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SR. NO. 9620

THAILAND NATIONAL PROGRAMME  
OF THE  
EARTH RESOURCES TECHNOLOGY SATELLITE

Sanga Sabhasri  
Secretary-General  
National Research Council  
Bangkok 9, Thailand

May 1974

Type III Report for Period November 1972 - March 1974

National Research Council  
196 Phahonyothin Road, Bangkok  
Bangkok 9  
Thailand

Goddard Space Flight Center  
Greenbelt,  
Maryland 20771  
U.S.A.

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		11. Mr. George Ensor
12. National Research Council 196 Phahonyothin Road, Bangkok Bangkok 9, Thailand		13. Multidisciplinary Resources Surveys, National
15. This report contains an introductory historical sketch covering major events, results of analyses conducted in several disciplines by user agencies (agriculture, forestry, land use, geology, water resources), statements of current status and future plans, and summaries of ongoing research and data utilization projects. Several ERTS image interpretations that have been verified by ground surveys and/or aerial reconnaissance flights are illustrated.		

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## PREFACE

## 1. Objectives

The overall objective of the Thailand National Program has been to evaluate the extent to which ERTS data can be beneficially applied in various sectors of the economy to assist in the task of acquiring reliable data needed for resources inventory, planning, and management at the national level. Participating Government Agencies have pursued objectives specific to their areas of responsibility in supplying the basic data required.

## 2. Scope of Activity

Fifty Thai scientists received basic training in remote sensing technology, with emphasis on ERTS sensors and data products, shortly after the initiation of the project (early 1973). Investigations based on visual analysis of ERTS images were then initiated in four disciplinary areas (agriculture, forestry, land use, geology) and interested participants in other areas, including irrigation, hydrology, oceanography, and resources inventory, pursued smaller scale studies within their own organizations or at the Applied Scientific Research Corporation of Thailand (ASRCT).

Ten Thai scientists have now received some training at U.S. centers of expertise in remote sensing or have attended relevant meetings such as the Purdue University short course on machine processing of remote sensing data and a data processing and management symposium at the EROS Data Center in Sioux Falls, South Dakota.

The scope of activity is presently being expanded to cover additional facets of the technology, such as computer processing of MSS magnetic tapes, and to encourage additional RTG agencies to engage in research and development.

## 3. Significant Analyses, Findings, and Techniques

## Category 1.A. Agriculture, Crop Survey and Classification

Intensive interpretation of ERTS-1 scenes covering agricultural regions near Bangkok, backed up by ground surveys and low altitude reconnaissance flights, has established that the major agricultural crops of Thailand can be positively differentiated, and in most cases identified, after some experience has been gained, by examination of ERTS imagery. Little use has been made thus far of time sequential imagery and crop calendar information, but it is clear that with these techniques a comprehensive survey of all major agricultural regions can be made during the growing seasons whenever current ERTS imagery is available. ERTS-1 images will be studied further in an effort to determine the total area devoted to each of the major crops during 1973. Analysis

of sample computer printouts furnished by the Purdue University Laboratory for Applications of Remote Sensing indicates a high potential for successful application of automatic data processing in agricultural crop determination.

#### Category 1.B. Forestry, Timber Survey and Classification

The Royal Forestry Department will complete within the current calendar year a country-wide survey of remaining forest cover, using ERTS images to delineate forested areas and existing air photos to assist with classification in several broad categories. This is a task of major economic importance that could only be accomplished prior to the advent of ERTS-1 by re-photographing at least half of the country (about 250,000 km<sup>2</sup>) from aircraft, a task that can be accomplished in Thailand only infrequently because of the great expenses involved.

#### Category 2.A. Land Use Classification

The Land Development Department has developed an interpretation scheme utilizing 1:1 million and 1:500,000 scale ERTS images, available maps, and field checks. A ten category classification system has been devised for temporary use and is being expanded as more interpretation experience is gained. Existing 1:1 million scale land use maps have been updated and corrected, and detailed mapping has been done from six ERTS scenes covering about 20% of the country.

#### Category 3. Mineral Resources, Geological Structure, and Landform Surveys

MSS band 5 and band 7 black and white positive transparencies were found to be the most desirable medium for identification of geological structure. Several scenes have been studied in detail and all have yielded new information for improvement of geological maps. A new tectonic map covering the whole country has been drafted, but is not yet ready for publication. It is anticipated that the improved delineation of geological structure yielded by the ERTS pictures will be of great assistance in mineral exploration planning in the future.

#### Category 4.J. Reservoir Monitoring

The Royal Irrigation Department conducted a pilot study to examine the possibility of determining water reservoir capacity from surface area measurements derived from ERTS images.

The technique utilized was to project MSS band 6 or band 7 transparencies at 20X enlargement directly onto 1:50,000 scale topographic maps. The maps were used to control scale, and the perimeter of the reservoir was then traced out on the map and the area determined by planimetry. Fairly satisfactory results were obtained on three reservoirs ranging in area from 35 to 135 km<sup>2</sup>. It is concluded that the technique can be improved and can be utilized successfully when current, repetitive satellite imagery is available.

#### 4. Conclusions

Work accomplished to date in the disciplinary areas discussed above has established that the data acquired by ERTS-1 have practical applications in each case. Applications in forestry and land use are clearly cost-effective under present circumstances, and a potential for answering some of the priority questions in the area of agricultural land utilization and production appears to have been demonstrated. The overall conclusion reached in Thailand is that survey by satellite will be accepted as an indispensable method of assessing and regulating the utilization and conservation of dwindling natural resources and of planning for future agricultural production on a global basis. There appears, in the present era of rapid population increase, serious shortages of food, and steeply rising costs, to be no viable alternative. There is no other way in which the true condition of the entire inhabited surface of the earth can be accurately assessed in such a short time, and intelligent planning for the future cannot occur in the absence of reliable information.

#### 5. Recommendations

Thailand, in view of the conclusions drawn above, recommends only that the opportunities for realization of improved knowledge created by ERTS-1 be pursued further. The question of whether or not we wish to utilize the new space technology appears to have been answered, and the question of how best to use it in order to realize maximum benefits remains to be answered. Recognizing that techniques of image interpretation and data analysis are continually changing and improving, we wish now to improve our own capabilities for data reproduction and interpretation, to investigate some additional techniques that appear to be applicable, and ultimately to reduce proven techniques to routines capable of supplying national resources inventory and production data that are critical to intelligent allocation and improved planning.

## INTRODUCTION

The Thailand National Programme of the Earth Resources Technology Satellite (ERTS) and Skylab operates through the Principal Investigator, the Secretary-General of the National Research Council of Thailand, and the National ERTS Committee. The National ERTS and Skylab Committee is composed of the Secretary-General, as Chairman, and representatives of the Office of the Prime Minister, the Bureau of the Budget, the National Economic and Social Development Board, and government agencies and educational institutions interested in applications of remote sensing data acquired both by spacecraft and by aircraft.

Interest in the programme at the national level has been high since the first ERTS-1 images of Thailand were received in November 1972. The United States Operations Mission to Thailand (USOM), working through the U.S. Geological Survey, implemented six week intensive remote sensing training course in January-February 1973, which served to acquaint Thai user agencies with the design philosophy of ERTS-1 and techniques of interpretation applicable to the small scale multiband imagery produced by the satellite. This was followed, in May and June 1973, by additional consultation to the investigating teams by members of the U.S. training team\*.

Awareness of the utility of ERTS-1 data has grown steadily since that time, and a number of unique and/or cost-effective applications have been found. The series of large, ancient alluvial fans along the margins of the central plain, for example, might never have been recognized in the absence of ERTS images, and there would be no reasonably economical way, without these pictures, to make the assessment of remaining forest cover in Thailand, reported here, that will be completed this year.

The National Research Council assigned responsibility for coordination of the ERTS Programme to the Environmental and Ecological Research Institute of the Applied Scientific Research Corporation of Thailand (ASRCT). Staff members of the Institute are experienced in interpretation of aerial photographs and construction of resources inventory maps. Existing facilities within ASRCT are also used for photographic data reproduction and maintenance of the primary data products received from NASA. Instruments supplied by USOM, including a four channel viewer/projector for color reconstruction and a zoom transfer scope, are housed and maintained at ASRCT and are available for use by all investigators.

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\*

U.S. Geological Survey Report No. TH - 13, in press.

Additional RTG funds for continuation of ERTS and Skylab investigations have been allocated recently, as detailed elsewhere in this report, and USOM, through negotiation of a new Project Agreement with the Government of Thailand and a Participating Agency Services Agreement with the U.S. Geological Survey, is providing additional technical support, expert advice, and special purpose commodities needed for upgrading data reproduction and interpretation procedures.

It is evident that the basic objective of Thailand's broad investigation programme, to assess the utility and economy of ERTS data in planning development and management of resources, has been achieved at least partially, with the result that the practical utility of earth resources surveys from spacecraft is considered now to be an established fact in several disciplinary areas.

The government has demonstrated its willingness to support further research and development, and has expressed confidence in the future of this new technology by encouraging planning toward the establishment of a permanent national remote sensing research, development, and training center.

## Final Report

Sector: Agriculture

Reported by

Pongpit Piyapongse

Utilization of ERTS-1 imagery in agricultural survey has been found very advantageous in Thailand. Since the first batches of ERTS-1 MSS imagery were supplied to Thailand, the agriculture sector of the Agriculture Department has been using color and black and white prints as base maps in many areas.

The study has been carried out in three major phases; preparation, ground information collection, and interpretation and analysis. The first phase included training of personnel by the U.S. team, test site selection, preparation of ground information forms, and contacting experiment stations near the test sites. The second phase was devoted to ground information collection at various test sites and field checking for covertype boundaries. Aircraft observations were made on two occasions. Interpretation and data analysis were done simultaneously with field checking.

Selection of Test Sites

In order to obtain a wide range of agricultural scenes, several test sites were selected in different parts of the country. Table 1 shows the location of the test sites and the types of agriculture involved.

Table I

<u>Frame No.</u>	<u>Location</u>	<u>Type of Agriculture</u>
1	Bangkok North	Floating rice, orchard and horticulture crops.
2	Bangkok South	Rice, field crops
3	Chainat	Rice, multiple cropping
4	Chiengmai	Rice, multiple cropping
5	Chantaburi	Orchard, rubber plantations
6	Ubol	Rice, kenaf
7	Songkhla	Rubber plantations and coconut
8	Petchabun	Corn, rice
9	Phuket, Samui Islands	Coconut, rubber plantations

### Procedures

ERTS-1 imagery and 1:50,000 scale topographic maps were used as base maps. The ERTS-1 imagery used included:

1. False Color composite 1:400,000 scale, North and South Bangkok frames. (Prints)
2. Diazochrome color transparencies.
3. Black and white prints.
4. Sample computer printouts furnished by Purdue/LARS.

The following procedures were employed.

1. Boundaries, indicated by differing spectral responses (tonal and color variations on the prints) were traced on acetate overlays.
2. Uniform areas of 5 x 5 kilometers were used as field checking plots for field crops and orchards; 10 x 10 kilometer plots were used in rice cultivation areas. Field checks were done occasionally for observation of temporal changes.
3. Aircraft observations were made twice, for visual checking of tentative boundaries and to acquire color photos on Ektachrome and Ektachrome IR film for evaluation.

Cropping regions delineated on the base maps will be corrected by subtracting areas of other land use and crop type, where possible, to obtain the actual area devoted to each specific crop. Then the individual crop areas will be measured with planimeters. We are confident that automatic data processing techniques will largely replace this conventional method in the future.

### Some Accomplishments and Results of the Study

1. The series of active alluvial fans along the margins of the Central Plain were first recognized on ERTS false color composite images. The soils occurring in these areas were found to be coarse textured at the upper ends of the alluvial fans and fine textured at the bases. Soils texture on these areas were largely sandy loam, clay loam and clay soils. The great soil groups and soil series found included Aeric Raleaquents, Typic Ustifluvents, Aeric Trophaquepts, Aeric Paleaquents and Entic Pelluderts soils according to the USDA Soil taxonomy 1970 classification.

2. Crop resources maps were drawn for the North and South Bangkok frames and the Eastern Coastal areas. From these maps area measurements will be made for comparison with area estimates previously made without reference to ERTS data.

3. Preliminary gray scale printouts of the Bangkok frame were field checked for classification and accuracy. The printouts were produced by the Purdue University Laboratory for Applications of Remote Sensing (LARS) for use in the 1973 training program. We found them very accurate and useful for several cover type identifications.

The symbols were keyed out as follows

	<u>Symbol</u>	<u>Class</u>	<u>Group</u>	<u>Classification</u>
1.	=	NS-4/10	VEG 1	bushes
2.	/	NS-5/10	VEG 2	orchard (citrus)
3.	+	NS-6/10	VEG 3	trees, wood land
4.	(.)	NS-7/10	SOIL URBN	urban, bare soil
5.	0	NS-8/10	VEG 4	grasses
6.	W	NS-9/10	WATER	water + Rice
7.	M	NS-10/10	SHAD & H <sub>2</sub> O	water + Rice

We found items 1 -5 accurate and consistent, especially item number 4.

We would recommend combining 6 and 7, as these two classes did not appear to represent different cover types.

4. Black and white photo mosaic maps of MSS band 5 and band 7 were made to up-date existing maps of Thailand. We are using them to correct water body areas and locations of our experiment stations.

#### Status and Future Plans

ERTS-1 imagery of Thailand is being utilized very successfully in the agriculture sector. We plan to use ERTS-1 imagery together with 4 band aerial photographs to identify coconut areas on Phuket and Samui islands, and along the coast of Thailand to detect the old and non productive coconut plantations for a planned replanting program. More extensive use of automatic data processing is also planned for improved crop differentiation and cover-type identifications. The other economical crops such as, cotton, sugar cane, and soybean will also be surveyed in this programme. Work on interpretation of present ERTS-1 data will continue, and we are looking forward to the launch of ERTS-B and to examination of SKYLAB data.

