51/14)

The following profile was examined near Ban Huai, Amphoe Si Prachan, at an elevation of 9 m. The surface is nearly flat with a slightly undulating microrelief. Fruit trees, sugar cane and bamboo are grown near the site.

Ap 0-28 1/ - Very dark greyish brown (10 YR 3/2 to 4/2) loam 2/; weak to moderate, medium subangular blocky; friable moist, slightly sticky, nonplastic wet; many fine mica flakes; many very fine interstitial, common very fine tubular pores; few fine and very fine roots; clear smooth boundary; pH 7.0 3/.

A3 28-46 - Dark brown (7.5 YR 4/2) loam; weak to moderate, medium subangular blocky; friable moist, slightly sticky, nonplastic wet; thin patchy clay coatings in pores and on ped faces; many fine mica flakes; many very fine interstitial, common very fine tubular pores; few very fine, fine and medium roots; gradual smooth boundary; pH 7.0.

B2t 46-100 - Strong brown (7.5 YR 5/6) clay loam; moderate medium subangular blocky; friable moist, slightly plastic, slightly sticky wet; thin broken clay coatings in pores and on ped faces; many fine mica flakes; many very

1/ All horizon measurements are in cm.
2/ Colours are for moist soil unless indicated otherwise.
3/ pH measured in the field with Truog-Hellige pH-kit.

fine interstitial, many very fine tubular pores; few very fine, fine and medium roots; gradual smooth boundary; pH 7.0.

C 100-160+ - Brown (7.5 YR 5/4) loam; weak medium subangular blocky; friable moist, slightly sticky, slightly plastic wet; many fine mica flakes; many very fine interstitial and few very fine tubular pores; few very fine roots; pH 8.0.

Range in characteristics

The colour of the A-horizon ranges from very dark greyish brown to greyish brown or brown. The surface texture ranges from sandy loam to clay loam and the subsoil texture from clay loam to light clay. Some brown mottles may occur in the lower part of the profile.

Nakhon Pathom series

The Nakhon Pathom series are Low Humic Gley Soils (Aeric Tropaqualfs), occurring on the higher parts of the backswamps on semi-recent alluvium. They are deep, somewhat poorly drained, dark greyish brown to brown, clayey soils with an Ap-Bt-C horizon sequence. The soils are mottled throughout, having some fine rounded iron-manganese concretions in the subsoil.

Typical profile: Nakhon Pathom silty clay loam (Profile SW 51/15)

The following profile was examined near Ban Don Phlu, Amphoe Si Prachan, at an elevation of 7 m. The surface is flat with termite mounds occurring in most fields. The land is used for transplanted rice with a second crop of high yielding varieties under irrigation.

Ap 0-15 - Dark greyish brown (10 YR 3/2 to 4/2) silty clay loam; many fine strong brown (7.5 YR 5/8) mottles; weak coarse subangular blocky; firm moist, slightly sticky, slightly plastic wet; common very fine interstitial, few very fine tubular pores; many very fine roots; clear smooth boundary; pH 8.0.

AB 15-53 - Brown (10 YR 4/3) silty clay; many, fine and medium yellowish brown mottles; weak coarse subangular blocky; firm moist, slightly sticky, slightly plastic wet; many fine interstitial, few very fine tubular pores; common very fine roots; clear smooth boundary; pH 8.0.

B2t 53-105+ - Dark greyish brown and brown (10 YR 4/2 and 4/3) silty clay; many fine and medium yellowish brown mottles; moderate medium subangular blocky, firm moist, slightly sticky, slightly plastic wet; thin patchy clay coatings in pores and on ped faces; common very fine interstitial, few very fine tubular pores; few small hard irregular calcium carbonate and few small soft black iron-manganese concretions; common very fine interstitial, few very fine tubular pores; few very fine roots; pH 8.0.

Range in characteristics

The colour in the A-horizon ranges from very dark greyish brown to greyish brown. The mottles in this horizon are very fine and occur mainly in pores, but are not present if the soils are cultivated to crops other than rice. The pH ranges from 5 to 6 in the surface and from 6.5 to 8 in the subsoil. Iron-manganese concretions are present in most profiles, while calcium carbonate concretions occur only in some soils. The texture of the surface layers may be loam, silt loam or silty clay loam, and the subsoil may be clay or silty clay.

Saraburi series

The Saraburi series are Alluvial Soils (Aeric Tropaquepts), occurring in backswamps on semi-recent alluvium. They are deep, somewhat poorly to poorly drained, dark greyish brown to brown or dark yellowish brown, clayey soils with distinct brown and yellowish brown mottles. The soils crack in the dry season and slickensides or pressure faces are present in the subsoil. Some soft and hard iron-manganese concretions occur in most soils. The soils are flooded by rain- and run-off water during the wet season.

Typical profile: Saraburi clay, high phase (Profile SW 51/9)

The following profile was examined near Ban Nong No Kaeng, Amphoe Muang, at an elevation of 8 m. The site is on flat land with some termite mounds, used for transplanted rice. The profile is somewhat poorly drained.

Apg 0-16 - Very dark grey (10 YR 3/1) moist, dark grey (10 YR 4/1) dry clay; many fine prominent yellowish red mottles, mainly in pores; very weak coarse subangular blocky; friable moist, slightly sticky, slightly plastic wet; many very fine and fine tubular, many fine and medium vesicular pores; many fine roots; fine sand on ped faces; clear smooth boundary; pH 5.5.

A3 16-56 - Very dark greyish brown (10 YR 3/2) and drak brown (10 YR 3/3) clay; many fine and medium yellowish brown mottles; weak fine subangular blocky; firm moist, sticky and plastic wet; few pressure faces; many very fine tubular, many very fine interstitial pores; few very fine roots; gradual smooth boundary; pH 5.0.

B2 56-100+ - Brown (10 YR 4/3) and dark brown (10 YR 3/3) clay; many fine and medium subangular blocky; firm moist, sticky and plastic wet; many very fine tubular and interstitial pores; few fine soft iron-manganese concretions; few very fine roots; pH 7.0.

Ranges in characteristics

The drainage and flood level varies. Soils at slightly higher elevation, such as the one described above, are somewhat better drained and numerous termite mounds may occur on these soils. In these cases a high phase has been mapped.

A weakly developed Bt-horizon with thin patchy clay coatings occurs in part of these soils.

The hues range from 10 YR to 2.5 Y. The soil reaction ranges from 5 to 7 in the surface horizon and from 6 to 8 in the subsoil. Calcium carbonate concretions are occasionally present in the subsoil.

Phimai series

The Phimai series are Alluvial Soils (Typic Tropaquepts), occurring in the lowest parts of backswamps on recent or semi-recent alluvium. They are deep, poorly drained, dark grey to grey, clayey soils with distinct strong brown and yellowish brown mottles. The soils crack in the dry season and slickensides or pressure faces are present in the subsoil. Some fine, hard iron-manganese concretions occur in most soils. The soils are deeply flooded with river water during the rainy season.

Typical profile: Phimai clay (Profile SW 51/17)

The following profile was examined near Ban Sao Thong, Amphoe Bang Pla Ma, at an elevation of 3 m. The site is on flat land, used for broadcasted rice.

Apg 0-18 - Dark grey (10 YR 4/1) clay; many fine and medium yellowish red mottles, mainly in root channels; few coarse yellowish red mottles on ped faces; weak to moderate coarse subangular blocky; very firm moist, sticky and plastic wet; many very fine interstitial, common very fine tubular pores; common very fine roots; clear, slightly wavy boundary; pH 6.0.

B1g 18-100 - Dark grey (10 YR 4/1) clay; common fine distinct yellowish brown mottles; weak to moderate medium angular blocky, breaking into fine angular blocks; firm moist, sticky and plastic wet; many pressure faces; common very fine interstitial and common very fine tubular pores; few very fine roots; clear smooth boundary; pH 7.0.

B2g 100-115+ - Grey (10 YR 5/1) clay; common fine distinct yellowish brown mottles; moderate medium angular blocky, breaking into fine angular blocks; firm moist, sticky and plastic wet; many slickensides and pressure faces; common very fine interstitial, few very fine tubular pores; very few very fine roots; pH 8.0.

