APPENDIX B

THE SECTORAL CASE STUDIES

APPENDIX B-1

MAPPING

APPENDIX B-1

MAPPING

The mapping case studies were divided into three categories:

- Mapmaking techniques using the photogrammetric and ground survey methods were studied in Lang Suan, Song Phi Nong, and Chiang Mai.
- Various technical improvements were considered, including the use of a control survey with permanent monuments and the inclusion of certain features on maps with a scale of 1:4,000.
- Various new hardware approaches were evaluated, including personal computers for the leveling net adjustment method, digital planimeters and digitizers for land use area measuring, and the implementation of an electronic total station approach.

Leveling Net Adjustment

Leveling was carried out on a large scale in Chiang Mai, and simultaneously calculated through the net adjustment method using a personal computer. The results are illustrated in Figure B-1-1, and they indicate that the method proposed is practical for ground surveys.

Electronic Total Station System

A comparison between the use of the electronic total station system and optical theodolites was made in terms of accuracy. The results indicated that:

- closed traverses conducted with the electronic total station system required only one-third the time of using an optical theodolite;
- the electronic total station system can be operated more easily than the optical theodolite method; and
- the electronic approach had an accuracy of 1/15,576, far better than the minimal acceptable accuracy of 1/10,000.

Traverse data adjustment using the electronic approach is illustrated in Table B-1-1.