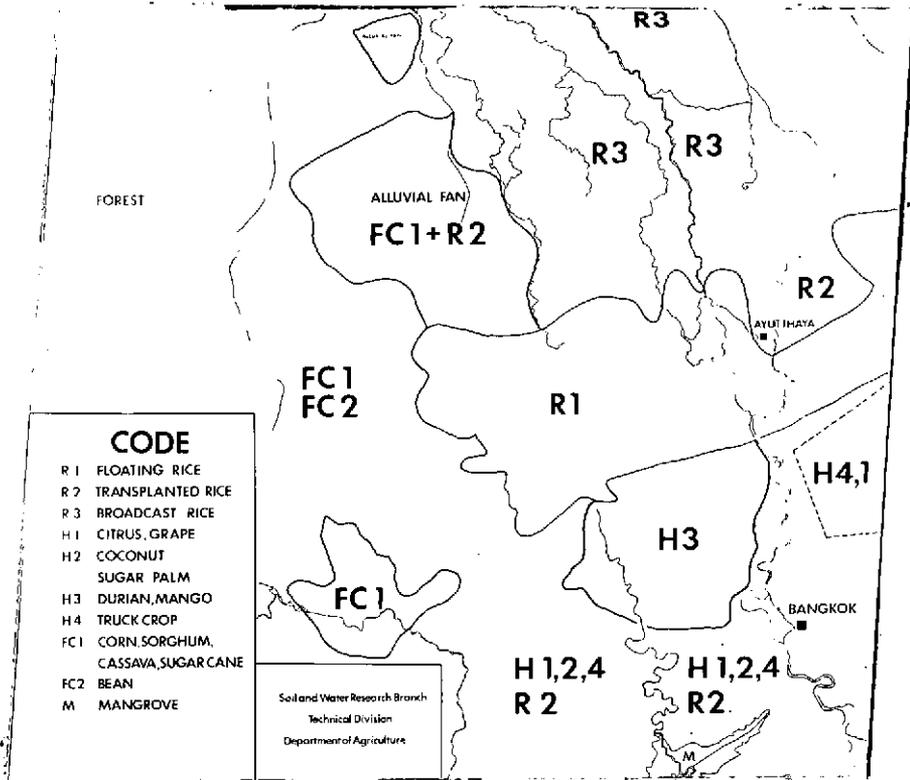


FIGURE 1 Example of Agricultural Land Use Mapping, Bangkok Area

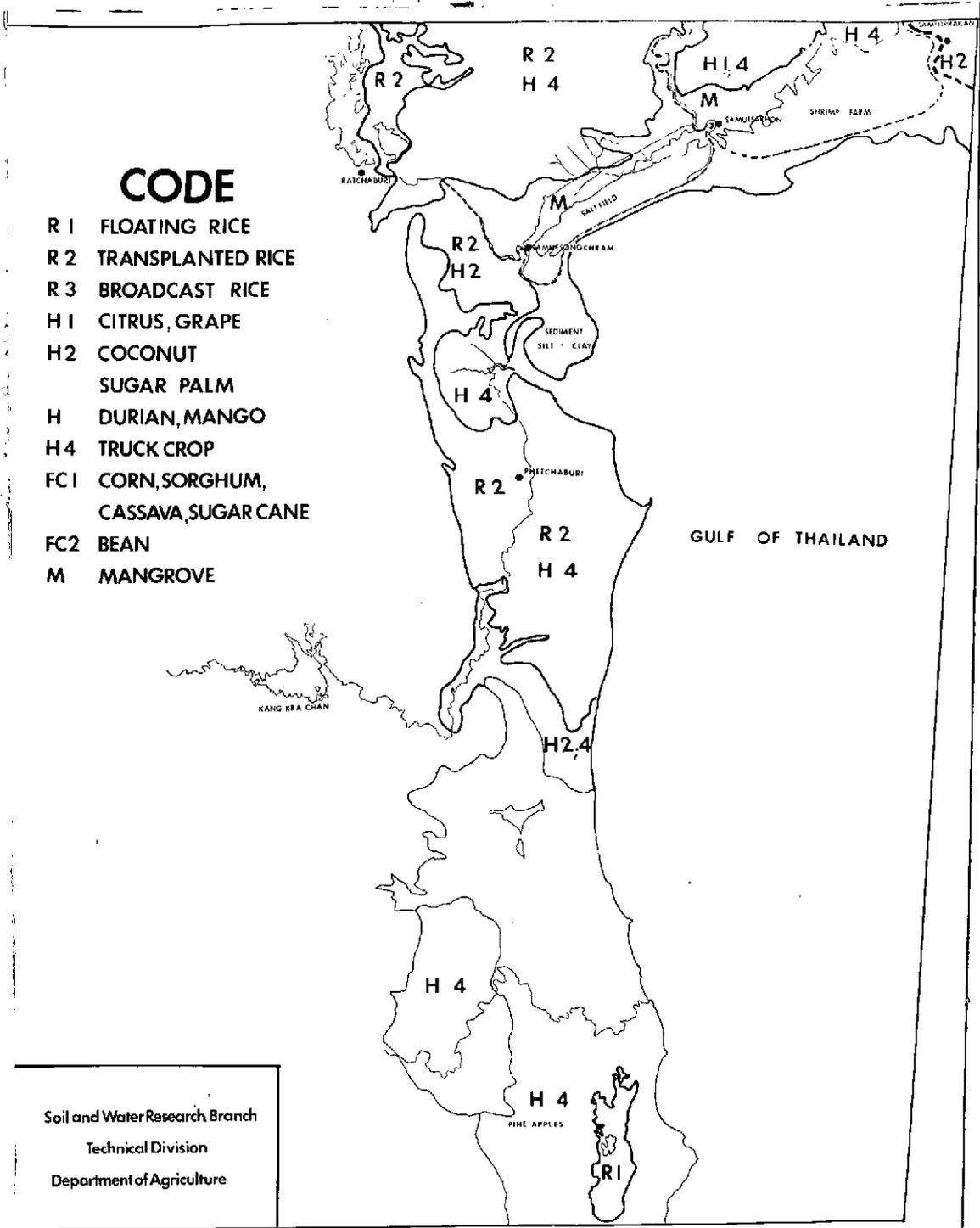


FIGURE 2 Example of Agricultural Land Use Mapping, South Bangkok Area .



## Final Report

Sector: Forestry

Reported by

Dr. Chamni Boonyobhas and Boonchana Klankamsorn

I. Introduction

The Earth Resources Technology Satellite (ERTS) is a newly developed technology to survey the existing natural resources of the earth by remote sensors aboard the spacecraft (satellite). Remote sensors, including aerial cameras, are merely tools for gathering data for the information needed. Space photography is remote sensing at long range, i.e., from a distant point. From this distant vantage point, the observer can view all of the forest in a large region. Each frame of ERTS imagery covers more than 34,000 square kilometers. Although photo index sheets made from conventional photographs will give a similar view, they have many distortions, and many index sheets are required to cover the same ground area included on one space photograph. By stratifying land use on space photographs the number of conventional photographs required to make a forest inventory is reduced. Successful use of space photography will depend on how closely information from space is related to information on conventional photographs.

In the field of forestry investigation, space photography can provide valuable information about forest land. It shows the distribution of forests and their relationship to other land uses, including urban centers and transportation systems. Our objectives during the first year were: (1) to study, by interpretation, the ERTS-1 imagery of the areas designated as "test site areas" (2) to identify the forest area separated from other land uses, (3) to survey the area which was cited earlier as forested area in order to learn of the changes.

II. The Study Areas

During the ERTS Remote Sensing Training Course held in January, February 1973 and with the advice of the expert, the forest areas were selected for studying. These areas are located in the North region, East region and South region of Thailand (Figure 1), having 3, 5 and 2 test site areas respectively. Owing to the limited budget, The Forestry Department could study and work intensively only in the East region and some parts of Chiangmai province in the North region.

The general topography of the East region is flat to gently rolling plains with crests generally more than 500 meters above adjacent valley bottoms; most slopes are between 10-30%. About 15,000 square kilometers of this area are covered by forests. Forested areas are classified mainly into Tropical Evergreen, Dry Dipterocarps and Mangrove Forests. Evergreen Forest type is very dense with considerable under-storey plants and climbers making ground checks difficult. In some parts the areas are

completely inaccessible. The surrounding areas near the coast are agricultural areas. Crops grown include rice, sugar-cane, cassava, fruit orchards and rubber plantations.

Five test site areas were selected for ground checking. For instance, test site area 2 located at Amphoe Pong Nam Ron, Chantaburi province. (Fig.2)

The size of each test site area is 25 x 25 kilometers, and the sample plots are 50 x 50 meters. Ten sample plots in each site were used for research work. Photographs were taken with ordinary 35 mm. cameras for field checks. Photos were taken, in each test site area, where various tone contrasts on the imagery were noted.

### III. The Procedure of ERTS-1 Imagery Analysis

The approach was divided into two stages as follows:

#### (1) Preparation of Task in the Office

In this step, ERTS-1 Frames E-1148-03011, E-1167-03063, E-1167-03070, E-1202-03014 and E1202-03020, band 5 and band 7, which covered the Eastern part of the Kingdom, enlarged to a scale of 1:500,000 were used as a base map. These prints were covered with microtrace drafting paper and the boundaries of the test site areas (each test site area = 25 x 25 km) were delineated under the condition of tonal differentiation. The expected legends were first labelled by using the code described in figure 3. However, in order to improve the accuracy of space-photo interpretation, aerial photographs of any scale which covered the study area were brought in to assist the recognition activity, and additional details were taken from diazo-chrome color film products and the false color composite viewer screen.

When the images had been stratified, the number and location of spot checks necessary to be conducted throughout the various strata were based on the relative sizes of individual strata. However, for economic reasons, the location of each spot check depended on existing facilities and the convenience of communication.

Three ground control points were set up within each frame of space photograph, in order to control the shape of the map when transferring the details to the map and for checking some details in the field. After interpretation activities were finished, the stratification and legend labelling on each photograph were carried out to completion.

The legends that were applied in the initial stage of interpretation could be classified as:

01 = Vegetated areas	04 = Water
02 = Cultivated areas	05 = Open land
03 = Urban areas	

## (2) Field Checks

Field checks were done occasionally at the test site areas. The locations of spot checks were guided by topographic maps of scale 1:50,000 and 1:250,000 and any scale of aerial photographs. Within a test site area, three sample plots were assigned for research work; one was 25 x 25m, the second one was 50 x 50 m, and the last one was 100 x 100 m. The availability of each size of sample plot was mainly dependent on the suitability and characteristics of the site. Every data point within the test plots was recorded on the data sheet form, and then the photographs of forest profile were taken with ordinary 35 mm cameras where there were variations in tone on the imagery of each test site area.

The preliminary map was checked in detail again and the legends were corrected for accuracy.

## (3) Data Recording

Every detail which was required and mentioned in the recording form was recorded (See the recording form in Fig. 4-8), for instance, photo-image characteristic, altitude, aspect, type of forest, degree of forest disturbance, crown density, leaf condition, ground moisture condition, prominent species, average height, etc., and pertinent remarks.

## (4) Symbolic legends.

Finally, after the map had been checked, the completed and verified symbolic legends with the description of the details were entered on the map and the map was completed. (Fig. 9)

## IV. Results

Although the interpretation task and the field data requirements are new and are still being improved, the results of this work clearly indicate that the ERTS<sup>1</sup> data is applicable to tropical forest mapping. Images can be classified broadly as forest area and non-forest area. Forest area was then measured using dot grid templates. The forest area was found to be 15,036 square kilometers in the East region. (See forest map in Fig. 10)

The comparisons of forest area derived from ERTS-1 imagery with the area from the land classification map worked out by the Land Development Department at the scale 1:250,000 and printed in 1971 are as follows: (See Table 2., p. 15)

Province (East region)	From land classifica- tion map		From ERTS-1 imageries	Depleted Forest area		% annual decrease (average)	Note
	Date of investiga- tion	Forest area (km <sup>2</sup> )	Forest area (km <sup>2</sup> )	(km <sup>2</sup> )	(%)		
Chonburi	1961	1,336	1,020	316	23.65	1.97	Some small forest areas distributed in the disturbed areas have been omitted from measurement because they are too small to be taken into account.
Rayong	1966	1,183	988	195	16.48	2.35	
Chanthaburi	1964	3,827	3,167	660	17.25	1.92	
Trad	1964	1,130	1,060	70	6.19	0.69	
Chachaengsao	1964	2,705	2,624	81	2.99	0.33	
Prachinburi	1963	7,407	5,592	1,815	24.50	2.45	
Nakhonnayok	1964	586	585	1	0.17	0.02	
		18,174	15,036	3,138	17.27	-	

Table 2. Forest Area Depletion

## V. Future Plan

During the current fiscal year, which started in October 1973, continuing checks and studies will be carried out throughout the country, except in the eastern region. The main emphasis will be on finding the location of existing forest areas and details of the changing situation. The expenses of these activities will be paid by the Thai government and the equipment will be supplied under the cooperation of the Royal Forestry Department, the Applied Scientific Research Corporation of Thailand and the National Research Council. Thereafter, intensive research will be pursued with the objective of finding the optimum technique for ERTS-1 imagery interpretation for forest area determination and forest typing.

## VI. Conclusion & Recommendation

From the research on ERTS-1 imagery (black-white prints of scale 1:500,000) in interpretation for forestry aspects already conducted, it is clearly evident that remote sensing will be an increasingly useful tool in forestry. It can contribute much to aid the forester in exploring, developing and managing forests and related wildlan's. The characteristics of forests can be recognized by combinations of texture and tone contrast. Because of the small scale of the imagery and the fact that the present application is in a preliminary stage, the utilization is limited in so far as the forest cover type identification is concerned, but the forested and non-forested areas can be separated completely by the use of MSS band 5 and band 7. The existing forest areas can be detected and the changing conditions due to man-made or natural disturbances can be known by comparing imagery from two different time periods.

The recommendation now can be given that imagery acquired during the rainy season should be avoided, because the soil moisture will be rather high in croplands close to the valley bottoms. This moisture and extremely high humus content will give soil a dark appearance very similar to that of the forest. Intensive research on ERTS-1 imagery interpretation should be carried out in order to find out the best technique for recognition until the various types of forest, volume of stand, forest damage, etc, can be recognized very clearly.