Range in characteristics

The colours in the surface may range from very dark grey to dark grey or dark greyish brown and in the subsoil from dark grey to grey. The soil reaction ranges from 6 to 7 in the surface and from 6.5 to 8 in the subsoil. Sandy clay or sandy clay loam layers may occur in the deep subsoil, just as red mottles, if acid brackish water deposits occur at relatively shallow depth. Also calcium carbonate concretions may occur in the subsoil.

Tha Muang, mottled variant

This variant is an Alluvial Soil (Typic Ustifluvent), occurring on low lying levees on recent river alluvium. The soils are deep, moderately well drained, brown, fine loamy with mottles throughout. The soil reaction is slightly acid to neutral.

Typical profile: Tha Muang silt loam, mottled variant (Profile SW 51/16

The following profile was examined near Ban Bang Pla Ma, at an elevation of 4.5 m on flat land under fruit trees and bamboo.

A1 0-17 - Light brownish grey (10 YR 6/2) dry, dark greyish brown (10 YR 4/2) moist silt loam; very few fine distinct yellowish brown mottles, mainly along root channels; weak medium subangular blocky; slightly hard dry, friable moist, non-sticky, non-plastic wet; many fine mica flakes; many very fine interstitial, common very fine and few coarse tubular pores; many very fine and few fine roots; abrupt smooth boundary; pH 6.5.

C1 17-49 - Brown (7.5 YR 5/4) silt loam; many medium faint strong brown and brown mottles; moderate medium subangular blocky; friable moist, non-sticky, non-plastic wet; many fine mica flakes; many very fine interstitial, common very fine and fine tubular pores; many very fine and fine, few medium roots; gradual smooth boundary; pH 6.5.

C2 49-100+ - Brown (7.5 YR 5/4) silt loam; many medium faint strong brown and brown mottles; weak to moderate medium subangular blocky; friable moist, slightly sticky, non-plastic wet; very thin patchy clay coatings on some vertical ped faces; many fine mica flakes; many very fine interstitial, many very fine and few fine tubular pores; common soft black manganese mottles; many very fine, fine and common medium roots; pH 6.5.

Range in characteristics

Contrary to the normal Tha Muang series this variant has mottles throughout. The texture may range from loam to light clay or from silt loam to silty clay. The colours may vary from dark greyish brown to light brownish grey or brown in the surface and from brown to yellowish brown in the subsoil.

Chai Nat series

The Chai Nat series are Alluvial Soils (Aeric Tropaquepts), occurring on the lower parts of river levees on recent alluvium. They are deep, somewhat poorly drained, greyish brown to brown, clayey soils with distinct mottles and a weak to moderate structural development. Few, fine iron-manganese concretions occur in the subsoil.

Typical profile: Chai Nat silty clay loam (Profile SW 51/13)

The following profile was examined near Wat Kaeo, Amphoe Muang, Suphan Buri at an elevation of 3.5 m. The site is on nearly flat land used for transplanted rice.

Ap 0-13 - Greyish brown (10 YR 5/2) silty clay loam; many fine distinct strong brown mottles, mainly in root channels, few coarse prominent yellowish red mottles on ped faces; weak medium subangular blocky; firm moist, slightly sticky, slightly plastic wet; common very fine tubular pores; common very fine roots; gradual smooth boundary; pH 5.5.

AB 13-33 - Brown (7.5 YR 5/2) silty clay loam; many medium and coarse prominent yellowish red mottles, some in root channels, but mainly on ped faces; weak coarse subangular blocky; firm moist, slightly sticky, slightly plastic wet; many very fine interstitial, common very fine tubular pores; few very fine roots; clear smooth boundary; pH 6.0.

B1 33-55 - Brown (7.5 YR 5/2) silt loam; many coarse faint strong brown and few coarse prominent yellowish red mottles; weak coarse subangular blocky; firm moist, slightly sticky, slightly plastic wet; many very fine interstitial, common very fine tubular pores; few very fine roots; gradual smooth boundary; pH 6.0.

B2 55-85 - Brown (7.5 YR 5/2) clay loam; many medium distinct strong brown and many medium faint brown mottles; weak to moderate fine subangular blocky; friable moist, slightly sticky, slightly plastic wet; thin continuous clay coatings in some pores; many very fine interstitial and tubular, few fine tubular pores; few small slightly hard black manganese concretions; few medium roots; clear smooth boundary; pH 6.5.

B3g 85-100+ - Grey (10 YR 5/1) silty clay; many medium brown mottles; weak coarse subangular blocky, breaking into fine blocks; firm moist; sticky and plastic wet; common very fine tubular, few very fine interstitial pores; few slightly hard black manganese concretions; few very fine roots; pH 6.5.

Range in characteristics

The texture of the Chai Nat series may range from clay loam to light clay or silt loam to silty clay. The colours range from dark greyish brown to greyish brown or brown. The pH ranges from 5 to 6.5.

Ratchaburi series

The Ratchaburi series are Alluvial Soils (Aeric Tropaquepts), occurring in the backswamps of recent river alluvium. They are deep, somewhat poorly to poorly drained, greyish brown, clayey soils with distinct mottles and few hard iron-manganese concretions. The soils crack in the dry season and slickensides occur in the subsoil. In the wet season the soils are flooded with river water for a prolonged period.

Profile of Ratchaburi clay with subsoil of brackish water deposits (Profile SW 51/2)

The following profile was examined near Amphoe Bang Pla Ma on the right side of the Suphan Buri river at an elevation of 3.5 m. A buried, acid soil developed on brackish water deposits is underlying the Ratchaburi clay at 120 cm

causing a slight acidification and formation of red mottles in the lower layers of the river clay. The land is flat and used for broadcasted rice.

Apg 0-13 - Greyish brown (10 YR 5/2) dry to dark greyish brown (10 YR 4/2) moist clay; many fine distinct strong brown mottles, mainly in root channels and on ped faces; strong medium subangular blocky; very hard dry, very firm moist, sticky and plastic wet; common very fine, few fine tubular, few medium vesicular pores; common very fine roots; gradual, slightly wavy boundary; pH 5.5.

ABg 13-30 - Dark greyish brown to dark grey (10 YR 4/2 to 4/1) clay; many fine distinct strong brown mottles, mainly in root channels; weak coarse angular blocky; very firm moist, sticky and plastic wet; few very fine tubular pores; few very fine roots; gradual smooth boundary; pH 6.5.

B21g 30-68 - Dark greyish brown (10 YR 4/2) clay; very many fine and medium distinct strong brown mottles; weak coarse angular blocky, breaking into fine blocks; firm moist, sticky and plastic wet; common large slickensides; few very fine tubular and interstitial pores; few small slightly hard black manganese concretions; few very fine roots; gradual smooth boundary; pH 6.5.

B22g 68-89 - Dark greyish brown to dark grey (10 YR 4/2 to 4/1) clay; many fine and medium distinct brown mottles; weak to moderate fine angular blocky; firm moist, sticky and plastic wet; few slickensides; common very fine tubular and interstitial pores; few small slightly hard black manganese concretions; few very fine roots; clear smooth boundary; pH 6.5.

B23g 89-120 - Dark grey (10 YR 4/1) clay; many fine and medium prominent red mottles; weak to moderate fine angular blocky; firm moist, sticky and plastic wet; few slickensides; many very fine tubular, common very fine interstitial pores; few small slightly hard black manganese concretions; no roots; pH 5.5.

IIA1g 120-160 - Very dark grey (10 YR 3/1) clay; few medium prominent red and distinct brown mottles; few fine gypsum crystals; pH 5.5.

IIB2g 160-200+ - Greyish brown (10 YR 5/2) clay; many coarse prominent red, common medium prominent brownish yellow mottles; many fine gypsum crystals; pH 4.5.

Range in characteristics

Colours are mostly greyish brown or dark greyish brown but may be brown as well. The pH in the surface ranges from 5 to 6.5. If not underlain by an acid soil on brackish water deposits like the profile described, the pH increases in the deeper subsoil to 7 or 7.5. The soils may have red mottles in the deeper subsoil, if underlain by acid soils.

Bang Len series

The Bang Len series are Alluvial Soils (Typic Haplaquolls), occurring in a flood plain with old brackish water deposits. They are deep, poorly drained, clayey soils with a black to very dark grey surface of more than 25 cm thick, underlain by a strongly mottled, light grey cambic horizon, containing fine gypsum crystals mainly occurring just below the A-horizon. The soils crack in the dry season and slickensides are present in the subsoil. A soft, reduced, greenish grey clay occurs below 150 to 200 cm. The soils are deeply flooded for a prolonged period.