LEVELING NET AT CHIANG MAI

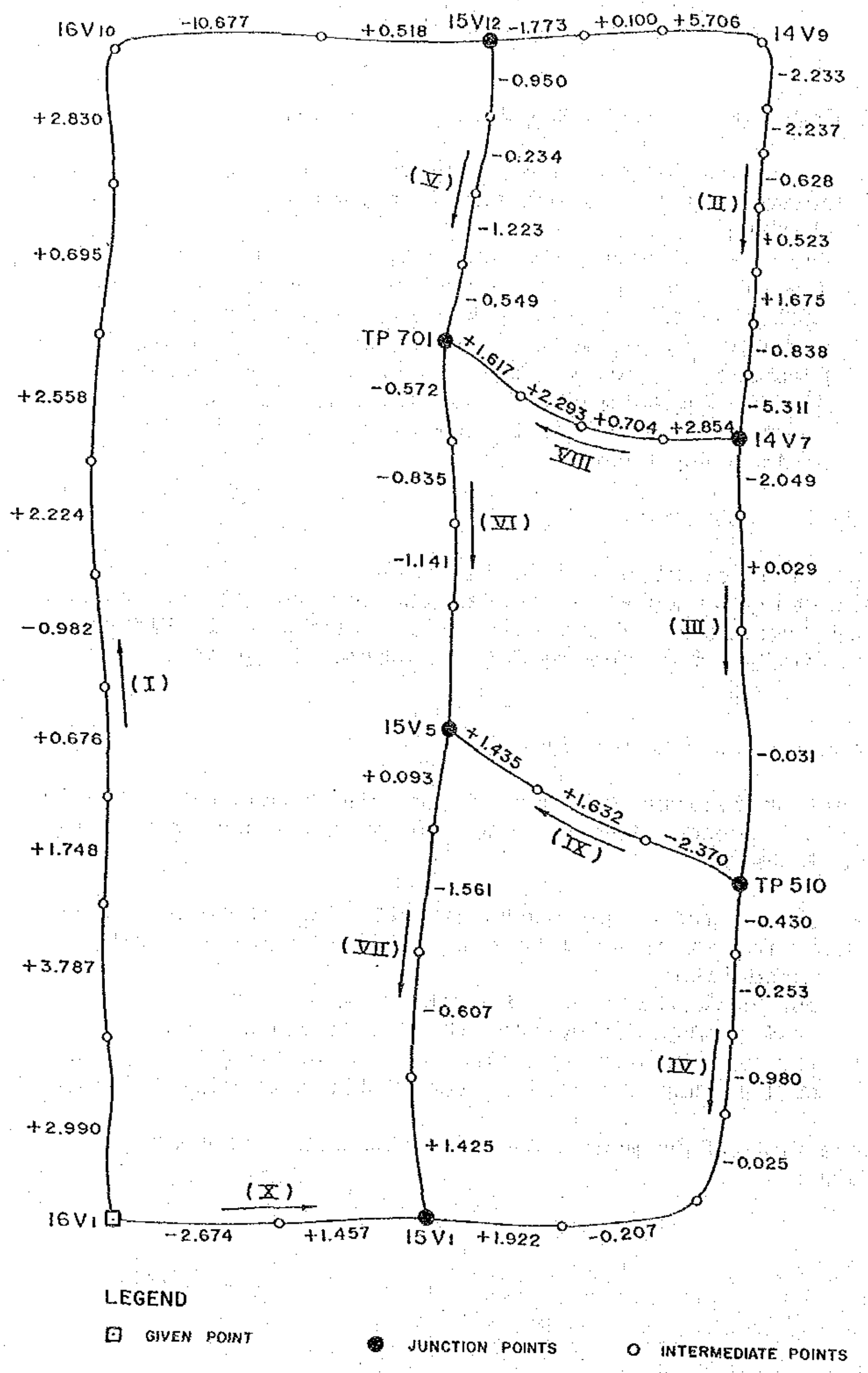


Fig. B-1-1 MEASURED LEVELING DATA

Table B-1-1 TRAVERSE DATA ADJUSTMENT

TOTAL ACCURACY	1 : 15576	
TOTAL TRAVERSE DISTANCE	610.672	meters
DIFF. IN LATITUDE	-0.039	meters
DIFF. IN DEPARTURE	-0.004	meters

STATION	HOR. ANGLE	AZIMUTH	DISTANCE	N. COORDINATE	E. COORDINATE
A		27.3214		1000.000	1000.000
B	97.1938	304.5152	64.234	1036.723	947.296
C	83.4606	208.3758	237.335	828.427	833.568
D	97.5910	126.3708	69.129	787.196	889.052
A	80.5506	27.3214	239.974	999.999	1000.000

Measurement of Land Use Area

Among the five methods of measuring land areas, a cartographic system using a digitizer and personal computer was selected for use in a case study.

When the points defining the corners of a polygon are coordinated with respect to some arbitrarily-chosen coordinate area, these coordinates are useful in calculating the area of a tract of land. In the example illustrated in Figure B-1-2, the tract is defined by points 1, 2, 3, and 4, which have the coordinates X_1, Y_1, ... X_4, Y_4. The area of the tract can be computed by summing algebraically the areas of the trapezoids formed by projecting a line upon the reference meridian.

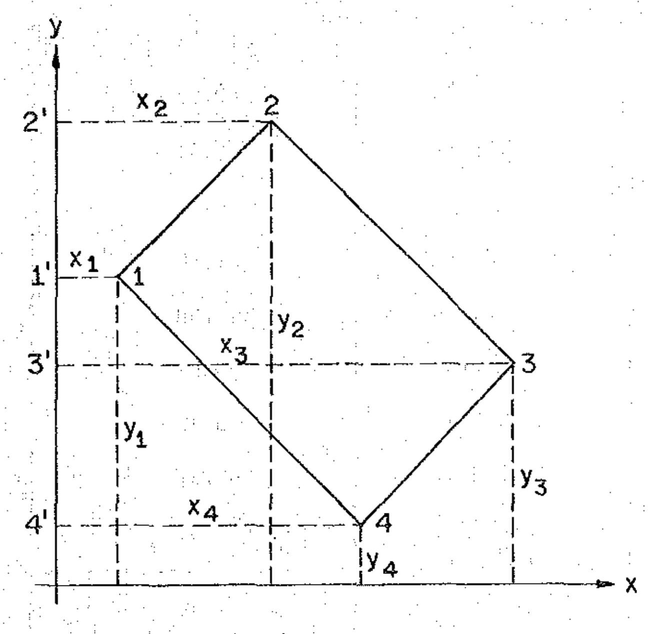


Fig. B-1-2 AREA BY COORDINATES

Area 1 2 3 4 = Area 2 2'3'3' + Area 3' 3 44' - Area 1 1'4'4 - Area 2 2'1'1.