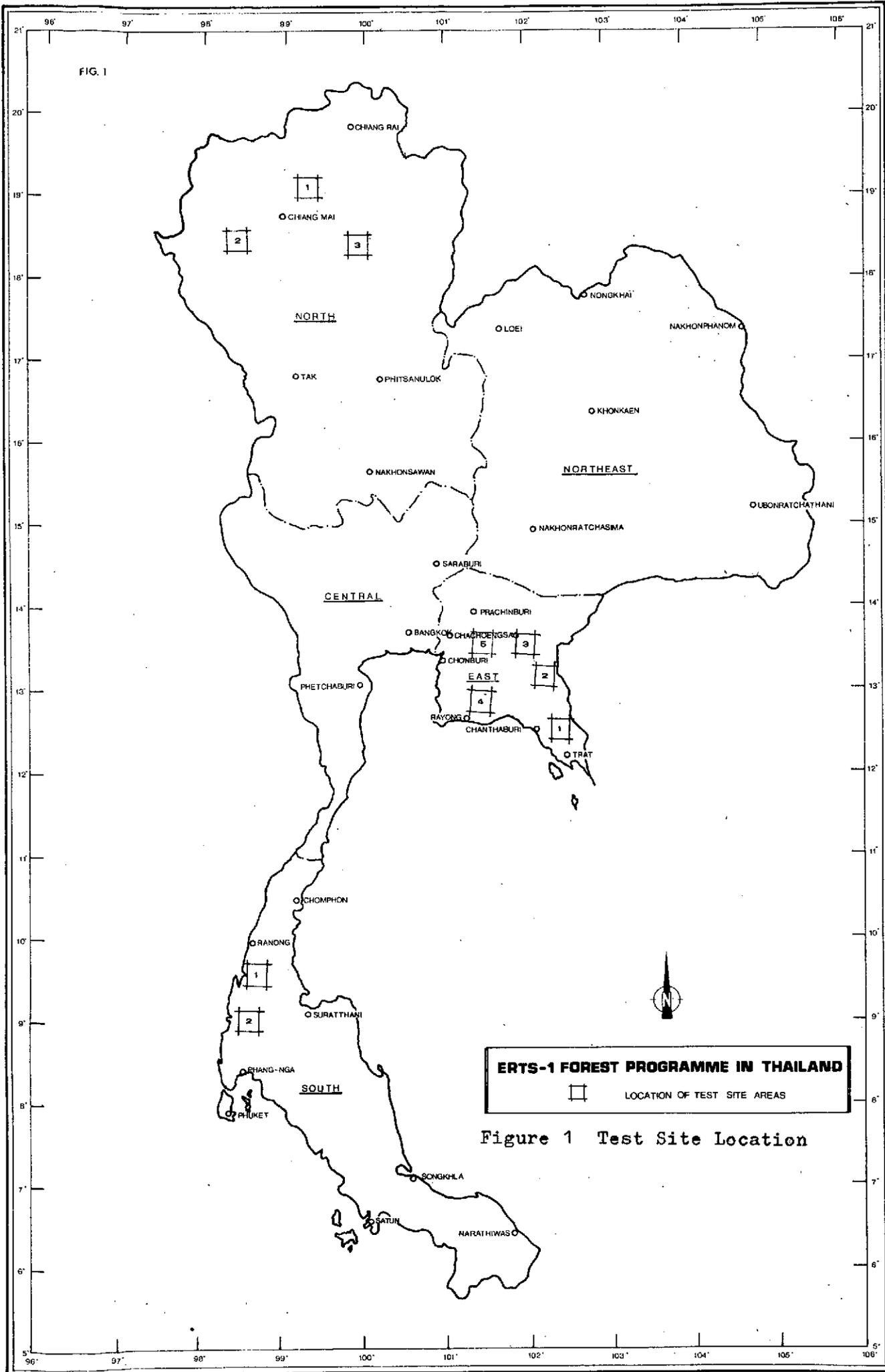
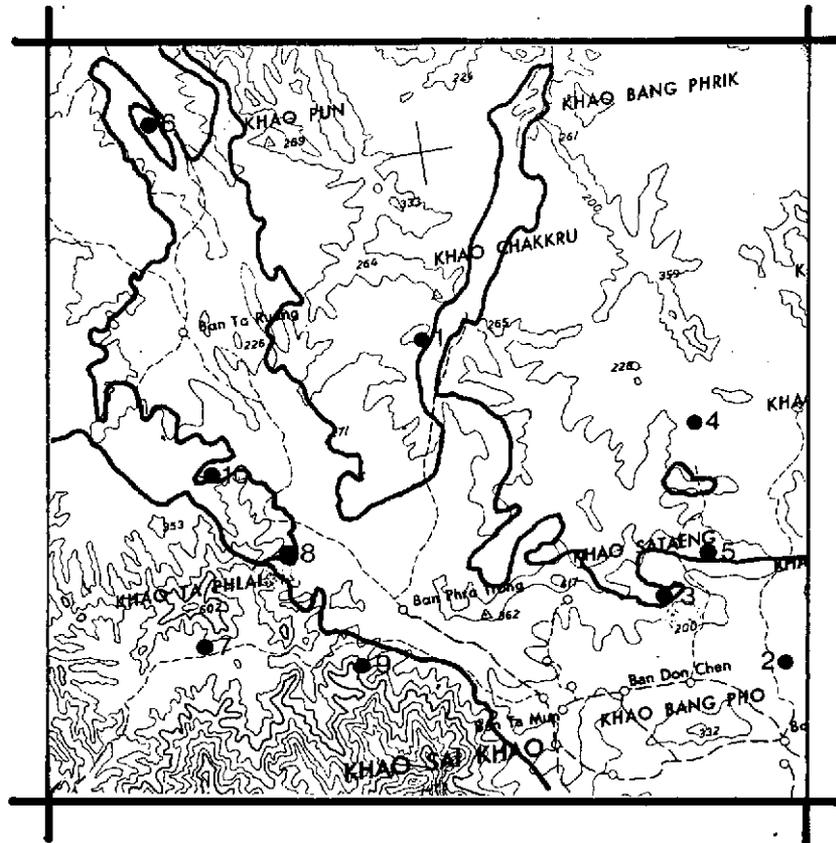


FIG 2

# TEST SITE AREA 2

AMPHOE PONG NAM RON CHANGWAT CHANTHABURI

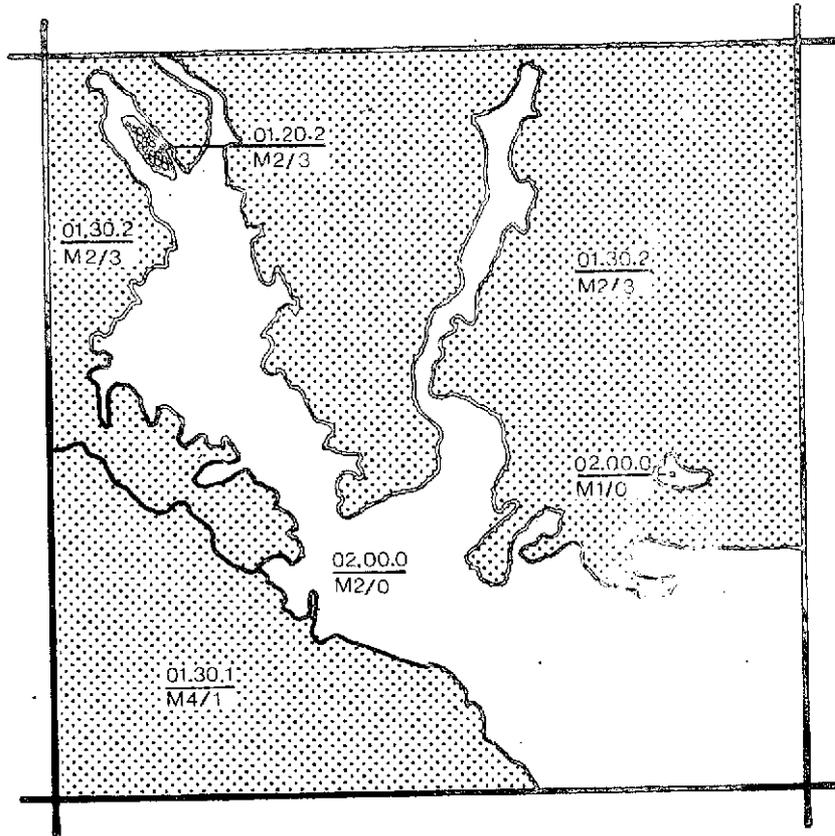


LOCATION OF SAMPLING PLOT

## TEST SITE AREA 2

FIG 3

AMPHOE PONG NAM RON CHANGWAT CHANTHABURI



LAND USE CATEGORY	01	VEGETATED AREA
	02	CULTIVATED AREA
TYPE OF FOREST	10	MIXED DECIDUOUS
	20	DRY DIPTEROCARP
	30	TROPICAL EVERGREEN
CROWN DENSITY	1	75 - 100 %
	2	25 - 75 %
	3	0 - 25 %
MACRORELIEF CLASSES	M1	FLAT LAND
	M2	UNDERLATING AND ROLLING
	M3	HILLY LAND
	M4	MOUNTAINOUS LAND
TYPE OF FOREST DISTURBANCES	1	NON DISTURBANCES
	2	CUTTING HEAVY
	3	CUTTING LIGHT

# ERTS-1 PROGRAM

## FOREST GROUND INFORMATION DATA SHEET.

SECTOR: FORESTRY

ERTS-1 INFORMATION			
LOCATION, AMPHOE <u>PONG NAM RON</u>		CHANGWAT <u>CHANTHABURI</u>	
ORBIT No. <u>E-1202-03014</u>	MSS BAND <u>5</u>	SCALE <u>1/500000</u>	
DATE PHOTO <u>10/2/73</u>		LAT <u>13°-04'-37"</u>	LONG <u>102°-20'-14"</u>

## FIELD PHOTOGRAPHY



LOCATION <u>BAN SAM RONG</u>		LAND USE CATEGORY					SAMPLING PLOT No. <u>2/2</u>				
		VEGETATED	AREA	<u>OK</u>			SIZE OF PLOT <u>50 X 50</u> M				
TYPE OF FLIM <u>COLOUR</u>		CULTIVATED	AREA	02.		ELEVATION <u>150</u> M					
TIME <u>14.15</u>		URBAN	AREA	03.		SLOPE <u>—</u> %					
DATE <u>25/6/73</u>		WATER	AREA	04.		ASPECT <u>—</u>					
OPEN		LAND		05.							
TYPE OF FOREST		10	20	30	40	50	60	70	DOMINANT TREE <u>Xylia kerrii Craib.</u>		
FOREST DISTURBANCES		1	2	3	4	5	6		HEIGHT <u>15 M.</u> $\odot$ <u>0.60</u> M		
CROWN DENSITY		1	2	3					MACRORELIEF <u>M<sub>1</sub></u>		
LEAF CONDITION		1	2	3	DECIDUOUS TREE			GROUND MOISTURE CONDITION <u>Medium</u>			
No.	PROMINANT SPECIES.	NO OF TREE	AVE HEIGHT M.	No.	PROMINANT SPECIES.	NO OF TREE	AVE HEIGHT M.				
1	<u>Xylia kerrii Craib.</u>	<u>8</u>	<u>15</u>	7							
2	<u>Cratoxylon pruniflorum Kurz.</u>	<u>1</u>	<u>16</u>	8							
3	<u>Terminalia bellerica Roxb.</u>	<u>1</u>	<u>16</u>	9							
4	<u>pterocarpus macrocarpus Kurz.</u>	<u>3</u>	<u>12</u>	10							
5	<u>Other</u>	<u>8</u>	<u>8</u>	11							
6				12							

REMARK \_\_\_\_\_

SIGNATURE M. S. S. S.DATE 26/6/73

R.F.D. 8/3/73.

Figure 4 Ground Truth Recording Form

# ERTS-1 PROGRAM

## FOREST GROUND INFORMATION DATA SHEET.

SECTOR: FORESTRY

## ERTS-1 INFORMATION

LOCATION AMPHOE PONG NAM RON CHANGWAT CHANTHABURIORBIT NO. E-1202-03014 MSS BAND 5 SCALE 1/500,000DATE PHOTO 10/2/73LAT 13°-07'-54" LONG 102°-19'-17"

## FIELD PHOTOGRAPHY



LOCATION <u>2 KM. FROM THE</u>		LAND USE CATEGORY			SAMPLING PLOT No. <u>2/5</u>		
SOUTH OF BAN SA TRON		VEGETATED	AREA	<u>01</u>	SIZE OF PLOT. <u>50 X 50</u> M		
TYPE OF FLIM. <u>COLOUR</u>		CULTIVATED	AREA	<u>02</u>	ELEVATION. <u>150</u> M		
TIME <u>13.20</u>		URBAN	AREA	<u>03</u>	SLOPE. <u>—</u> %		
DATE <u>26/6/73</u>		WATER	AREA	<u>04</u>	ASPECT. <u>—</u>		
		OPEN	LAND	<u>05</u>			
TYPE OF FOREST.		<u>10</u>	<u>20</u>	<u>30</u>	<u>40</u>	<u>50</u>	
		<u>60</u>	<u>70</u>	DOMINANT TREE. <u>Xylia kerrii Craib</u>			
FOREST DISTURBANCES.		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	
		<u>6</u>	HEIGHT. <u>30 M.</u> ☉ <u>1.20</u> M				
CROWN DENSITY.		<u>1</u>	<u>2</u>	<u>3</u>	MACRORELIEF. <u>M</u>		
LEAF CONDITION.		<u>1</u>	<u>2</u>	<u>3</u>	GROUND MOISTURE CONDITION. <u>MEDIUM</u>		
		DECIDUOUS TREE					
No.	PROMINANT SPECIES.	NO OF TREE	AVE HEIGHT M.	No.	PROMINANT SPECIES.	NO OF TREE	AVE HEIGHT M.
<u>1</u>	<u>Xylia kerrii Craib</u>	<u>8</u>	<u>34</u>	<u>7</u>	<u>Vitex peduncularis Wall.</u>	<u>2</u>	<u>8</u>
<u>2</u>	<u>Lagerstroemia floribunda Jack.</u>	<u>10</u>	<u>25</u>	<u>8</u>			
<u>3</u>	<u>Cratoxylon pruniflorum Kurz.</u>	<u>2</u>	<u>32</u>	<u>9</u>			
<u>4</u>	<u>Dalbergia oliveri Gamble.</u>	<u>4</u>	<u>35</u>	<u>10</u>			
<u>5</u>	<u>Croton oblongifolius Roxb.</u>	<u>1</u>	<u>20</u>	<u>11</u>			
<u>6</u>	<u>Litsea palyantha Juss.</u>	<u>2</u>	<u>32</u>	<u>12</u>			