Typical profile: Bang Len clay (Profile SW 51/7)

The following profile was examined near Ban Pho Ta Khen at an elevation of 2 m. The site is on flat land, used for broadcasted rice.

Apg 0-8 - Very dark grey (10 YR 3/1) and black (N 2/0) clay; many fine distinct, strong brown mottles, mainly along rice root channels; weak, coarse subangular blocky, very firm moist, sticky and plastic wet; common very fine tubular and interstitial pores; many very fine roots; clear wavy boundary; pH 6.0.

ABg 8-38 - Very dark grey (10 YR 3/1) and grey (10 YR 5/1) clay; many medium distinct, yellowish brown and few fine distinct yellow mottles; moderate fine angular blocky; very firm moist, sticky and plastic wet; many pressure faces; common very fine tubular and interstitial pores; very few, very fine roots; clear smooth boundary; pH 6.5.

Abg 38-56 - Very dark grey (10 YR 3/1) clay; common fine faint yellowish brown mottles; weak fine and medium angular blocky; plastic and sticky wet; common slickensides, many pressure faces; common very fine tubular and interstitial pores; very few, very fine roots; clear wavy boundary; pH 7.5.

ABg 56-86 - Very dark grey (10 YR 4/1) clay; many medium distinct light olive brown mottles; moderate fine angular blocky; sticky and plastic wet; common slickensides, many pressure faces; many very fine tubular and interstitial pores; very few, very fine roots; clear wavy boundary; pH 7.8.

Bg 86-105+ - Light grey (10 YR 6/1) clay; few dark grey and many fine and medium distinct yellow mottles; moderate fine angular blocky; sticky and plastic wet; many large slickensides; common very fine tubular and interstitial pores; very few fine gypsum crystals; very few, very fine roots; pH 8.0.

Range in characteristics

The thickness of the A-horizon may vary from 25 cm to 80 cm. The gypsum content also varies from only a few fine crystals in some profiles to as much as 10 per cent in other soils.

Ayutthaya series

The Ayutthaya series are Alluvial Soils (Sulfic Tropaquepts), occurring in a flood plain with old brackish water deposits. They are deep, poorly drained, very fine clayey soils with an A-B-C horizon sequence. The A-horizon is a thick, very dark grey layer overlying a greyish brown B-horizon with a red mottled upper part containing fine gypsum crystals, and a yellow mottled lower layer, containing the mineral jarosite below 100 cm. The soft, reduced, dark grey C-horizon having a high content of pyrites, occurs below 150 cm. The soils crack and slickensides occur in the B-horizon. In the rainy season they are flooded with river water for a prolonged period. The soil reaction is very acid with a pH of 4.5 to 5 in the surface, decreasing to 3.5 or 4 in the lower part of the B-horizon and than increasing again to 6 in the reduced C-horizon. The soils are deeply flooded for a prolonged period.

Typical profile: Ayutthaya clay (Profile SW 51/6)

The following profile was examined near Makham Lom, Amphoe Bang Pla Ma, at an elevation of 2 m. The site is on flat land used for broadcasted rice.

Apg 0-11 - Very dark grey (10 YR 3/1-2) clay; many fine distinct strong brown mottles; weak platy and crumb in upper 5 cm, very weak coarse subangular blocky below, very firm moist, sticky and plastic wet; common fine tubular and interstitial pores; many fine and very fine roots; clear wavy boundary; pH 6.5.

ABg 11-46 - Very dark grey (10 YR 3/1 to 4/1) clay; many medium prominent red and few fine distinct strong brown mottles; weak fine subangular blocky; firm moist, sticky and plastic wet; many pressure faces; common very fine tubular and interstitial pores; few very fine roots; clear smooth boundary; pH 5.0.

Abg 46-72 - Very dark grey (10 YR 3/1) and black (10 YR 2/1) clay; common fine and medium distinct strong brown and many medium and coarse, prominent red mottles; weak fine angular blocky; firm moist, sticky and plastic wet; many pressure faces; common very fine tubular and interstitial pores; common fine gypsum crystals; very few, very fine roots; abrupt irregular boundary; pH 4.5.

Bg 72-110+ - Light brownish grey (10 YR 6/2) and greyish brown (10 YR 5/2) clay; few fine and medium distinct brownish yellow and many coarse prominent red mottles, few large very dark grey inclusions; weak coarse subangular blocky; firm moist, sticky and plastic wet; few very fine tubular and interstitial pores; few fine gypsum crystals; few very fine roots; pH 4.0.

Range in characteristics

The depth of the A-horizon may vary between 30 and 100 cm. The pH may range from 4.5 to 6 in the surface and from 3.5 to 5 in the subsoil. Pale yellow jarosite mottles do not always occur below 100 cm.

Sena series

The Sena series are Alluvial Soils (Sulfic Tropaquepts), occurring in a flood plain with old brackish water deposits. They are deep, poorly drained, very fine clayey soils with an A-B-C horizon sequence. The A-horizon is a thick, very dark grey layer overlying a greyish brown B-horizon with a red mottled upper part containing fine gypsum crystals, and a yellow mottled lower layer, containing the mineral jarosite, having its upper boundary between 40 and 100 cm. The soft reduced, dark grey C-horizon having a high content of pyrites, occurs below 150 cm. The soils crack and slickensides occur in the B-horizon. The soil reaction is very acid with a pH of 4 to 5 in the surface, decreasing to 3.5 or 4 in the lower part of the B-horizon and than increasing again to 6 in the reduced C-horizon. The soils are deeply flooded with river water for a prolonged period.

Typical profile: Sena clay (Profile 51/10)

The following profile was examined near Bang Li, Amphoe Song Phi Nong, half kilometer West of the survey area at an elevation of 3.5 m. The site is on flat land, used for broadcasted rice.

Apg 0-12 - Very dark grey (10 YR 3/1) clay; few fine distinct reddish brown mottles, mainly in root channels; strong granular on surface, weak fine subangular to angular blocky below; very firm moist, sticky and plastic wet; few fine interstitial and tubular pores; many fine and very fine roots; clear smooth boundary; pH 5.0.

A12g 12-34 - Very dark grey (10 YR 3/1) and dark grey (10 YR 4/1) clay; common medium distinct red and very few medium distinct yellowish brown mottles; very weak coarse prismatic, breaking into moderate medium and fine angular blocks; very firm moist, sticky and plastic wet; few pressure faces; common fine and very fine tubular pores; clear wavy boundary; pH 4.5.

B21g 34-64 - Grey (10 YR 5/1 and 6/1) clay; many medium prominent red and few medium prominent yellowish brown mottles; moderate coarse prismatic structure, breaking into moderate medium angular blocks; firm moist, sticky and plastic wet; thin humus-clay coatings on vertical prisma faces; few slickensides; many very fine and few fine tubular pores; common very fine gypsum crystals in lower part of horizon; clear wavy boundary; pH 4.0.

B22g 64-150 - Greyish brown to brown (10 YR 5/2 to 7.5 YR 5/2) clay; common coarse prominent brownish yellow and pale yellow mottles, mainly in vertical root channels and on ped faces; moderate very coarse prismatic, breaking into moderate medium angular blocks; sticky and plastic wet; patchy thin dark humus-clay coatings on vertical prisma faces; few slickensides; common very fine horizontal tubular pores, many very fine and few fine vertical tubular pores; many very fine gypsum crystals, mainly in upper part of horizon; very few very fine roots; gradual smooth boundary; pH 4.0.

B23g 150-180 - Greyish brown (10 YR 5/2) clay; few coarse prominent pale yellow and common coarse prominent brownish yellow mottles; sticky and plastic wet, nearly ripe, few fine partly decomposed roots; pH 4.0.

C1g 180-280 - Dark greyish brown (10 YR 5/2) clay; no mottles; sticky and plastic wet, half ripe; few root channels with coarse gypsum crystals; few fine partly decomposed roots; thin layer with coarse organic matter at 270 cm; pH 6.0.

C2g 280-380 - Dark brown (10 YR 3/3) slightly peaty clay; no mottles; sticky and plastic wet, nearly ripe; pH 6.5.