Therefore,

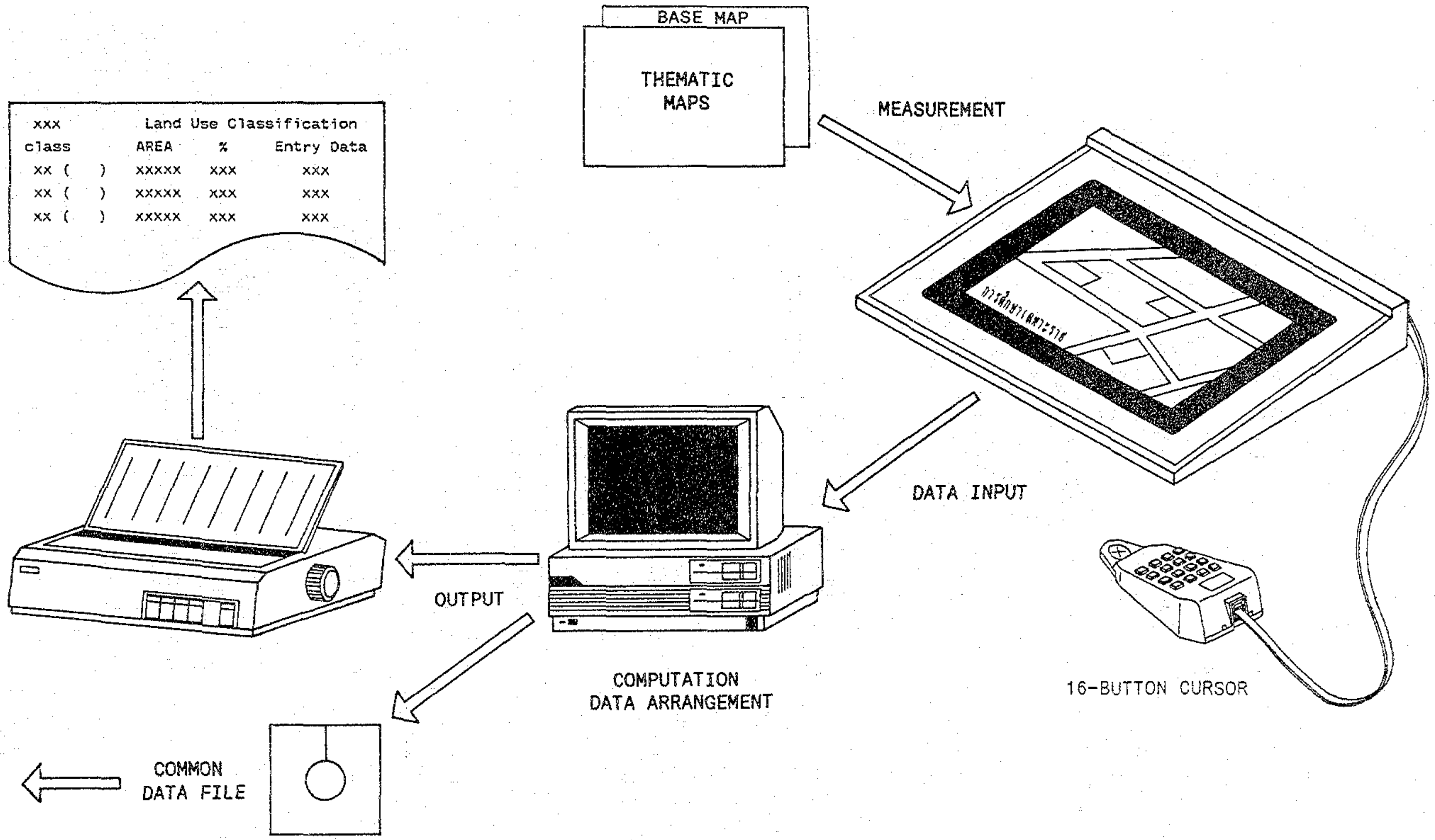
$$\text{Area} = 1/2\ (x_2 + x_3)\ (y_2 - y_3) + 1\ (x_3 + x_4)\ (y_3 - y_4)$$
$$- 1/2\ (x_4 + x_1)\ (y_1 - y_4) - 1\ (x_1 + x_2)\ (y_2 - y_1).$$

The above coordinates can be obtained by means of a cartographic system using a digitizer and personal computer (see Figure B-1-3), and calculations can be carried out on a computer (see Figure B-1-4).

The case study methods are compared with the existing method in Table B-1-2.