REMARK \_\_\_\_\_

SIGNATURE [Signature]DATE 26/6/73

REF. 8/9/73

Figure 5 Ground Truth Recording Form

# ERTS-1 PROGRAM

## FOREST GROUND INFORMATION DATA SHEET.

SECTOR: FORESTRY

ERTS-1 INFORMATION

LOCATION, AMPHOE PONG NAM RON CHANGWAT CHANTHABURI

ORBIT No. E-1202-03014 MSS BAND 5 SCALE 1/500000

DATE PHOTO 10/2/73 LAT. 13°-15'-39" LONG. 102°-09'-01"

FIELD PHOTOGRAPHY



LOCATION <u>BAN TUB CHANG</u>		<u>LAND USE CATEGORY</u>			SAMPLING PLOT No. <u>2/6</u>				
		VEGETATED	AREA	01.	SIZE OF PLOT. <u>100 x 100</u> M				
TYPE OF FLIM. <u>COLOUR</u>		CULTIVATED	AREA	02.	ELEVATION. <u>120</u> M				
TIME. <u>11.10 A.M.</u>		URBAN	AREA	03.	SLOPE. <u>—</u>				
DATE. <u>27/6/73</u>		WATER	AREA	04.	ASPECT. <u>—</u>				
		OPEN	LAND	05.					
TYPE OF FOREST.	10	20	30	40	50	60	70	DOMINANT TREE. <u>Shorea obtusa.</u>	
FOREST DISTURBANCES.	1	2	3	4	5	6		HEIGHT. <u>40 M.</u> $\odot$ <u>1.30</u>	
CROWN DENSITY.	1	2	3					MACRORELIEF. <u>M<sub>1</sub></u>	
LEAF CONDITION.	1	2	3	DECIDUOUS TREE	GROUND MOISTURE CONDITION. <u>Medium</u>				
No.	PROMINANT SPECIES.		NO OF TREE	AVE HEIGHT M.	No.	PROMINANT SPECIES.		NO OF TREE	AVE HEIGHT M.
1	<u>Irvingia malayana Oliver.</u>		<u>3</u>	<u>32</u>	7	<u>Sindora siamensis Teysm.</u>		<u>5</u>	<u>24</u>
2	<u>Pentacme suavis A.DC.</u>		<u>4</u>	<u>26</u>	8	<u>Garuga pinnata Roxb.</u>		<u>3</u>	<u>26</u>
3	<u>Shorea obtusa</u>		<u>5</u>	<u>27</u>	9	<u>Phyllanthus emblica Linn.</u>		<u>4</u>	<u>15</u>
4	<u>Terminalia tomentosa W.&amp;A.</u>		<u>1</u>	<u>26</u>	10	<u>Lagerstroemia speciosa Pers.</u>		<u>1</u>	<u>14</u>
5	<u>Cassia garrettiana</u>		<u>1</u>	<u>24</u>	11	<u>Dalbergia nigrescens Kurz.</u>		<u>2</u>	<u>26</u>
6	<u>Careya arborea Roxb.</u>		<u>2</u>	<u>22</u>	12	<u>Cratoxylon pruniflorum Kurz.</u>		<u>3</u>	<u>16</u>

REMARK \_\_\_\_\_

SIGNATURE [Signature]

RFD 8/9/73.

DATE 27/6/73

Figure 6 Ground Truth Recording Form

ERTS-1 PROGRAM											
FOREST GROUND INFORMATION DATA SHEET.								SECTOR: FORESTRY			
ERTS-1 INFORMATION											
LOCATION, AMPHOE <u>PONG NAM RON</u>					CHANGWAT <u>CHANTHABURI</u>						
ORBIT No. <u>E 1202 - 03014</u>			MSS BAND <u>5</u>		SCALE <u>1/500000</u>						
DATE PHOTO <u>10/2/73</u>			LAT <u>13°-07'-57"</u>		LONG <u>102°-10'-36"</u>						
FIELD PHOTOGRAPHY											
											
LOCATION <u>NORTH OF THE WILD</u>				LAND USE CATEGORY				SAMPLING PLOT No. <u>2/8</u>			
LIFE PROTECT STATION, <u>KAO</u>				VEGETATED	AREA	<input checked="" type="checkbox"/>	SIZE OF PLOT <u>50 x 50</u>				
SOI DAO ABOUT 2.5 KM.				CULTIVATED	AREA	<input type="checkbox"/>	ELEVATION <u>200</u>				
TYPE OF FLUM, <u>COLOUR</u>				URBAN	AREA	<input type="checkbox"/>	SLOPE <u>-</u>				
TIME <u>10.25 AM</u>				WATER	AREA	<input type="checkbox"/>	ASPECT <u>-</u>				
DATE <u>29/6/73</u>				OPEN	LAND	<input type="checkbox"/>					
TYPE OF FOREST.			10	20	30	40	50	60	70		
FOREST DISTURBANCES.			1	2	3	4	5	6			
CROWN DENSITY.			1	2	3						
LEAF CONDITION.			1	2	3	DECIDUOUS TREE					
			GROUND MOISTURE CONDITION, <u>WET</u>				DOMINANT TREE, <u>Lagerstroemia calyculata Stapf.</u>				
			HEIGHT, <u>40 M.</u> $\odot$ <u>5.80</u>				MACRORELIEF, <u>M</u>				
							2				
No.	PROMINANT SPECIES.				NO OF TREE	AVE HEIGHT M.	No.	PROMINANT SPECIES.			
1	<u>Oths.</u>				<u>9</u>	<u>25</u>	7				
2	<u>Dipterocarpus alatus Roxb.</u>				<u>2</u>	<u>18</u>	8				
3	<u>Lagerstroemia calyculata</u>				<u>4</u>	<u>40</u>	9				
4	<u>Terminalia mucronata.</u>				<u>1</u>	<u>40</u>	10				
5							11				
6							12				
REMARK											
SIGNATURE <u>Antun J. Prastika</u>											
DATE <u>29/6/73</u>											
REF. 6/9/73.											

Figure 7 Ground Truth Recording Form

# ERTS-1 PROGRAM

## FOREST GROUND INFORMATION DATA SHEET.

SECTOR FORESTRY

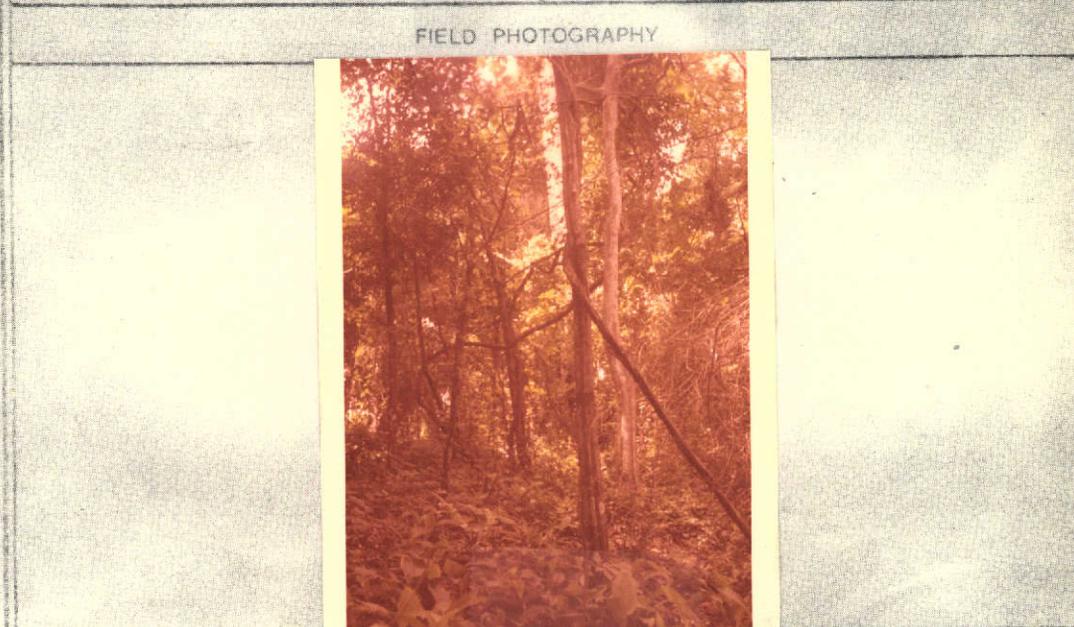
ERTS-1 INFORMATION

LOCATION AMPHOE PONG NAM RON CHANGWAT CHANTHABURI

---

ORBIT No. E-1202-03014 MSS BAND 5 SCALE 1/500000

DATE PHOTO 10/2/73 LAT 30°-10'-21" LONG 102°-08'-45"



LOCATION <u>BAN KAO GLUER</u>		<u>LAND USE CATEGORY</u>			SAMPLING PLOT No. <u>2/10</u>	
		VEGETATED	AREA	<input checked="" type="checkbox"/>	SIZE OF PLOT. <u>50x50</u> M.	
TYPE OF PLIM. <u>COLOUR</u>		CULTIVATED	AREA	<input type="checkbox"/>	ELEVATION. <u>150</u> M.	
TIME <u>12.00</u>		URBAN	AREA	<input type="checkbox"/>	SLOPE. <u>-</u> %	
DATE <u>20/6/73</u>		WATER	AREA	<input type="checkbox"/>	ASPECT. <u>-</u>	
		OPEN	LAND	<input type="checkbox"/>		
TYPE OF FOREST.		10	20	<input checked="" type="checkbox"/>	40	50
		60	70	DOMINANT TREE <u>Lagerstroemia caliculata</u>		
FOREST DISTURBANCES.		1	<input checked="" type="checkbox"/>	3	4	5
		6	HEIGHT. <u>40 M.</u> <input type="checkbox"/> <u>1.55</u> M.			
CROWN DENSITY.		1	2	<input checked="" type="checkbox"/>	MACRORELIEF. <u>M<sub>2</sub></u>	
LEAF CONDITION.		1	2	3	GROUND MOISTURE CONDITION. <u>wet</u>	
		DECIDUOUS TREE				
No.	PROMINANT SPECIES.	NO OF TREE	AVE HEIGHT M.	No.	PROMINANT SPECIES.	NO OF TREE
1	<u>Lagerstroemia caliculata</u>	<u>1</u>	<u>41</u>	7	<u>Jacaranda mimosifolia</u>	<u>1</u>
2	<u>Terminolia mucronata</u>	<u>1</u>	<u>40</u>	8		
3	<u>Gmelina arborea Roxb.</u>	<u>2</u>	<u>40</u>	9		
4	<u>Oth</u>	<u>12</u>	<u>35</u>	10		
5	<u>Dipterocarpus spp.</u>	<u>2</u>	<u>15</u>	11		
6	<u>Cedrela toona</u>	<u>1</u>	<u>20</u>	12		

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SIGNATURE [Signature]

DATE 20/6/73

REF. 819/73

Figure 8 Ground Truth Recording Form

**CODE**

<u>TYPE OF FOREST</u>	<u>CODE</u>	<u>TYPE OF FOREST DISTURBANCES</u>	<u>CODE</u>
Mixed Deciduous	10	Non-Disturbance	1
Dry Dipterocarp	20	Cutting-Heavy	2
Tropical Evergreen	30	Cutting-Light	3
Pine Forest	40	Fire Damage	4
Mangrove Forest	50	Old clearing and Shifting cultivation	5
Bamboo Forest	60	Infestation	5
Scrub	70		

<u>MACRORELIEF CLASSES</u>	<u>CODE</u>	<u>CROWN DENSITY</u>	<u>CODE</u>
Flat Land	M1	75 - 100 %	1
Underlying and Rolling Land	M2	25 - 75 %	2
Hilly Land	M3	0 - 25 %	3
Mountainous Land	M4		

<u>GROUND MOISTURE CONDITION</u>	<u>CODE</u>	<u>LEAF CONDITION (DECIDUOUS TREES)</u>	<u>CODE</u>
Wet	1	Shedding	1
Medium	2	Spring	2
Dry	3	Flowering	3
Very Dry	4		



Figure 9 ERTS-1 Band 5 Mosaic of East Thailand Used to Make Forest Map



## Final Report

Sector: Land Use

Reported by

Manu Omakupt and Staff

1. Objectives

1. Study of the ERTS-1 imagery by interpretation
2. Acceleration of the programme to prepare land use maps in a reasonable period of time.
3. Evaluation of the value of repetitive coverage.

As the ERTS-1 acquires information at regular intervals, it is possible to repeat the observation as needed for identification of changes in land use patterns, and permits updating of existing maps.

2. Procedure

1:1,000,000 and 1:500,000 scale ERTS-1 images were used. Topographic maps at scales 1:250,000 and 1:50,000 were also used for comparisons. Two levels of interpretation were employed to derive information from a single image or data format.

1. Rapid recognition of self-evident features such as dam-sites, reservoirs, lakes, rivers, forests, agricultural and urban patterns, transportation and geological structure. This level of interpretation may be undertaken by anyone with an appreciation of scales, maps and regional geography. It is very useful for broad land use mapping.

2. Skilled interpretation of data by specialists. This level of interpretation is supplemented by more detailed data from ground observations and false-color images.

Field checks have been carried on since Jan 1973. A record of information is obtained for each land use pattern.

A temporary classification has been developed for land use mapping on ERTS-1 images. The classification development requires pre-eminently a consideration of purpose and mappable categories. There are a number of decidedly different land use classifications extant. The classification which is presented below serves the immediate problem here on identification - and recognition on small-scale imagery of that which occupies the earth's surface.

### 3. Classification

A very general classification of use categories was developed based on the premise that only gross types of use or occupancy could be identified at such scales for the first stage of this research. Each category is identified numerically and descriptively with the combination of visual or inferential criteria (location, association, etc.) collectively constituting its respective signature. Numerical designations identify major groups by whole numbers, subdivisions by decimals.

#### 1. Dense forest

Signature: darkness and evenness of tone, uneven terrain, substantial areal extent (small isolated wooded areas were excluded from this category but equally small clear cut areas were ignored and thus included), and softening of ridge and drainage feature contours by vegetation cover.