C3g 380-410 - Dark grey (10 YR 4/1) clay; no mottles; sticky and plastic wet, half ripe; little organic matter. pH 7.0.

Range in characteristics

Thickness of catclay horizon may vary, but upper boundary of this horizon should always be between 40 and 10 cm. The content of gypsum varies also from a few crystals to more than 5 per cent in the upper B-horizon. In some soils red mottles do not occur.

Don Chedi series

The Don Chedi series are grey Podzolic Soils (Ustoxic Dystropepts), occurring on old levees on coalescing alluvial fans. They are deep, well to moderately well drained, fine loamy soils with medium to coarse, angular sand fraction. The soil has a dark A-horizon overlying a brown or strong brown B-horizon.

Typical profile: Don Chedi sandy loam (Profile SW 51/2)

The following profile was examined near Ban Nong Krok, Amphoe Don Chedi, at an elevation of 11 m. The site is on flat land with slightly undulating microrelief, which is used for bananas and fruit trees.

Ap 0-32 - Very dark greyish brown (10 YR 3/2) sandy loam; very weak fine crumb; soft dry, very friable moist, non-sticky, non-plastic wet; many very fine and fine interstitial and tubular pores; common fine and very fine roots; gradual smooth boundary; pH 5.5.

B1 32-64 - Dark brown (7.5 YR 4/2) sandy clay loam; many fine faint dark brown mottles; weak fine crumb and subangular blocky; soft dry, friable moist, non-sticky, non-plastic wet; many fine and very fine interstitial and tubular pores; common very fine roots; gradual smooth boundary; pH 5.0.

B2 64-104 - Yellowish red (5 YR 4/6) and brown (7.5 YR 5/3) sandy clay loam; weak coarse subangular blocky; hard dry, friable moist, non-sticky; non-plastic wet; common very find interstitial; many very fine tubular, few very fine vesicular pores; few very fine roots; pH 5.0.

Range in characteristics

There is a considerable range in hues from 5 YR to 10 YR, however chromas are always 2 or higher. The pH range is from 4.5 to 7. Occasionally sandy clay textures may occur in the subsoil. Also weak mottling may occur.

Deum Bang series

The Deum Bang series are Low Humic Gley Soils (Aeric Tropaqualfs) occurring on the lower parts of the coalescing alluvial fans. They are deep, somewhat poorly drained, strongly mottled, greyish brown to brown, clayey soils with an A-Bt-C horizon sequence. Most of the sand fraction consists of medium, angular quartz grains. The A-horizon has somewhat darker colour than the underlying, weakly developed B-horizon, which is characterized by the presence of thin patchy clay coatings on red faces and in some pores. Small, rounded, hard iron-manganese concretions occur frequently in these soils. The soil reaction is moderately acid in the surface and becomes neutral or mildly alkaline in the deeper subsoil.

Typical profile: Deum Bang sandy clay loam (Profile SW 51/8)

The following profile was examined near Ban Nong Makhwit, Amphoe Don Chedi, at an elevation of 8 m. The site is on nearly flat land with some termite mounds, used for transplanted rice.

Ap 0-10 - Very pale brown (10 YR 7/3) dry, brown (10 YR 4/3) moist sandy clay loam; many fine distinct strong brown mottles, mainly in root channels; weak medium subangular blocky, weak platy in upper few centimeters; hard dry, firm moist, non-sticky and non-plastic wet; few very fine tubular and few fine vesicular pores; very few small hard iron-manganese concretions; many fine and very fine roots; clear smooth boundary; pH 5.5.

B1 10-20 - Brownish yellow (10 YR 6/6) dry, yellowish brown (10 YR 5/6) moist clay; many medium distinct, strong brown and common medium faint light brownish grey mottles; plough pan; massive; very hard dry, very firm moist, slightly sticky, slightly plastic wet; few small hard iron-manganese concretions; few very fine tubular pores, few very fine roots; clear smooth boundary; pH 5.5.

B12 20-40 - Pale brown (10 YR 6/3) dry, yellowish brown (10 YR 5/4) moist clay; many medium faint strong brown mottles; moderate coarse subangular blocky; hard dry, firm moist, slightly sticky, slightly plastic wet; many small pressure faces; few fine tubular, many fine and very fine interstitial pores; frequent small hard iron-manganese concretions; few very fine roots; clear smooth boundary; pH 6.0.

B13 40-63 - Light olive brown (2.5 Y 5/4) and greyish brown 2.5 Y 5/2) clay; common fine and medium distinct yellowish brown mottles; weak coarse subangular blocky; firm moist, slightly sticky, slightly plastic wet; very thin patchy clay coatings; many pressure faces; common very fine tubular pores; few small hard iron-manganese concretions; very few, very fine roots; gradual smooth boundary; pH 6.0.

B2t 63-100+ - Greyish brown (2.5 Y 5/2) clay; many medium faint yellowish brown mottles; weak coarse subangular blocky; firm moist, slightly sticky and slightly plastic wet; thin patchy clay coatings; many pressure faces; few very fine tubular pores; very few small iron-manganese concretions; very few very fine roots; pH 6.5.

Range in characteristics

The texture of the surface soil ranges from sandy loam to clay. The subsoil texture may be sandy clay. A sandy clay loam type, with medium textured surface soil and a clay type with fine textured surface soil are distinguished. Red mottled variants of both types are distinguished if red mottles occur in the subsoil.

Lop Buri series

The Lop Buri series are Grumusols (Typic Pelluderts) occurring on marl terraces. They are deep, somewhat poorly drained, black, clayey soils with an A-C horizon sequence. The soils develop deep cracks in the dry period and many intersecting slickensides and pressure faces occur throughout. The clay is mainly montmorillonite and very sticky when wet. Structural development is normally very strong in the surface, except in the survey area where many soils have developed a crust due to high salinity. The soil contains many fine calcium carbonate concretions and some fine iron-manganese nodules. The soil reaction is mildly to moderately alkaline.

Typical profile: Lop Buri clay, saline phase (Profile SW 51/18)

This profile was examined near Ban Khok Samrong, Amphoe U Thong, at an elevation of 14 m. The site is on flat land, partly in use for rice cultivation, partly bare were the land was abandoned due to strongly increased salinity.

Ap 0-12 - Very dark grey (10 YR 3/1) clay; few very fine strong brown mottles in root channels; weak to moderate medium subangular blocky, granular in spots; friable moist; very sticky, very plastic wet; common very fine tubular and interstitial pores, few fine tubular and interstitial pores; common very fine roots; clear smooth boundary; pH 8.0.

A12 12-77 - Black (10 YR 2/1) clay; many coarse sand grains; moderate medium subangular blocky, breaking into fine blocks; friable moist, very sticky and very plastic wet; many pressure faces and slickensides; many very fine interstitial and few very fine tubular pores; many very small ($\frac{1}{2}$ to 2 mm) lime concretions, few small, round, hard, black manganese concretions; common very fine roots; gradual smooth boundary; pH 8.0.

A13 77-130 - Very dark grey (10 YR 3/1) moist clay; many coarse sand grains; moderate medium subangular blocky; friable moist, very sticky and very plastic wet; many pressure faces, few large slickensides; common very fine interstitial and few fine tubular pores; common fine and medium irregular lime concretions; few fine rounded, hard manganese concretions; few very fine roots; diffuse smooth boundary; pH 8.0.

AC 130-190+ - Dark grey (10 YR 4/1) to dark greyish brown (10 YR 4/2) clay; very many small, and large calcium carbonate concretions; few rounded, small, hard iron-manganese concretions; many coarse sand grains; pH 8.0.

Range in characteristics

The soils may be very saline and in this case have no granular structure in the surface, but a hard crust instead.

Ban Mi, dark variant

This variant is a Grumusol (Typic Pelludert) occurring on terraces of montmorillonitic, marl-derived clay. They are deep, somewhat poorly drained, very dark grey, clayey soils. The clay is very sticky when wet. Wide cracks develop in the dry season and many slickensides and pressure faces occur in the subsoil. The soil is self-mulching with a granular structure in the surface. Few, fine iron-manganese concretions occur throughout. Soil reaction is slightly acid to mildly alkaline.

Typical profile: Ban Mi clay, dark variant (Profile 51/3)

The following profile was examined near Ban Khonti, Amphoe U Thong, at an elevation of 13 m. The site is on flat land used for transplanted rice.