2. Cut forest: dominantly forest (mostly are secondary growth) but which include some agriculture (shifting cultivation) and non-used areas.

Signature: variable intermediate gray tones indicating stages of regrowth, variably shaped but sharply defined outline, absence of clumps of mature trees, no field shapes and ragged boundaries separating forest and clearings.

3. Agriculture and forest: dominantly crops with some forest (secondary growth and bushes, shrubs)

##### 3.1 Field crop + forest

##### 3.2 Paddy + forest

Signature: separation of these two categories has been imperfectly achieved; the intent, however, is clear from the category titles. We can confirm it by using false-color images which are taken at the proper time accompanied by field checks. Tonal variation from very light to intermediate, few wooded tracts and those typically along stream courses, cluttered, untidy mixture of ragged dark-toned wooded tracts and lighter toned cultivated areas.

#### 4. Field crop

Signature: mainly even-toned intermediate gray, no evidence of field boundaries within the area. The distinction between this category and 3 is lighter and finer tone, presence of few dark spots of bushes, shrubs and hills.

#### 5. Paddy field

Signature: lightness and evenness of tone, even terrain, few wooded tracts and those typically along river or stream courses. The large areas occupying alluvial plains and depressed areas. The distinc-

tion between this category and 4 is by finer and lighter tone, accompanying darker tracts of stream courses.

5'. Double cropping or crop rotation are active after the rice season, in this area. Interpretation is by darker tone that represents high soil moisture content and standing crops

6. Perennial: orchards, trees (rubber, coconut, tea, coffee, etc.)

Signature: quite even intermediate to darker tone; fine texture; mapping of this category was based on location mainly.

7. Horticulture: truck cropping mixed, with various crops such as corn, sugarcane, bananas, and small fruit trees.

Signature: variable intermediate gray tones indicating mixture of crops, location (low land, surrounded by rice field and perennial crop) is very important for identification; experience of interpreter is needed.

8. Non-productive areas

Signature: variable darkness and intermediate tones, identification of a surface undesirable for or incapable of use in the same sense as above. This category is composed of idle land, poorly drained areas (swamps, oxbows), and shifting cultivation.

9. Water surface

Signature: very fine texture, solid darkness and evenness of tones in band 7.

10. Urban area

Signature: very light or white-toned where there is a city or big town, minute patches of wood or fields within the area, location adjacent to an urban unit.

#### 4. Results

Experimental studies are being carried out with satellite imagery in an attempt to assist the land use planning program. Discrimination of land use patterns to the degree that certain crops are separable on the basis of their spectral and temporal characteristics (for some, more experimentation is needed); surface soil color patterns, but relationship to soil survey has yet to be established for broad areas.

Six frames of ERTS-1 imagery (see figure I) were studied, which were very useful for mapping of broad land cover-type. The results of the effort are considered satisfactory as illustrated in figures shown on the later pages. Summarization of the experimental studies is expressed below:

1. Broad land use classification was mapped distinctly (examples are shown in Figures 2 to 6) which saved time and cost of survey. It provided good information, more accurate maps, and up-to-date production of land use mapping. Comparing, for example, traditional use of aerial photographs of 1:50,000 scale, approximately 500 photographs are required for coverage of Eastern Thailand, an area covered by two frames of ERTS imagery. A land use assessment from the photographs would require about three months, while using the ERTS images and an experienced team of equal size, the job could be completed in about two weeks time, including field checking.

2. Changes on the earth's surface could be observed immediately in certain circumstances. Figures 7 (A, B, C, & D) are samples of temporal changes that occurred along the Mun River Basin. A flooding situation was observed on Figure 7A which was taken on 25 October 1972. It was a large flooded area and caused a lot of damage to this region (both rice fields and field crops) during the late rainy season accompanying a barometric depression. The water level was lower on 18 December 1972 (Figure 7B) but the level was still over the bank of the Mun River and its tributaries. The normal situation came back in January 1973 (Figure 7C) which was the cool season in Thailand. A second depression attacked Thailand in February 1973 (Figure 7D), and brought damage to some areas in the River Mun Basin again.

Evaluation of damage can be made as soon as the data come in, and this will in future help those who have responsibility to assess the damage faster.

3. A photo-mosaic of Thailand was made (Figure 8) from ERTS-1 band 7 images. The author thought that it was the most fantastic scene he ever saw. It showed the primary water resources (dams, lakes, rivers and their tributaries, etc.) very clearly. Size, shape, and location of these water resources are clearly defined. Some of them have not been shown on any existing map before.

Present land use patterns are easily recognized on the ERTS-1 band 5 mosaic, and also geological features are shown quite clearly. Recognition of shore-line and shape of some islands are seen to have changed when comparing to existing maps.

4. False-color images and photographs with different color filters were studied. They provided more detailed data on crop type and density, soil moisture, and related information. The authors could not have it shown in this report because the lack of budget for color reproduction.

## 5. Conclusion and Discussion

A classification for broad land use mapping has been developed and employed in the investigation. The results of the effort are considered satisfactory. Further improvement of the procedures would have resulted in a more accurate map. Not only is more accurate mapping possible, but also a more detailed and complete classification could be developed for use with this imagery.

ERTS-1 data can assist in the task of monitoring the environment and the changes that occur naturally as well as those that are induced by man. It will also provide information which can contribute to optimal land use. Savings in time and costs have been recognized as a clearly established advantage of cartographic mapping by ERTS-1. The best current method of obtaining accurate small scale maps of large areas appears to be high altitude aerial imaging (satellite data).

For further study a combination of data obtained from aircraft and other sensing platforms, in close correlation with data obtained from ground truth, will be required. In addition, for obtaining accurate up-to-date and timely land use information concerning our resource base, there appears to be strong evidence that a need exists for making use of automatic data processing (by computers and other mechanical aids). However, such interpretation techniques are complex and relatively expensive.

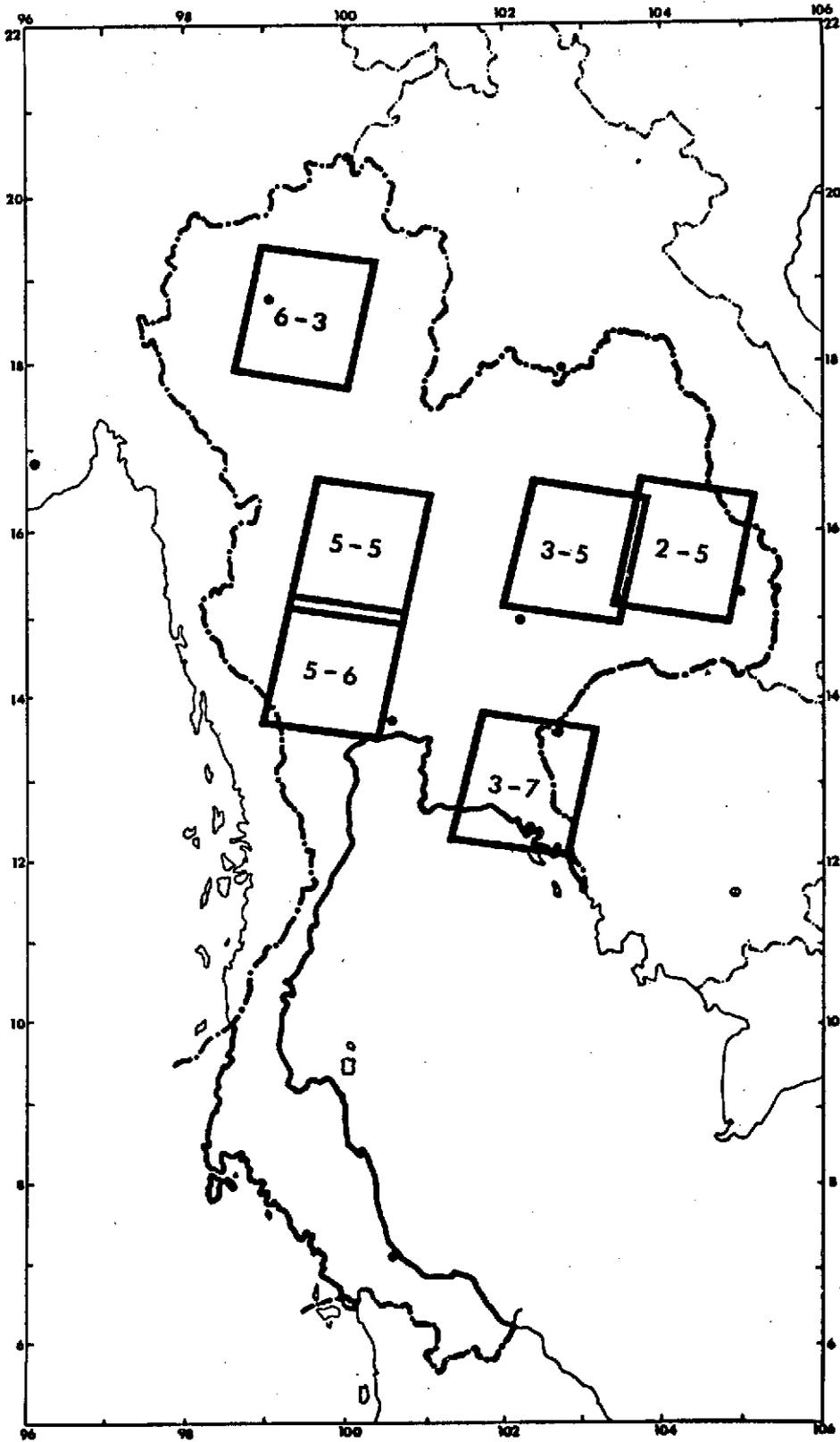


FIGURE 1. Locations of ERTS-1 Frames Selected for Initial Land Use Mapping

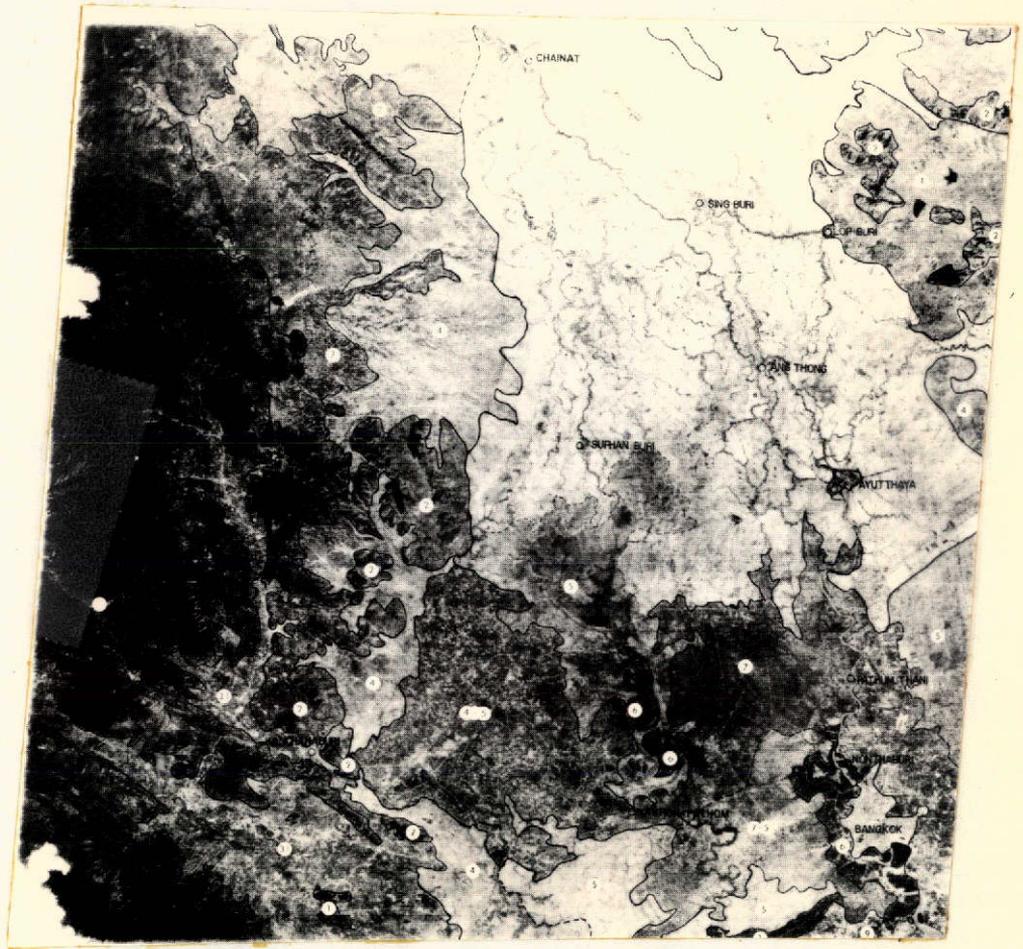


FIGURE 2 Example of Land Use Mapping, Bangkok Area, Frame 5-6.  
(See text for explanation of numbers)



FIGURE 3 Example of Land Use Mapping, East Thailand, Frame 3-7. (See text for explanation of numbers)



FIGURE 4 Example of Land Use Mapping, North Thailand,  
Frame 6-3. (See text for explanation of numbers)