Apg 0-25 - Black (10 YR 2/1) clay; common fine prominent yellowish red mottles in root channels and on ped faces; granular on surface, weak coarse angular blocky below; very hard dry, very firm moist, very sticky and very plastic wet; wide cracks; few fine and very fine tubular and interstitial pores, common fine and very fine roots; gradual smooth boundary; pH 6.5.

A3g 25-90 - Very dark grey (10 YR 3/1) clay, black (10 YR 2/1) inclusions; weak very fine angular blocky; firm moist, very sticky, very plastic wet; many pressure faces and slickensides; many very fine interstitial pores; few small iron-manganese concretions; few very fine roots; gradual smooth boundary; pH 6.5.

A3g 90-110+ - Very dark grey (2.5 Y 3/1) clay; weak very fine angular blocky; firm moist; very sticky, very plastic wet; many pressure cutans and slickensides; many very fine interstitial pores; few small iron-manganese, few small calcium carbonate concretions; few very fine roots; gradual smooth boundary; pH 8.0.

Range in characteristics

In the normal Ban Mi series the colours are dark grey with some brown mottles. Calcium carbonate concretions may occur in the deeper subsoil.

Chong Kae series

The Chong Kae series are Grumusols (Aquentic Chromuderts) occurring on terraces of montmorillonitic, marl-derived clay. They are deep somewhat poorly drained, greyish brown, clayey soils with fine red mottles. The clay is very sticky when wet. Cracks develop in the dry season and many slickensides and pressure faces occur in the subsoil. The soil is self-mulching with a granular structure in the surface. The soil reaction is moderately acid.

Typical profile: Chong Kae clay (Profile C 3/8)

The following profile was examined near Ban Sa Krabuang, Amphoe Ban Mi, outside the survey area. The site is at an elevation of 13 m on flat land used for transplanted rice.

Apg 0-21 - Dark grey (10 YR 4/1) clay; common fine and medium prominent strong brown mottles; strong fine and medium granular on surface, weak medium angular blocky below; very hard dry, very firm moist, very sticky and plastic wet; wide cracks; many fine and medium interstitial, common coarse vesicular pores; many very fine and fine roots; clear smooth boundary; pH 5.5.

B21g 21-46 - Greyish brown (10 YR 5/2) clay; many fine prominent red (10 R 4/6) and few fine prominent yellowish red (5 YR 4/8) mottles; moderate fine to very fine angular blocky; very firm moist, very sticky and very plastic wet; cracks closing in lower part of horizon; common pressure faces; many fine and medium interstitial pores; few very fine roots; gradual smooth boundary; pH 5.5.

B22g 46-100+ - Greyish brown (10 YR 5/2) clay; many fine and medium prominent red mottles; moderate very fine and fine angular blocky; very sticky and very plastic wet; many pressure faces and large slickensides: few fine tubular and interstitial pores; few very fine roots; pH 6.0.

Range in characteristics

The red mottles in the subsoil may have hues ranging from 10 R to 5 YR. Few fine iron-manganese nodules may occur.

Khok Krathiam series

The Khok Krathiam series are Grumusols (Typic Pelluderts) occurring in the flood plain bordering the terraces on marls and limestone. They are deep, poorly drained, very dark, very fine clayey soils developed on montmorillonitic clays. The soils crack in the dry season and slickensides and pressure faces occur in the subsoil. Some fine, hard, iron-manganese concretions are mostly present. The reaction is moderately acid to neutral. The soils are flooded for a prolonged period during the wet season.

Typical profile: Khok Krathiam clay (Profile 51/4)

The following profile was examined near Ban Khonti, Amphoe U Thong, at an elevation of 9 m. The site is on flat land used for broadcasted rice.

Apg 0-20 - Very dark grey (10 YR 3/1) clay; many fine, medium and coarse prominent strong brown mottles in root channels and on ped faces; weak medium and coarse angular blocky; very hard dry, very sticky and very plastic wet; wide cracks; few medium vesicular, common fine and medium tubular and interstitial pores; many fine and very fine roots; clear smooth boundary; pH 6.0.

A31g 20-60 - Very dark grey (10 YR 3/1) and very dark greyish brown (10 YR 3/2) clay; few medium faint brown mottles; weak very fine angular blocky; firm moist, very sticky and very plastic wet; few slickensides; many very fine interstitial pores; few very fine roots; clear wavy boundary; pH 6.0.

A32g 60-80 - Very dark grey (10 YR 3/1) clay; weak very fine angular blocky; firm moist, very sticky, very plastic wet; large slickensides, common small pressure faces; many fine interstitial pores; few very fine roots; clear wavy boundary; pH 6.0.

Abg 80-115+ - Black (10 YR 2/1) clay; moderate very fine angular blocky; firm moist, very sticky; very plastic wet; many pressure faces, few large slickensides; many very fine interstitial pores; no roots; pH 7.0.

Range in characteristics

The colour of the soils may be very dark grey or black (10 YR 3/1 to 10 YR 2/1). The soils are somewhat similar to the Ban Mi, dark variant but more poorly drained and deeper flooded.

APPENDIX II

LABORATORY DATA AND INTERPRETATION

ANALYSES AND METHODS

Certain chemical and mechanical analyses were made in the laboratory of the Soil Survey Division, Land Development Department. The analyses and methods used are as follows:

1. Particle size. Air-dry soil is ground and passed through a 2 mm. sieve; coarse fragments are estimated by weighing; USDA 3-fraction grading of fine soil is done by pipette method after dispersing with sodium hexametaphosphate (3A1).

2. pH. pH is determined with a glass electrode and KCl reference electrode in 1:1 soil:water and 1:1 soil:normal KCl suspensions (8C1a, 8C1c).

3. $CaCO_3$. A simple "acid neutralization" method is used to give an approximate measurement of the calcium carbonate content (6 E1e).

4. Moisture. A sub-sample of soil is dried in an oven and reweighed to estimate percentage moisture in the air-dry soil (4B5).

5. Conductivity. The electrical conductivity (EC) is determined on a 1:5 soil: water mixture.

6. Carbon. The Walkley-Black wet oxidation method is used. Finely ground soil is mixed with potassium dichromate and sulphuric acid and excess dichromate is titrated (6 A1a).

7. Nitrogen. A macro-Kjeldahl method is used; 5 g soil being digested with potassium and copper sulphate plus sulphuric acid. The ammonia is distilled off into excess acid and the unused acid titrated (6 B1).

8. Exchangeable cations. Ca-Mg-K-Na are determined by extracting with four aliquots of normal ammonium acetate. Ca and Mg are measured by Atomic Absorption Spectroscopy and K and Na by Flame Photometry.

9. Extractable Acidity. A sub-sample is leached with a 0.5 normal solution of barium chloride mixed with triethanolamine adjusted to pH 8.0. The leachate is then titrated with acid (6 H1).

10. CEC. A sub-sample of soil is mixed with normal ammonium acetate (pH 7.0), shaken and allowed to stand over-night. The suspension is filtered under suction and the soil leached with more ammonium acetate solution. Excess is washed out with ethyl alcohol and the absorbed ammonia displaced by acidified sodium chloride solution. The ammonia is then determined by distillation into excess acid (as for Nitrogen determination) (5 A1 and 5 A1b).

11. Phosphorus. Bray's No. 2 method is used to determine "available" P. Soil is extracted with a solution containing 0.03 N ammonium fluoride and 0.1 N hydro-

chlorid acid. P is determined by colorimetric molybdenum blue method.

12. Potassium. A sub-sample of soil is shaken with normal ammonium acetate and the extracted K measured by flame photometry.

The numbers and letters between brackets refer to more detailed descriptions in the Soil Survey Investigations Report (USDA, 1967).

The samples of the Chong Kae series were analysed at the Royal Tropical Institute in Amsterdam, The Netherlands.

DISCUSSION OF THE ANALYSIS RESULTS

The laboratory data confirm that the majority of soils in the project area have clay textures, with very high contents of fine particles (0.002 mm) for the soils on brackish water deposits, marl-derived clays and riverine back-swamp deposits of the recent and semi-recent alluvium.

Soil reaction varies considerably between extremely acid in the acid sulphate soils in the south of the project area to mildly alkaline in some soils of the river alluvium.