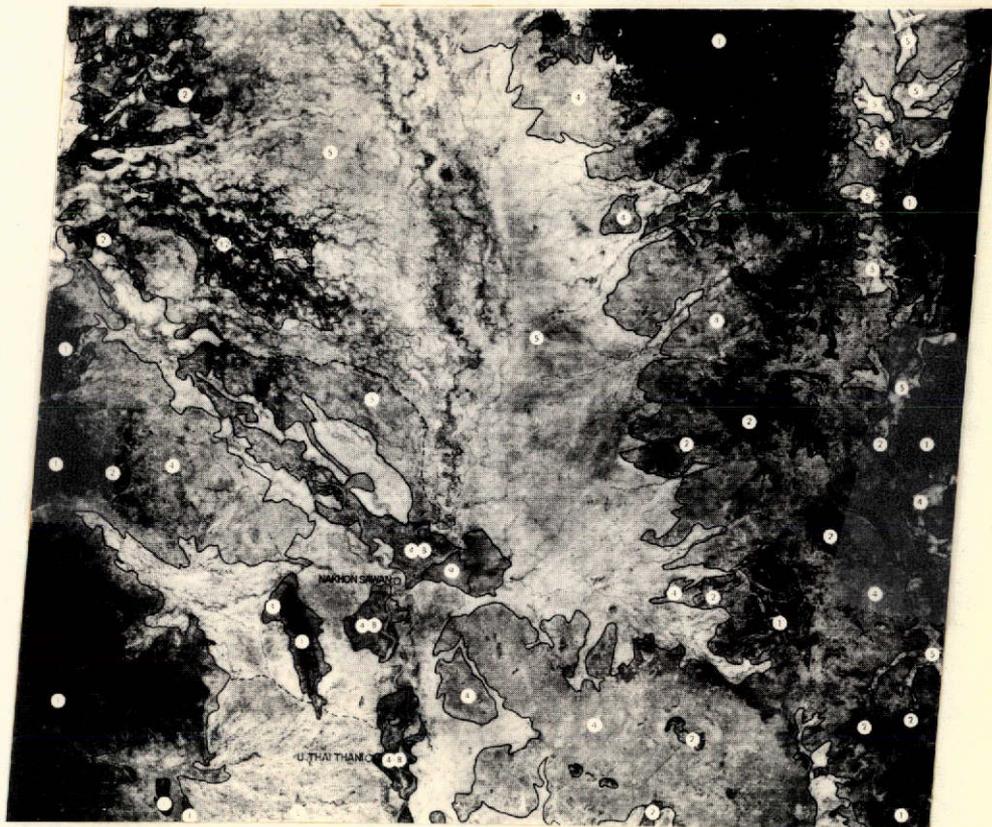


FIGURE 5 Example of Land Use Mapping. Central Thailand, Frame 5-5. (See text for explanation of numbers)

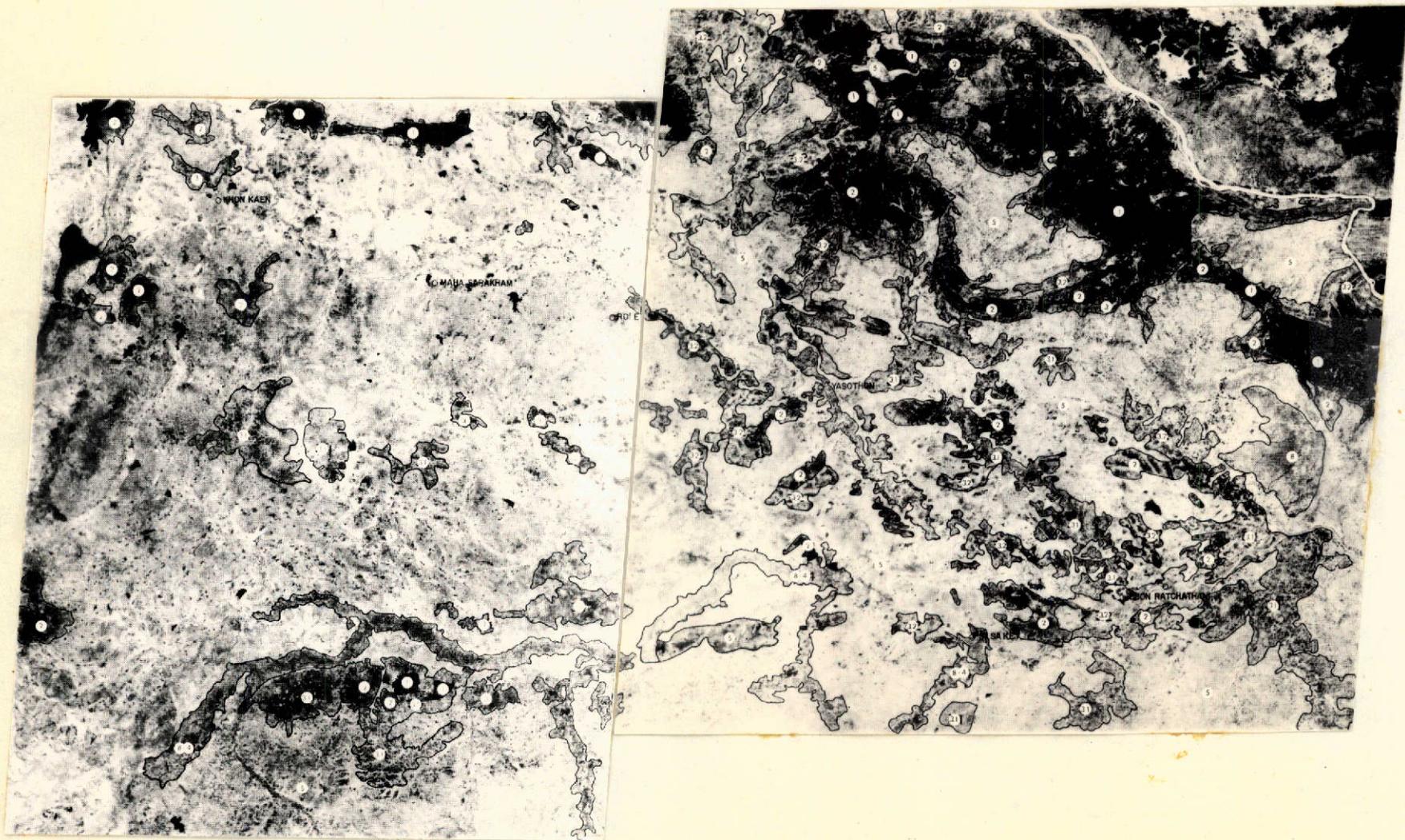


FIGURE 6. Example of Land Use Mapping, North-East Thailand. Frames 2-5 and 3-5.  
(See text for explanation of numbers)



25 OCT 72

E-1094-03003-7

A. Flood Stage - Major Crop Damage



18 DEC 72

E-1148-03004-7

B. Partial Recovery - Wet Areas Along Mun River



23 JAN 73

E-1184-03003-7

C. Normal Dry Season Appearance



28 FEB 73

E-1220-03010-7

D. Recurrence of Flooding in some Areas

FIGURE 7. Mun River Basin, Thailand, 25 OCT 72 - 28 FEB 73

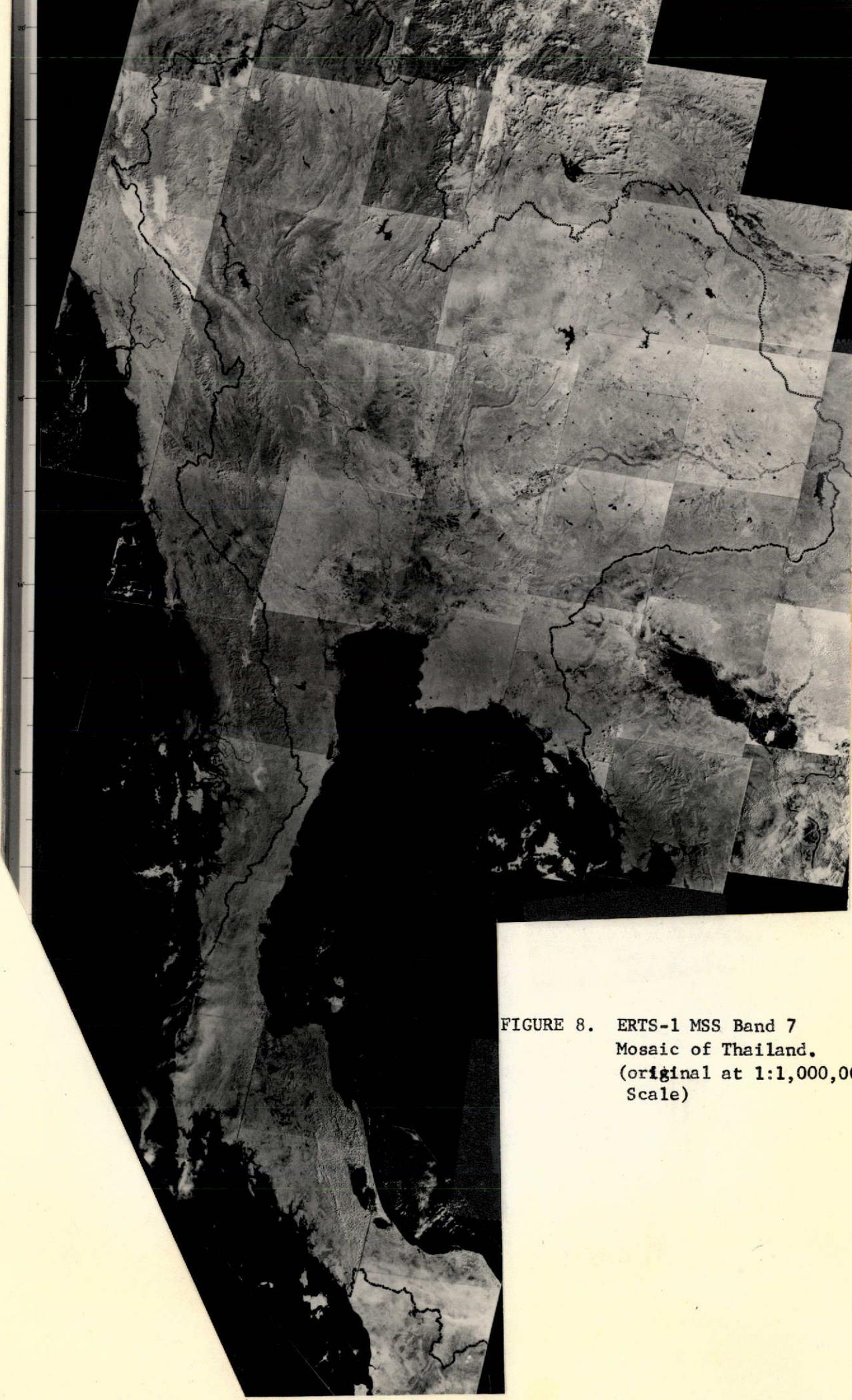


FIGURE 8. ERTS-1 MSS Band 7  
Mosaic of Thailand.  
(original at 1:1,000,000  
Scale)

## Final Report

Sector: Geology

Reported by

Prayong Angsuwatana

The work described in this section was carried out in the Photo-Geological Survey Laboratory of the Department of Mineral Resources, Ministry of Industry, by using photogeological interpretation techniques applied to ERTS-1 imagery. Black and white positive transparencies of MSS band 5 imagery, which show some geologic features with high contrast, were used for most of the work. Features were plotted on Koda-Trace material taped over the transparencies on a light table, first working in the visible drainage patterns, dips, strikes, major structures and boundaries of rock types.

The area studied (Figure 1) consists of sedimentary, metamorphic, and igneous rocks. The oldest rock is exposed along the Kwai Yai River. The land in this area was uplifted and extensively eroded in earlier geologic times. The younger rock lies above. Accessibility of this area is very poor. The area is quite mountainous and there are no roads for vehicles.

The work was separated into three parts:

1. Discrimination was done by consideration of drainage patterns, tonal and textural variations, and identification of structures; faults, fractures, and folds.
2. Several rock types were discriminated, using considerations of physical and chemical properties and the known erosion rates of the various rock types, reflecting differences in geomorphology. Studies of drainage patterns, surface roughness, type of erosion, tone of certain rock types, and vegetation types all give help in identification. Dominant rock types, for example limestone, sandstone, shale, igneous rock, and some metamorphic rocks can be identified from the space imagery.
3. Field investigations were conducted after the laboratory work was terminated, to check the results of the interpretation.

### Structural Geology

The structure of the study area is complex due to many periods of tectonic movement, including igneous intrusions. Anticlines and synclines up to anticlinorium and synclinorium were formed, and there was considerable faulting, with movements of several kilometers. Several kinds of faults occur in this area, including normal faults, thrust faults, and wrench faults, resulting from tension and release pressures.

### Folding

The study area can be divided into two parts by structural trends and folding:

Part I. Trending approximately from the NW to the SE corner of the map. The majority of dipping is to the NE according to the granite intrusion along the Burma border, parallel to the granite trend, and the syncline of Permian lies on top.

Part II. The northern part of Part I. Generally, striking NS Dipping NW and SE. The approximate central section of the upper part is a large anticline of old rock plunging to the south and the permian limestone lies above. The eastern part of this scene shows the old anticlines and synclines of rock of Ordovician age.

It can be assumed that the rocks in this area were folding in Ordovician times. Dipping of the strata varies from  $45^{\circ}$ - $80^{\circ}$ , and in some parts from  $10^{\circ}$ - $25^{\circ}$ . In several later times, large anticlines and synclines up to anticlinorium and synclinorium were formed. Most of the folding is assymetric, and is overturned in the western limb. The eastern part of this area was uplifted higher than the western part. Erosion is more prominent in the eastern part.

### Faults

Faults exhibited in the study area can be classified into four types:

1. Normal faults
2. Reverse faults
3. Thrust faults
4. Wrench faults

The longest fault in this area is more than 80 km long -- it is a contact fault between Permo-Carboniferous rocks. It is a normal fault, and there are secondary faults cut through in some places, resulting in horizontal displacement of the primary fault. This fault is bifurcated at the southern end.

### Reference to Image and Overlay

Symbol 1. Deposition from erosion of the older rocks. It consists of conglomeratic sandstone, sandstone, siltstone, mudstone, carbonate shale, consolidated conglomerate, white calcereous tufa and residual soil.

Symbol 2. This formation consists of limestone (Ratburi limestone) which extends along the Kwai Noi and Kwai Yai Rivers. It is massive limestone, with color varying from light grey to dark grey. In some places dolomite, chert beds and chert nodules are interbedded with the limestone.

Symbol 3. This formation consists mostly of red limestone conglomerate with some chert and quartzite, and with calcareous and ferruginous cementing materials.

Symbol 4. This formation is red sandstone, interbedded with siltstone. There is a small amount of rounded to sub-rounded quartz and feldspar, in calcareous, siliceous, and ferruginous matrix.

Symbol 5. This formation consists of hard shale, with calcereous cementing.

Symbol 6. This formation occurs between two rivers. The formation is quite thick, and exhibits a varying degree of metamorphism. It has a folded structure, composed of banded limestone, calc. silicate, biotite schist, quartz schist, and gneiss in the lowest part of the formation.

Symbol 7. The color varies from light grey to dark grey, and it is somewhat interbedded with very thin bedded sandstone.

Symbol 8. This is the oldest rock in the study area, forming an anticline in the Southeastern corner of the frame and in the west at Thong Pa Phum. The formation consists of quartzite, quartzitic sandstone, sandy limestone, argillaceous limestone, and shale. The sandstone is interbedded with thin bedded limestone, the sandstone sometimes having a high percentage of  $\text{CaCO}_3$  as the matrix, with argillaceous limestone in some areas. It is a shallow marine deposition.

#### Water Sedimentation, Phuket Tin Region

ERTS images of the Phuket Island region, Phuket Province, South Thailand, were examined for evidence of turbidity in the coastal waters resulting from intensive tin mining operations. Band 7 images were used to obtain an outline map of the island and mainland. Band 4 and 5 images all show varying patterns of siltation in the water at tin mine locations. Images acquired on 9 October 1972, (E-1078-03134) were used to plot four apparent levels of sedimentation, which are arbitrarily referred to here as heavy, light, very light, and clear (no evidence of reflective suspended matter). Figure 2 indicates that areas of "heavy" sedimentation occur close to shore along the western Indian Ocean coast, and that the sediment either settles out in the deeper offshore waters or is dispersed rapidly. In the bay to the east of Phuket island, however, the patterns of apparently heavy sedimentation are persistent and much more extensive, and in this relatively shallow area there may also be some contribution from bottom reflection.

No attempt has been made as yet to determine turbidity levels and relate them to image gray scales.

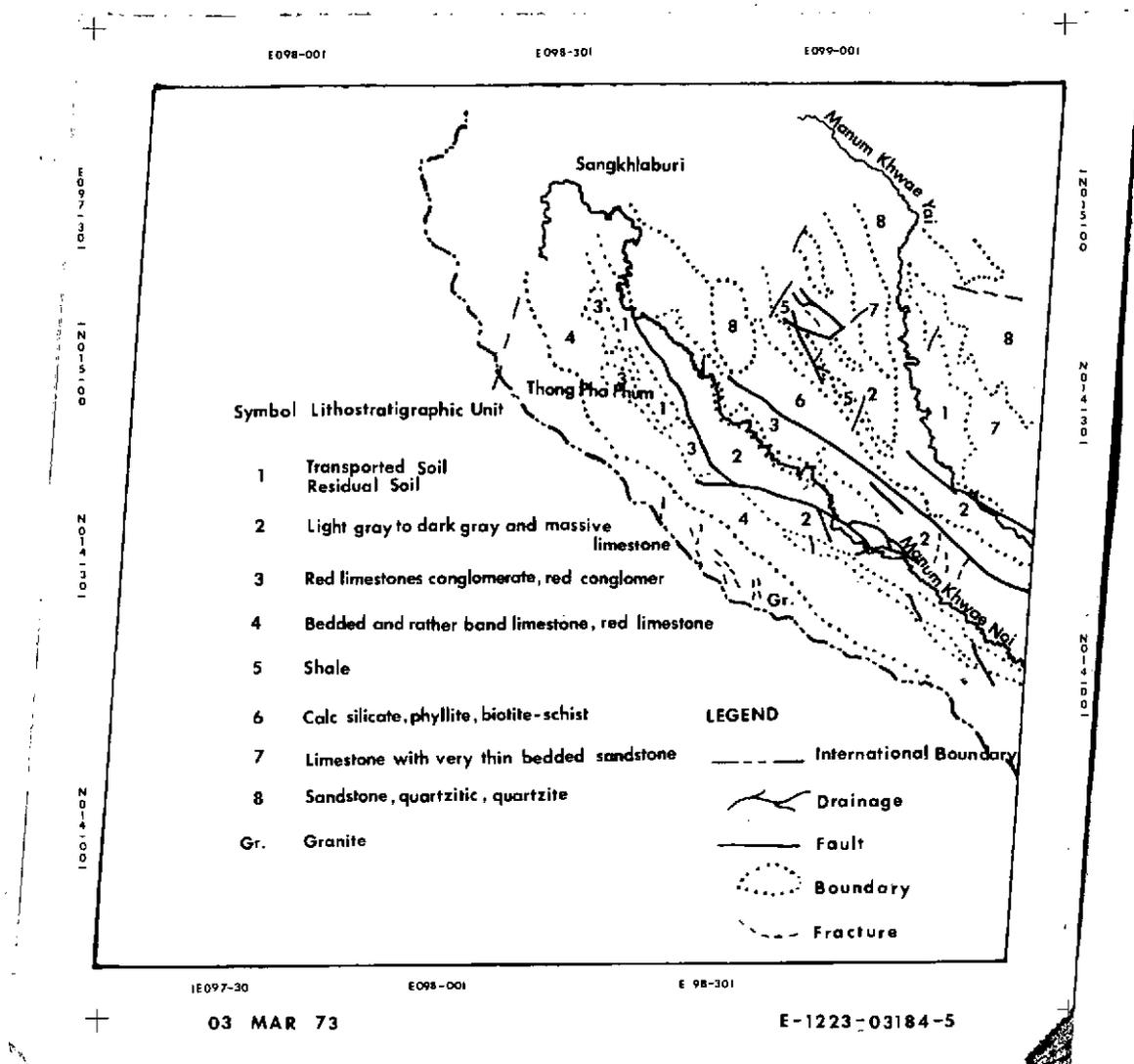


FIGURE 1. Geological Mapping, from ERTS-1 Imagery and Field Survey, Kanchanaburi and River Kwai Area, Thailand.

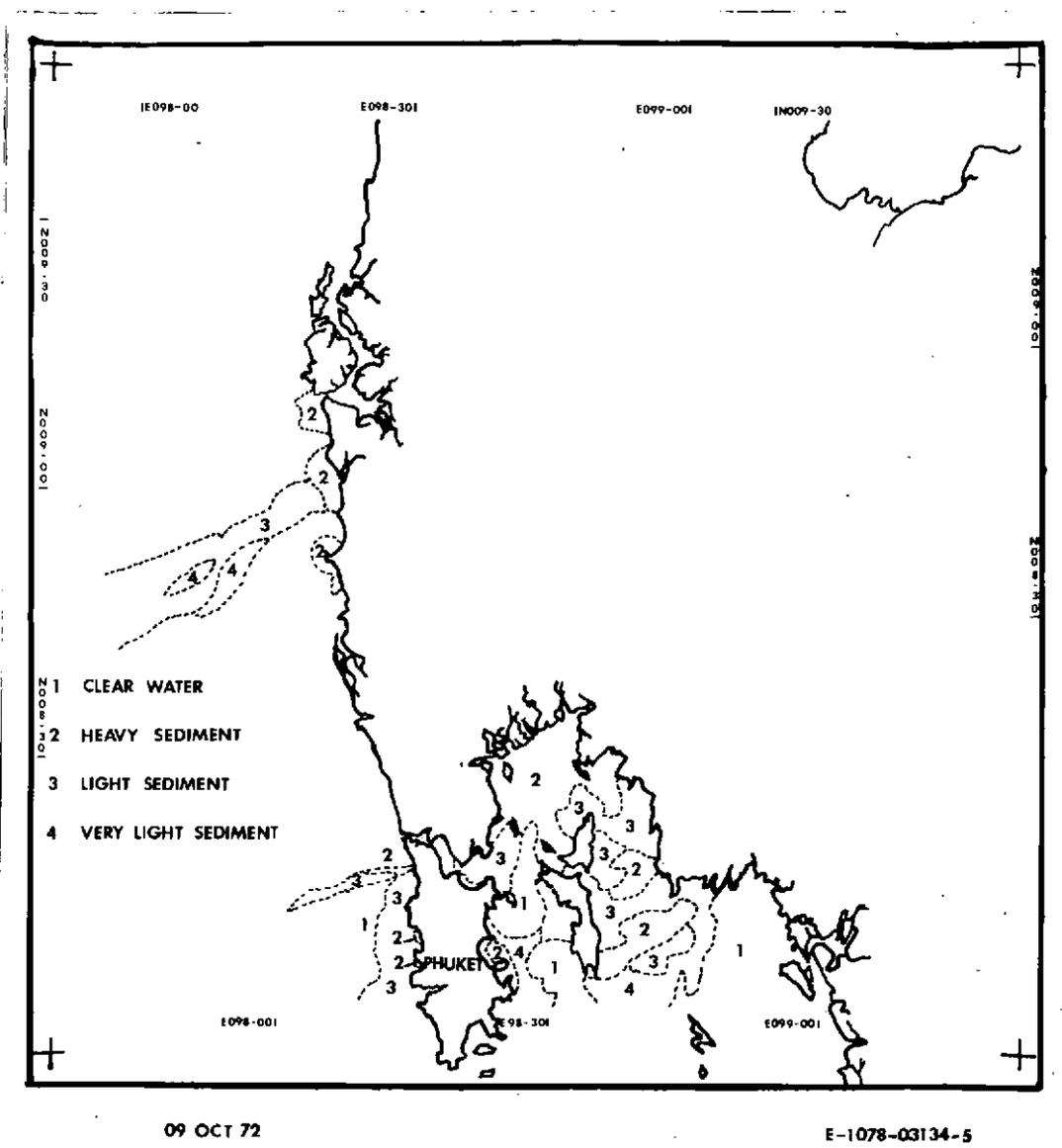
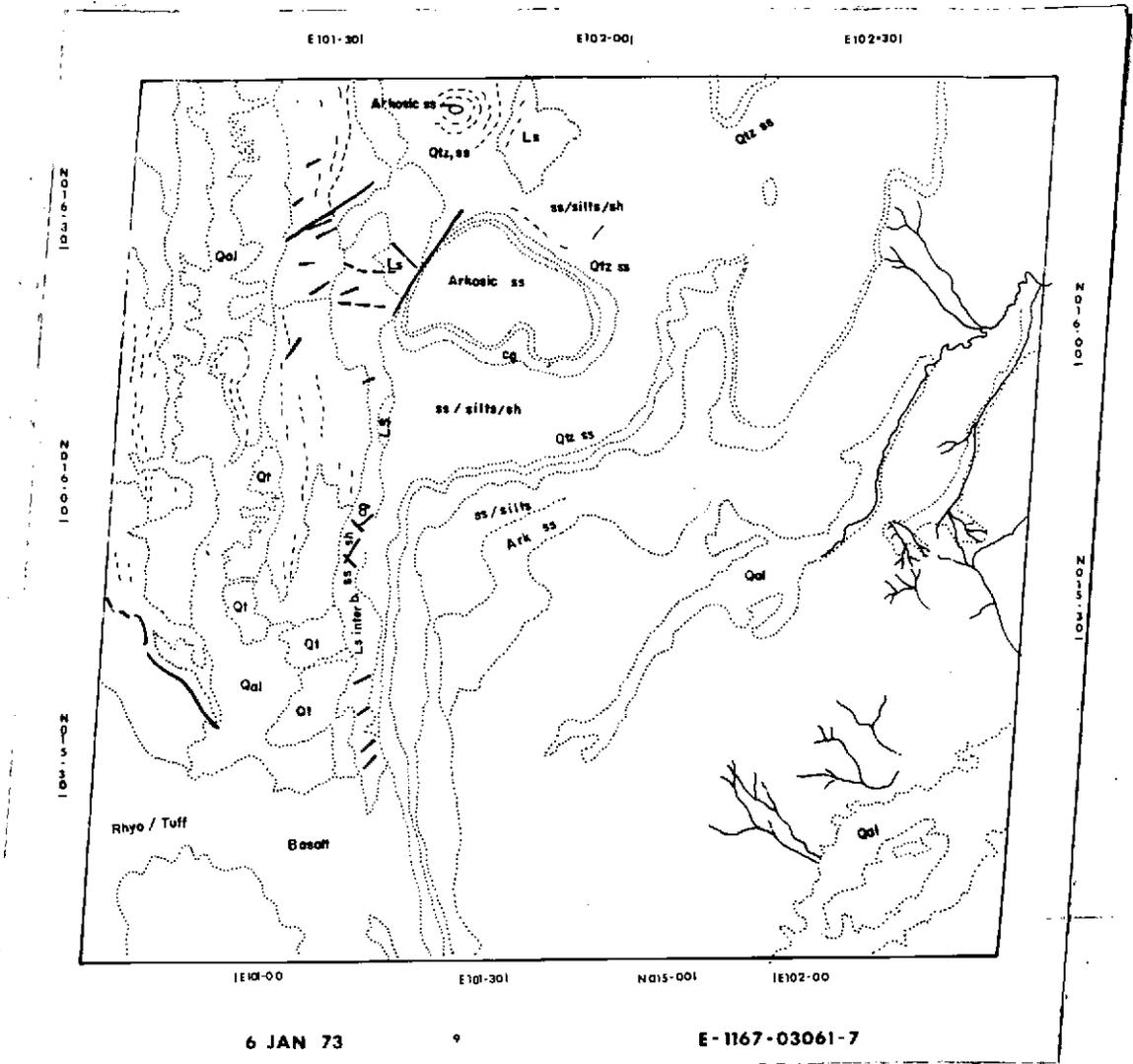


FIGURE 2. Near-shore Water Sedimentation, Phuket Area, South Thailand



FIGURE 3. ERTS-1 Band 7 of North-East Thailand, the geological Mapping being shown in Figure 4.



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FIGURE 4. Geological Mapping of Figure 3 ERTS-1 Imagery

## Final Report

Sector: Hydrology

Reported by

Hydrology Division

Royal Irrigation Department

1. Purpose

Study of ERTS imageries reveals that they can make significant contribution in water resources and applied hydrology, such as mapping of inundated or flooding areas as well as the reservoir areas of the water resources projects in which finally the reservoir capacity can be determined and checked with those originally planned. A case study of some reservoirs in Thailand has been carried out by the Hydrology Division of the Royal Irrigation Department (RID). The purpose of the study is to determine the reservoir areas at different reservoir levels; ground truth is regularly surveyed by project operations. If the imageries are available at all corresponding reservoir levels, then the present reservoir capacity curve can be prepared and compared to the designed one obtained from the topographic map.

2. Procedure and Equipment Used.

4-channel viewer/projector is used to enlarge a black and white 9-in transparency of 1:1,000,000 scale to match with the 1:50,000 scale topographic map prepared by Army Map Service fixed on the screen. Coordination was made by observation of clear road crossings or river courses or other clear marks. The reservoir boundary was then drawn on the map and the reservoir area at a corresponding level can be measured by planimeter.