Carbon content is relatively low in all soils and rarely exceeds 1.5 per cent. There is a good relation with drainage, the poorer drained soils having the highest carbon content. Nitrogen content is accordingly low, notwithstanding the low C/N ratios, that lie mostly below 10.

Cation exchange capacity (CEC) is moderate to low in most soils, depending on clay content, except for the soils on marl-derived clays in the southwest of the survey area where CEC levels are high, due to the presence of montmorillonite clay.

Of the exchangeable bases calcium is the most important in most soils, though in the soils on brackish water deposits magnesium is well represented. Sodium is rather high in the Lop Buri series, though not as high as was expected from the presence of salt on the surface of many of these soils.

Base saturation is moderate to high in most soils. Even in the acid sulphate soils it is higher than 40 to 50 per cent, notwithstanding the extremely low pH in most horizons. It is expected that this is due to the fact that, with the analytical methods used, cations of soluble salts were also measured. As soluble salts were not determined separately, the figures for exchangeable bases could not be corrected, and might be considerably lower than listed in the table for some samples.

Of the available plant nutrients potassium is well represented in most soils, but there is often a shortage of nitrogen and phosphorus. The content of phosphorus in some soils is influenced by fertilizer applications, in which case much higher quantities are found than normally available (f.i. Kamphaeng Saen,

Tha Muang, Nakhon Pathom and Don Chedi series).

The laboratory data are particularly useful in answering questions in soil classification and correlation. Certain determinations, such as cation exchange capacity, base saturation, soil reaction, potassium, phosphorus and nitrogen status are useful in assessing the need for fertilizers and liming. Table 11 gives average tentative levels of selected chemical characteristics that might be useful in evaluating the fertility of a soil and its land capability class. However, it must be taken into consideration that some crops have special requirements, which must be carefully considered in evaluating the suitability of soils for those crops.

Table 11. Levels of Selected Chemical Characteristics Useful for the Evaluation of Relative Nutrient Status of the Soils

Relative nutrient status	pH 1:1 H_2O	Carbon %	Milli-equiv./100 gr.			Base Sat. %	P (Bray No. 2) ppm	ECe x 10^6
			CEC	Ca	K			
good	5.5-7.5	> 1.5	>10	> 5	> 0.3	>50	>25	<2000
moderate	4.5-5.5 7.5-8.0	0.8-1	5-10	2-5	0.1-0.3	20-50	10-25	2000-5000
poor	<4.5 and >8	<0.8	<5	<2	<0.1	<20	<10	>5000

In Table 12 the results of the laboratory analyses are given for every profile described in Appendix I.

TABLE 12

RESULTS OF SOIL ANALYSIS

(OVEN DRY BASIS)

SOIL SURVEY LABORATORY, SOIL SURVEY DIVISION, DEPT. OF LAND DEVELOPMENT

SOIL NAME AND LABORATORY NUMBER	HORIZON	DEPTH (cm)	PARTICLE SIZE ANALYSIS				pH		$CaCO_3$	CONDUCTIVITY 1:5 EC x 10^6	CARBON	NITROGEN	EXCHANGE CAPACITY AND CATIONS (Milli-equiv / 100 g)									BASE SATURATION % B x 100 / B + A	P p.p.m. BRAY No. 2	K p.p.m. AMMON ACETATE
			COARSE FRACTION %	USDA GRADING % SAND	SILT	CLAY	1:1 H_2O	1:1 KCl	%		%	%	Ca	Mg	K	Na	SUM BASES (B)	EXTR ACIDITY (A)	SUM (B + A)	CEC SOIL	CEC CLAY			
Kamphaeng Saen	Ap	0-28		38	44	18	6.8	6.1		48	0.88		9.0	1.5	0.7	0.2	11.4	2.6	14.0	11.0	61	81	123	271
P.a. - 942-945	A3	28-46		35	44	21	6.9	6.1		33	0.31		7.5	4.6	0.4	0.3	12.8	2.2	15.0	9.4	45	85	14	188
	B2t	46-100		22	46	32	7.3	6.5		80	0.18		8.0	4.3	0.6	0.8	13.7	2.3	16.0	13.1	41	86	7	274
	C	100-160		36	38	26	8.1	7.0		52	0.13		6.6	3.7	0.7	0.5	11.5	1.4	12.9	10.2	39	9	9	277
Nakhon Pathom	Ap	0-15		17	47	36	7.0	6.8	1.0	100	1.01		17.6	3.5	0.6	0.9	22.6	4.1	26.7	20.1	56	85	28	262
P.a. - 946-948	AB	15-53		12	45	43	8.3	7.3	3.3	120	0.51		33.4	6.9	0.8	2.4	43.5	1.9	45.4	28.8	60	96	143	404
	B2t	53-105		11	43	46	8.7	7.5	6.0	54	0.23		29.5	10.1	0.7	8.7	49.0	1.8	50.8	25.9	56	96	70	279
Saraburi, high	Apg	0-16		14	39	47	4.8	3.7		6	1.19	0.11	9.7	5.4	0.3	0.9	16.3	13.0	29.3	20.3	43	55	3	111
phase	A3	16-56		12	33	55	4.8	3.5		6	0.41	0.09	12.1	6.4	0.2	1.7	20.4	12.9	33.3	25.4	46	61	4	81
P. 982/68-984/68	B	56-100		8	42	50	5.9	4.9		53	0.11	0.04	11.6	8.6	0.2	4.9	25.3	4.9	35.1	21.7	43	72	3	61
Phimai	Apg	0-18		4	36	60	5.0	4.0	1.04	170	1.66		15.0	3.7	0.5	1.0	20.2	16.3	36.5	32.2	54	55	3	202
P.a. - 952-954	Blg	18-100		2	27	71	7.2	6.0	2.09	126	0.30		29.9	5.9	0.3	1.5	33.6	5.5	39.1	34.1	48	86	7	146
	B2g	100-115		1	31	68	7.0	6.5	1.34	215	0.21		23.3	5.2	0.2	1.6	30.3	3.6	33.9	29.9	38	89	5	97
Tha Muang, mottled	Ap	1-17		16	63	21	6.0	4.9		126	1.30		7.9	2.5	0.4	0.5	11.3	9.1	20.4	15.2	72	55	114	182
variant	C1	17-49		27	53	20	5.8	5.2		700	0.28		6.6	3.1	0.3	2.7	12.7	4.1	16.8	9.8	49	76	10	155
P.a. - 949-951	C2	49-100		18	55	27	6.1	5.7		1400	0.21		6.3	5.1	0.3	6.8	18.5	4.9	23.4	11.6	43	79	18	104
Chai Nat	Ap	0-13		15	56	29	5.0	4.1		56	0.69		7.3	1.9	0.2	0.5	9.9	9.2	19.1	13.4	46	52	11	97
P.a. - 937-941	AB	13-33		12	57	31	5.6	4.3		32	0.39		8.4	2.9	0.1	0.5	11.9	7.1	19.0	15.5	50	63	4	54
	B1	33-55		18	56	26	5.4	4.4		27	0.24		7.3	2.9	0.1	0.5	10.8	5.6	16.4	12.5	48	66	3	51
	B2	55-85		28	43	29	6.0	5.0		26	0.24		8.4	3.7	0.1	0.6	12.8	5.2	18.0	15.5	53	71	6	69
	B	85-100		11	44	45	6.1	5.1		32	0.26		13.4	7.0	0.2	1.0	21.6	6.9	28.5	24.2	54	76	4	72
Ratchaburi	Apg	0-13		3	43	54	5.1	4.3		75	1.24		11.6	3.7	0.4	0.7	16.4	15.4	31.8	26.4	49	52	9	185
P.a. - 930-936	ABg	13-30		4	36	60	5.2	4.6		110	0.81		15.7	4.2	0.3	0.8	21.0	11.8	32.8	30.5	51	64	7	143
	B21g	30-68		4	35	61	5.4	4.7		175	0.37		17.1	5.1	0.2	1.1	23.5	8.8	32.3	32.6	84	73	4	110
	B22g	68-86		7	31	62	5.0	4.5		270	0.32		16.1	5.4	0.2	1.2	22.9	10.7	33.6	30.8	50	68	4	107
	B23g	86-120		6	22	72	4.3	4.0		360	0.47		15.9	5.2	0.3	1.4	22.8	17.0	39.8	34.1	47	57	6	131
	IIA1g	120-160		3	36	61	4.0	3.8		750	0.37		22.0	4.3	0.2	1.5	28.0	19.6	47.6	29.6	48	59	11	119
	IIB2g	160-200		9	36	55	3.9	3.6		1100	0.15		109.0	3.9	0.2	1.5	114.6	15.1	129.7	19.3	35	88	8	131
Bang Len	Apg	0-8		2	34	64	4.8	3.9	1.5	150	1.46	0.02	16.4	8.3	0.5	1.0	26.2	17.4	43.5	34.5		60	5	195
P. - 977/68 to	ABg	8-38		1	26	73	6.1	5.3	0.1	140	0.75	0.11	19.7	11.6	0.3	1.9	33.5	7.9	41.4	34.1		81	4	129
981/68	Abg	38-56		1	24	75	6.8	5.9	2.0	190	0.47	0.01	18.0	16.5	0.3	2.4	37.2	5.8	43.0	36.2		87	6	134
	ABg	56-86		2	22	76	7.0	6.2	1.5	200	0.33	0.06	20.1	12.5	0.3	2.5	35.4	4.8	40.2	35.2		88	7	126
	Bg	86-100		0	32	68	7.3	6.5	1.5	64	0.16	0.05	18.7	14.5	0.2	2.5	35.9	3.4	39.3	29.8		96	6	105

TABLE 12 continued

RESULTS OF SOIL ANALYSIS

(OVEN DRY BASIS)

SOIL SURVEY LABORATORY, SOIL SURVEY DIVISION, DEPT. OF LAND DEVELOPMENT

SOIL NAME AND LABORATORY NUMBER	HORIZON	DEPTH (cm)	PARTICLE SIZE ANALYSIS				pH		$CaCO_3$	CONDUCTIVITY 1:5 EC x 10^6	CARBON	NITROGEN	EXCHANGE CAPACITY AND CATIONS (Milli-equiv / 100 g)									BASE SATURATION % B x 100 / B + A	P p.p.m. BRAY No.2	K p.p.m. AMMON ACETATE
			COARSE FRACTION %	USDA GRADING % SAND	SILT	CLAY	1:1 H_2O	1:1 KCl	%		%	%	Ca	Mg	K	Na	SUM BASES (B)	EXTR ACIDITY (A)	SUM (B + A)	C E C SOIL	C E C CLAY			
Ayutthaya	Apg	0-11		7	26	67	4.5	3.8		300	1.20		12.5	7.7	0.6	1.7	22.5	18.0	40.5	29.3	43	53	7	224
P. - 973/68 to	ABg	11-46		6	24	70	4.0	3.4		350	0.49		8.3	4.3	0.2	2.1	14.9	25.6	40.5	28.2	40	37	4	102
976/68	Abg	46-72		-	-	-	3.8	3.4		300	0.24		11.4	6.5	0.2	2.5	20.6	22.5	43.1	20.3		45	10	96
	Bg	72-110		-	-	-	3.6	3.3		300	0.23		7.9	2.3	0.2	1.7	12.1	19.2	31.3	17.6		39	6	75
Sena	Apg	0-12		5	46	49	4.2	3.6		140	1.11		5.2	7.7	0.5	0.9	14.3	19.9	34.2	22.8	47	42	12	177
P. - 851/68 to	A12g	12-34		6	46	48	3.9	3.5		350	0.30		4.5	6.5	0.3	1.7	13.0	19.9	32.9	21.5	45	39	3	102
858/68	B1g	34-64		-	-	-	3.6	3.3		140	0.15		-	-	0.4	3.2	-	15.9	-	19.6	-	-	5	143
	B21g	64-150		3	31	66	3.6	3.3		270	0.19		8.1	17.7	0.5	2.7	29.0	14.3	43.3	22.9	30	67	22	137
	B22g	150-180		3	29	68	3.7	3.4		300	0.51		11.3	15.7	0.5	4.3	31.8	16.6	48.4	25.8	38	65	21	177
	C1g	180-280		-	-	-	3.0	2.7		300	3.53		16.1	22.0	0.5	5.4	44.0	21.1	65.1	29.5	-	68	55	201
	C2g	280-380		-	-	-	3.1	2.8		350	4.57		9.3	21.8	0.4	7.5	39.0	31.6	70.6	31.6	-	55	38	250
	C3g	380-410		-	-	-	6.0	5.6		200	1.12		11.1	16.5	0.7	6.9	35.2	7.1	42.1	27.6	-	83	40	282
Don Chedi	Ap	0-32		55	26	19	5.8	4.6	0.2	30	0.64		2.0	1.9	0.2	0.3	4.4	5.1	9.5	5.2	27	46	63	67
P. - 489/67 to	A3	32-64		61	18	21	5.8	4.6	0.1	12	0.24		1.8	1.7	0.1	0.3	3.9	2.4	6.3	4.1	19	62	7	192
491/67	B	64-104		59	17	23	5.8	4.3	0.4	14	0.14		1.4	1.8	0.5	0.3	4.0	3.2	7.2	4.3	19	55	14	288
Deum Bang	Ap	0-10		51	16	33	5.5	4.2		30	0.33		3.2	1.8	0.1	0.8	4.9	4.7	9.6	7.7	24	51	3	49
P. - 985/68 to	B1	10-20		21	20	59	6.1	4.7		39	0.15		7.7	3.8	0.1	2.5	14.1	5.6	19.7	15.9	27	71	3	52
989/68	B12cn	20-40		24	17	59	5.7	4.0		29	0.23		5.6	2.1	0.1	1.4	9.2	9.8	19.0	13.9	24	48	4	49
	B12	40-63		23	20	57	6.6	5.6		240	0.18		8.3	3.1	0.2	5.6	17.2	4.0	21.2	15.5	27	81	3	93
	B2t	63-100		37	20	43	5.8	3.9		20	0.39		2.6	2.7	0.1	0.8	6.2	8.9	15.1	9.4	22	41	4	37
Lop Buri, saline	Ap	0-12		28	40	32	7.4	7.2	2.7	680	2.13		37.9	7.3	3.9	3.4	52.5	3.4	55.9	38.8	121	94	1030	1550
phase	A12	12-77		18	35	47	7.5	7.3	5.1	530	0.83		32.5	9.5	3.6	2.5	48.1	3.0	51.1	41.5	88	94	510	2290
Pa. - 955 to	A13	77-130		21	30	49	7.6	7.3	10.4	800	0.49		41.2	16.5	3.0	3.1	63.8	2.2	66.0	39.6	81	97	415	1190
958	AC	130-190		20	29	51	7.8	7.3	19.8	600	0.25		50.4	20.1	0.6	4.1	75.5	2.4	77.9	40.8	80	97	44	208
Ban Mi, dark variant	Apg	0-25					6.9	7.2	1.4	192	1.24		25.6	16.6	1.0	1.2	44.4	8.3	52.7	45.0		84	10	172
P. - 492/67 to	AClg	25-90					5.7	5.6	2.2	94	0.34		22.6	23.8	0.7	3.8	50.9	8.5	59.4	49.2		85	8	250
493/63																								
Chong Kae	Ap	0-21		8	25	67	5.6	4.1		-	0.77		17.5	3.8	0.1	tr	21.4	-	-	34.6	51			39
AO 591-3	B21g	21-46		6	19	75	5.6	4.1		-	0.41		19.7	3.5	0.1	tr	23.3	-	-	36.9	49			39
	B22g	46-100		6	22	72	5.6	4.2		-	0.34		21.6	3.8	0.2	0.1	25.7	-	-	38.0	53			78
Khok Krathiam	Apg	0-20					5.4	4.2		147	1.02		16.3	13.4	0.9	1.2	31.8	14.8	46.6	36.5		68	4	189
P. - 494/67 to	AClg	20-60					5.5	4.1		165	0.35		19.9	14.0	0.6	2.2	36.7	10.7	47.9	38.1		77	5	166
496/67	Abg	80-115					6.6	5.4		260	0.54		21.9	17.0	0.6	3.7	43.2	6.9	50.1	41.2		86	12	282

List of Publications by the Soil Survey Division

x 1. Report on the Preliminary Soil Survey of the Mae Klong Irrigation Project Area. (1962)

x 2. Report on the Preliminary Soil Survey of the Lam Takong Irrigation Project Area. (1962)

x 3. Report on the Preliminary Soil Survey of the Tung Sarit Irrigation Project Area. (1962)

x 4. Report on the Preliminary Soil Survey of the Lam Nam Pong Irrigation Project Area. (1962)