The transparencies used were of band 6 and 7 of the following:

Kang Kra Chan Reservoir

NASA 1078-03122	9 Oct. 1972
NASA 1168-03124	7 Jan. 1973
NASA 1222-03132	2 Mar. 1973

Lam Ta Kong Reservoir

NASA 1167-03063	6 Jan. 1973
NASA 1221-03071	1 Mar. 1973

Lam Pao Reservoir

NASA 1094-03000      25 Oct. 1972  
NASA 1220-03003      28 Feb. 1973

3. Result

The reservoir areas at different levels of the three reservoirs were measured from the enlargement and compared to those measured from 1:20,000 topographic map used in the original planning. The result is shown in table 3.

The result shows that with a range of reservoir areas from 36 to 134 km<sup>2</sup>, the differences appear to be both greater and smaller than those obtained from topographic maps within the range of  $\pm 2\%$  to  $\pm 10\%$ . The error may be caused by **the** scale of the enlargement which in some cases cannot be clearly fixed or because the distinct water line can hardly be drawn on the enlarged projection with precision.

4. Conclusion

1. The case study does not give a clear result due to the fact that only a few cloud-free imageries for each reservoir can be selected from the available data.

2. It is believed that reservoir capacity can be determined correctly if clear imageries are available at regular intervals throughout the year by means of which low to high reservoir levels can be observed.

3. The method and accuracy of enlargement can be improved by comparing the water areas obtained from the enlargements with those from computer printouts.

Table 3 Reservoir Areas

Reservoir	Date	Reservoir Elevation M. (m.s.l.)	Area in km <sup>2</sup>		% different + greater - smaller
			From Topo map	From ERTS-1	
Kang Kra Chan	9 Oct 72	97.98	46.0	50.3	+10%
	7 Jan 73	99.55	48.0	52.0	+10%
	2 Mar 73	99.21	47.9	51.7	+ 8%
Lam Ta Kong	6 Jan 73	277.21	37.5	38.35	+ 2%
	1 Mar 73	276.70	36.0	35.40	- 2%
Lam Pao	25 Oct 72	158.16	134.0	136.42	+ 2%
	28 Feb 73	156.57	100.0	92.17	- 8%

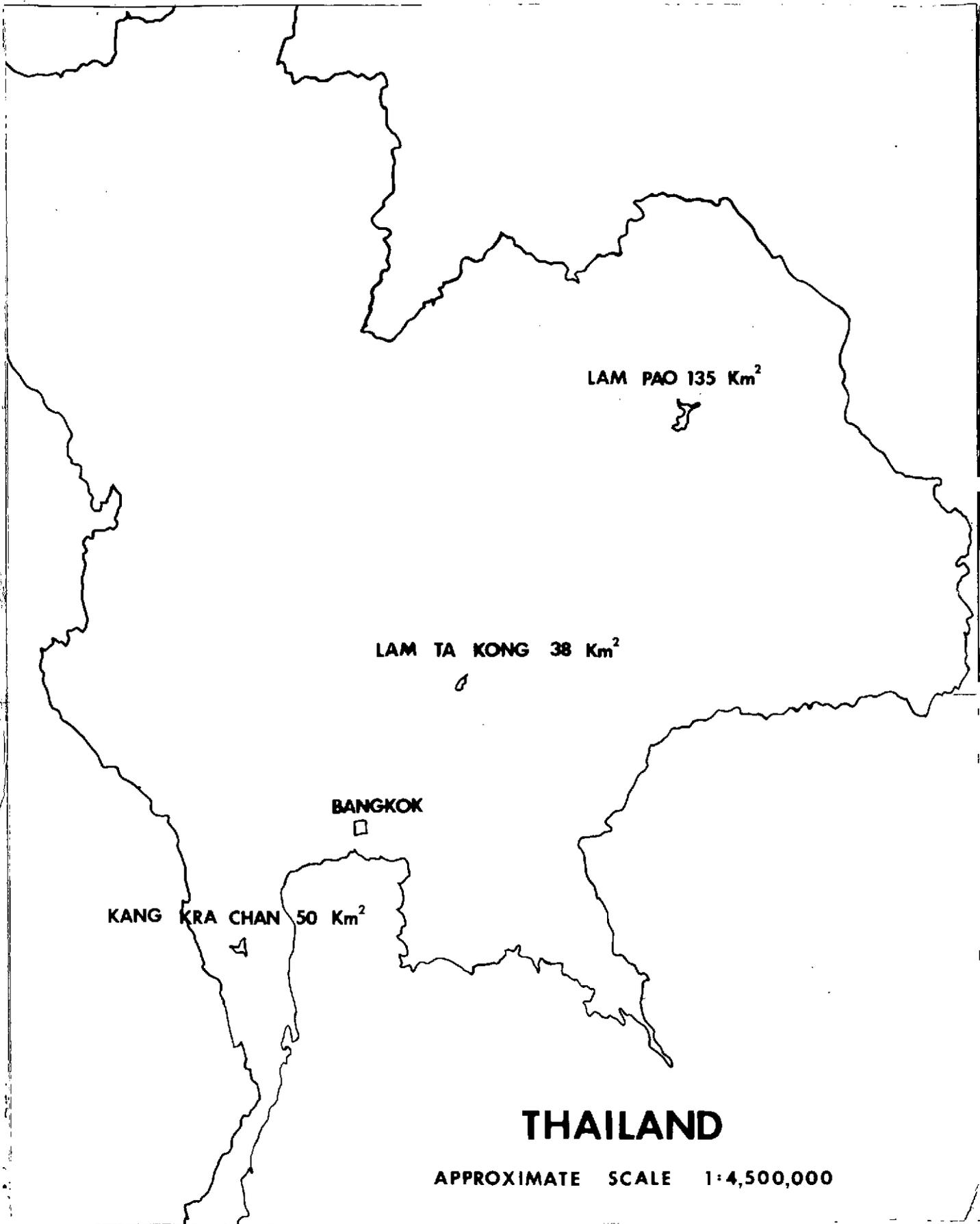


FIGURE 1. Location of Reservoirs Studied.

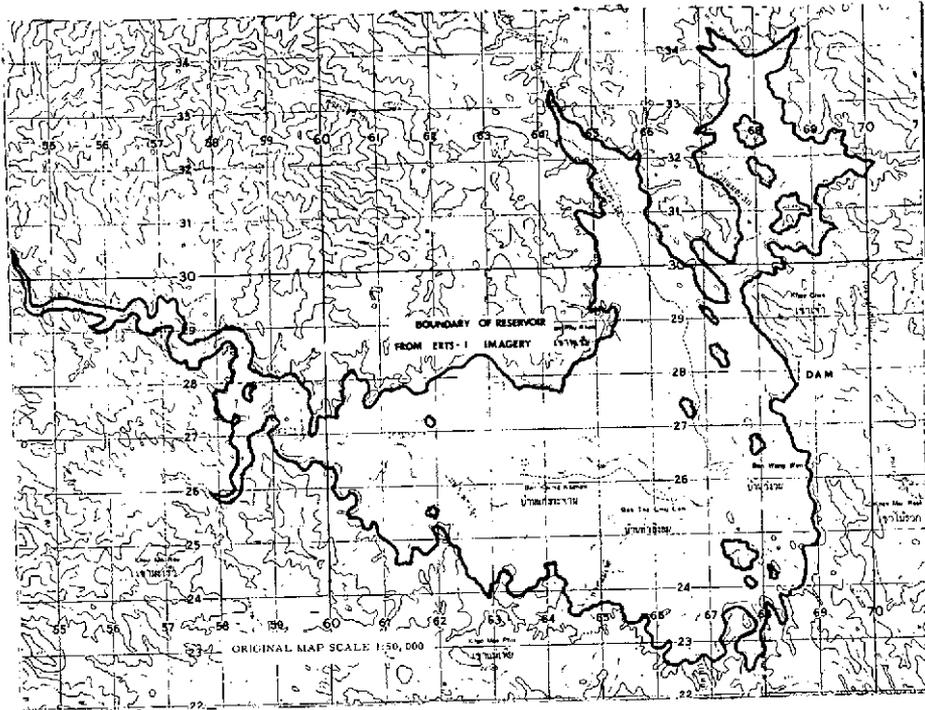


FIGURE 2. Projection of ERTS-1 Imagery onto the Topographic Map at 1:50,000 scale for Kang Kra Chan Reservoir Area Study

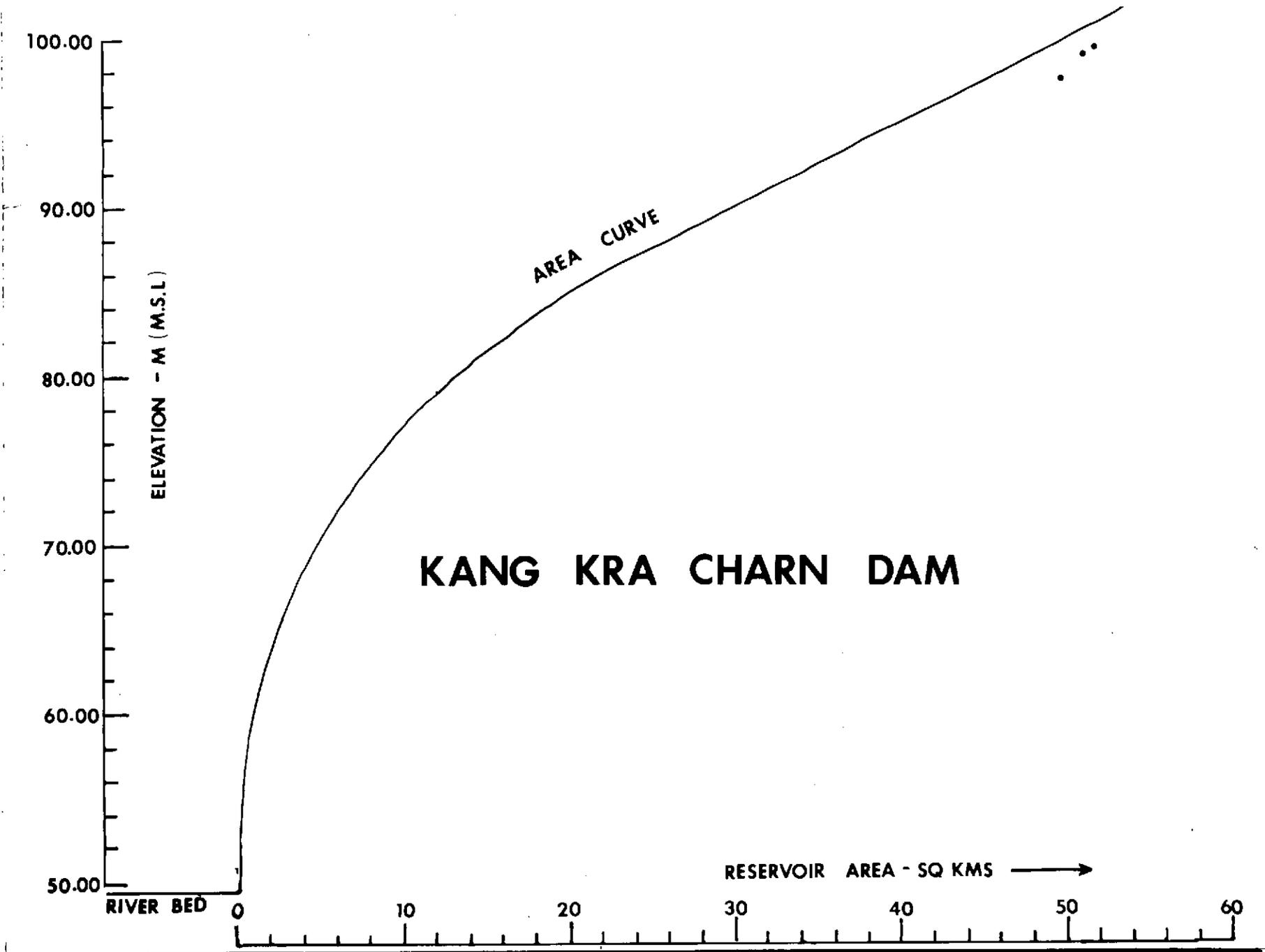


FIGURE 3. Area Curve of Kang Kra Chan Dam.

### Budget and Planning Notes

A Royal Thai Government (RTG) budget of approximately Baht 1.6 million (\$ U.S. 80,000) was allocated to the National Research Council in March 1974 for the current Thai fiscal year (ending September 30, 1974) and approximately the same amount has been approved in principle for operations during Thai FY 2518 (1975). This has permitted the National Research Council to hire three additional professional staff members (as of 1 May 1974) to supplement the ERTS staff of the Applied Scientific Research Corporation, where the data files, data reproduction facilities, and image interpretation facilities are presently accommodated. The NRC has, in addition, requested for the FY 2518 (1975), Baht 3 million (\$ U.S. 150,000) for construction of a building for permanent accommodation of a National Remote Sensing Center, and has submitted to the Budget Bureau a five year plan covering projected operating costs including establishment of a regional data receiving station and data reproduction and dissemination facilities, at approximately Baht 192 million (\$ U.S. 9,600,000). Formal consideration of this plan will necessarily follow NASA announcements of plans for additional earth resources satellite survey projects and further consideration of long term operational systems.

The funding mentioned above, together with additional RTG funds allocated for continuation of several Departmental ERTS investigations and the support provided by USOM, will permit upgrading of data reproduction standards and introduction of additional data products such as contrast enhanced images and improved color composites. This will permit investigation of additional interpretation techniques and further improvement of those already in use. While looking forward to acquisition of more current data from ERTS-B, efforts will be concentrated on acquiring additional information from the available ERTS-1 data products.

Some funds are available for experimentation with automatic data processing of MSS computer compatible magnetic tapes and for additional consultation with U.S. experts in several disciplines. Current planning calls for establishing suitable programme inputs and processing routines using one of several computers available in Thailand, with technical assistance as needed from centers of expertise in this field in the U.S.

Plans for the near future also include the acquisition of multiband aerial photographs of several areas where proper interpretation of ERTS images is still in question, and considerable additional field work for confirmation of ERTS and air photo interpretation.