5. Report on the Soil Survey of the Huai Si Thon Irrigation Project Area. (1962)

x 6. Report on the Preliminary Soil Survey of the Greater Chao Phya Irrigation Project Area. (1962)

7. Report on the Soil Survey of 10 Villages in Changwat Ubon. (1962)

8. Major Soils of South - East Asia. (1966)

9. A key to the Soil Survey of North - Eastern Thailand. (1962)

10. Report on the Soil Survey of the site of the Proposed Agricultural Centre near Sathani Nam Phong (Khon Kaen Province). (1962)

11. Report on the Soil Survey in the Ban Si Than Area (Khon Kaen Province). (1963)

x 12. Detailed Reconnaissance Soil Survey of the Lam Pao Irrigation Project Area (Kalasin Province). (1963)

x 13. Report on the Soil Survey of a Pilot Area in Changwat Roi Et. (1963)

x 14. Detailed Reconnaissance Soil Survey of the Mae Taeng Irrigation Project Area (Chiang Mai Province). (1963)

x 15. Report on the Soil Survey of the Tha Phra Agricultural Station and surroundings (Khon Kaen Province). (1963)

x 16. Detailed Reconnaissance Soil Survey of the Lam Phra Phleng Irrigation Project Area (Nakhon Ratchasima Province). (1963)

List of Soil Survey Reports

17. Note on the Soil Survey of the Khao Tao Area. (1964)

18. Report on the Soil Survey of the Proposed Land Settlement Area at Nam Phong (Khon Kaen Province). (1964)

19. Report on the Soil Survey of the Nong Ya Ma Tank-Irrigation Project Area (Roi Et Province). (1964)

x 20. Note on the Soil and Land Use in the Hills of Tak Province. (1964)

21. Reports on the Soil Survey of the Huai Kut Kaen Tank-Irrigation Project Area (Roi Et Province). (1964)

x out of print

x 22. Report on the Soil Survey of the Kut Daeng Tank-Irrigation Project Area (Roi Et Province). (1964)

x 23. Report on the Soil Survey of the Thawat Chai Tank-Irrigation Project Area. (1964)

x 24. Report on the Soil Survey of the Proposed Land Settlement Area at Non Sang (Udon Province). (1964)

x 25. Report on the Soil Survey of the Land Development Project Area in Kamphaeng Phet Province. (1964)

x 26. Report on the Soil Survey of the Chiang Pin Land Settlement Project Area (Udon Thani Province). (1964)

27. Report on the Thai-Malayan Soil Correlation Meeting, (1964)

x 28. Interim Reports on the Great Soil Group Survey. I : Khon Kaen Study Area. (1964)

29. Report on the Soil Survey in the Sam Roi Yot Area. (Prachuab Khiri Khan Province). (1964)

30. Report on the Soil Survey of Roi Et Province. (1966)

31. Interim Reports on the Great Soil Group Survey. II : Pran Buri Study Area. (1964)

x 32. Characteristics of soils on which paddy is grown in relation to their capability classification. (1965)

x 33. Report on the Survey of the Hup Kapong Development Project Area (Petchaburi Province). (1965)

34. Report on the Soil Survey for the Pulpwood Project in Sisaket Province. (1965) (1965)

x 35. Interim Reports on the Great Soil Group Survey : III. Chiang Mai Study Area (1965)

36. Survey for a Power Pump Irrigation Demonstration Province in Amphoe Tha Bo, Nong Kai Province. (1965)

37. Chao Phya Irrigation Project : II. The Manorom Tract. (1965)

38. Interim Reports on the Great Soil Group Survey : IV. Chanthaburi Study Area. (1965)

39. Chao Phya Irrigation Project : III. The Boromdhart Tract. (1965)

40. Chao Phya Irrigation Project : IV . The Khok Krathiam Tract. (1965)

41. Interim Reports on the Great Soil Group Survey :V. Hat Yai Study Area. (1965)

42. Chemical and Mineralogical Study of Subsurface Horizons of Chiang Mai. (1965)

43. Interim Reports on the Great Soil Group Survey : VI. Nakhon-Sawan Study Area. (1966)

44. Interim Reports on the Great Soil Group Survey : VII. Lop Buri Study Area. (1966)

45. Report on the Soil Survey in the Pet Buri Irrigation Tract. (1965)

46. Soil Series Survey of the MERS Chanthaburi Study Area. (1966)

x out of print

47. Report on the Soil Survey of the Kud Ling Ngah Tank-Irrigation Area (Udon Thani Province). (1967)

48. Final Report on the Great Soil Group Survey of Seven Selected Areas in Thailand. (1966)

49. Soil Series Survey of the MERS Lop Buri Study Area. (1966)

50. Soil Series Survey of the MERS Chiang Mai Study Area. (1966)

51. Soil Series Survey of the MERS Khon Kaen Study Area. (1966)

52. Soil Series Survey of the MERS Nakhon Sawan Study Area. (1966)

53. Chao Phya Irrigation Project : V. The Maharat Tract. (1966)

54. Chao Phya Irrigation Project : VI. The Pholathep Tract. (1967)

55. A Detailed Soil Survey of the Rubber Research Centre, Hat Yai. (1967)

56. Report on the Soil Survey in the Nong Chang Yai Tank-Irrigation Area (Ubon Province). (1967)

57. Chao Phya Irrigation Project : VII. The Chong Kae Tract. (1967)

58. Reconnaissance Soil Survey of Rubber Growing Areas in Thailand, Chanthaburi Area. (1967)

x 59. Soil Survey Interpretation Handbook for Northeast Thailand. Part I : Soil and Their Uses. (1967)

60. Soil Survey Interpretation Handbook for Northeast Thailand. Part II : Land Capability Classification. (1967)

61. Chao Phya Irrigation Project : VIII. The Channasut Tract. (1967)

62. Reconnaissance Soil Survey of Rubber Growing Areas in Thailand, Songkhla Area. (1967)

63. Reconnaissance Soil Survey of Rubber Growing Areas in Thailand, Trang Area. (1968)

64. Reconnaissance Soil Survey of Rubber Growing Areas in Thailand, Phanga Area. (1968)

65. Reconnaissance Soil Survey of Rubber Growing Areas in Thailand, Ranong Area (1968)

66. Chao Phya Irrigation Project : IX. The Yang Mani Tract. (1968)

67. Reconnaissance Soil Survey of Rubber Growing Areas in Thailand, Chumphon Area. (1968)

xx68. Reconnaissance Soil Survey of Rubber Growing Areas in Thailand, Surat Thani Area.

69. Chao Phya Irrigation Project : X. The Tha Bot Tract. (1969)

70. Reconnaissance Soil Survey of Rubber Growing Areas in Thailand, Nakhon Si Thammarat Area. (1968)

71. Report on the Detailed Soil Survey in the Channasut Land Consolidation Project Area. (1968)

72. Soils of Thailand. (1968)

x out of print
xx in preparation

73. Detailed Soil Survey of the North-Eastern portion of ASRCT Sakaerat Experiment Station (Nakhon Ratchasima Province). (1969)

74. Transfer of Boundaries From Air-Photo onto Base Map. (1969)

75. Soil Suitability Survey of Teacher Training School, Changwat Sakon Nakhon. (1969)

76. General Land Suitability for Crop Diversification in Peninsular Thailand. (1969)

77. Soil Survey of Ubon.

78. Soil Survey Interpretation Report for Ubon Province. (1969)
(Land Classification Division Report No. 3)

79. Notes on Soil Temperature Regimes in Thailand. (1969)

80. Guide for writing Province Soil Survey Reports. (1969)

81. Acid Sulphate Soils in Thailand. (1969)

82. Detailed Soil Survey and Land Classification in the Kui Buri River Valley (1969)

83. Air-photos and Air-photo Interpretation in Soil Survey. (1970)

84. Some Morphological Physical and Chemical Aspects of Acid Sulphate Soils in Thailand.

85. Method and Procedure by Photo-Interpretation for Survey of Rubber Plantations in Thailand.

86. Detailed Reconnaissance Soil Survey of the Northern Part of Chiang Rai Province (1972).