Table B-1-2 COMPARISON OF EXISTING METHOD WITH CASE STUDY METHOD (LANG SUAN)

Land Use \ Methods	Existing Method + analy Planimeter (1)	Existing Method + Digital Planimeter (2)	Digitizer Method + Microcomputer (3)
1 Residential	670.52	686.30	680.65
2 Commercial	215.47	221.56	219.51
3 Industrial	345.87	342.27	337.87
4 Warehouse	71.84	69.92	69.45
5 Religious	34.90	36.81	36.00
6 Education	49.22	46.17	45.31
7 Governmental	22.85	27.40	20.57
8 Livestock	120.38	117.68	117.03
9 Open Space	48.61	50.98	50.18
10 Road, Soi	682.15	675.18	675.18
11 River, Canal	715.97	709.52	740.61
12 Agriculture	15,906.96	15,888.52	15,620.12
Total	18,894.74	18,866.52	18,613.12
Ratio	(+1.5%)	(+1.3%)	



M-5 Fig. B-1-3 COMPOSITION OF CARTOGRAHIC SYSTEM

Figure B-1-4 OUTPUT OF DIGITIZER METHOD

	Residuals of x (Vx)	Residuals of y (Vy)
1	1.9021	-1.3986
2	-1.8995	1.3968
3	1.9004	-1.3986
4	-1.9031	1.4003

Mean Square Error = 3.337927 m.

1

Name	Area sq.m.	Area rai
residential	1089042.00	680.65

Total area = 1089042 sq.m. = 680.6513 rai

2

Name	Area sq.m.	Area rai
residential	187257.10	117.04

Total area = 187257.1 sq.m. = 117.0357 rai

3

Name	Area sq.m.	Area rai
government	351217.10	219.51

Total area = 351217.1 sq.m. = 219.5107 rai

4

Name	Area sq.m.	Area rai
industrial	80287.21	50.18

Total area = 80287.21 sq.m. = 50.1795 rai

5

Name	Area sq.m.	Area rai
warehouse	32907.75	20.57

Total area = 32907.75 sq.m. = 20.56735 rai

6

Name	Area sq.m.	Area rai
religion	540593.60	337.87

Total area = 540593.6 sq.m. = 337.871 rai

APPENDIX B-2

SOCIOECONOMIC ANALYSIS

APPENDIX B-2

SOCIOECONOMIC ANALYSIS

Study Areas and Subjects

Taking the proposed technical improvement plan into consideration, the case study sites and purposes were set as follows:

Tha Rua (Case Study I)

- To study the effects of 1) an addition of survey items, 2) data collection and tabulation by grid cell, and 3) computerization of data compilation for the household, commercial, and industrial surveys.

Tha Rua and Tha Mai (Case Study II)

- (Part 1) To study the feasibility of the proposed analytical methods by making use of the pilot database in Case Study I (Tha Rua).
- (Part 2) To study methods to improve the pilot database, including the data on social services and urban facilities (Tha Mai).

CASE STUDY I

Additional Data Items

In Case Study I, the following items were added to the survey instruments previously used:

- place of work (grid cell) for the employed population (household survey);
- place of schooling (grid cell) for pupils and students (household survey); and
- monthly salary paid by commercial and industrial establishment (commercial survey and industrial survey).

Data Tabulation by Zone

The study area was divided into approximately 160 grid cells that were 500 m x 500 m. The following basic information was compiled by grid cell.

Household Survey

- Population and number of households
- Employed population by occupation and by place of residence
- Employed population by occupation and by workplace
- Employed population by place of residence and workplace
- Pupils and students by place of residence
- Pupils and students by location of school

Commercial Survey

- Number of establishments by type of business
- Persons engaged by type of employment

Industrial Survey

- Number of establishments by type of industry
- Persons engaged by type of employment

Socioeconomic Database

In addition to the programs for data compilation by zone, programs for the following tables were developed.

Household Survey

- Population by sex and age group
- Working age population by occupational status, sex, and age group
- Employed population by occupation, sex, and age group

Commercial Survey

- Number of establishments, persons engaged, and monthly salary paid by type of business
- Number of employees by place of residence

Industrial Survey

- Number of establishments, persons engaged, and monthly salary paid by type of industry
- Number of employees by place of residence

CASE STUDY II

Applicability of the Socioeconomic Analysis Manual (Part 1)

Using the basic tables compiled in Case Study I and related data gathered from various sources, the analysis and projection methods proposed in the manual were examined in this study. Since the methods and data proposed in the manual are almost the same as those used by the Research and Analysis Division for analyzing a study area as a whole, the case study focused on the zonal distribution of population and employment in relation to urban structure.

Distribution of Population and Employment

Figure B-2-1 shows population distribution, while Figure B-2-2 shows employment distribution. From such figures it is possible to derive an overview of urban areas and the extent of concentration of population and employment.

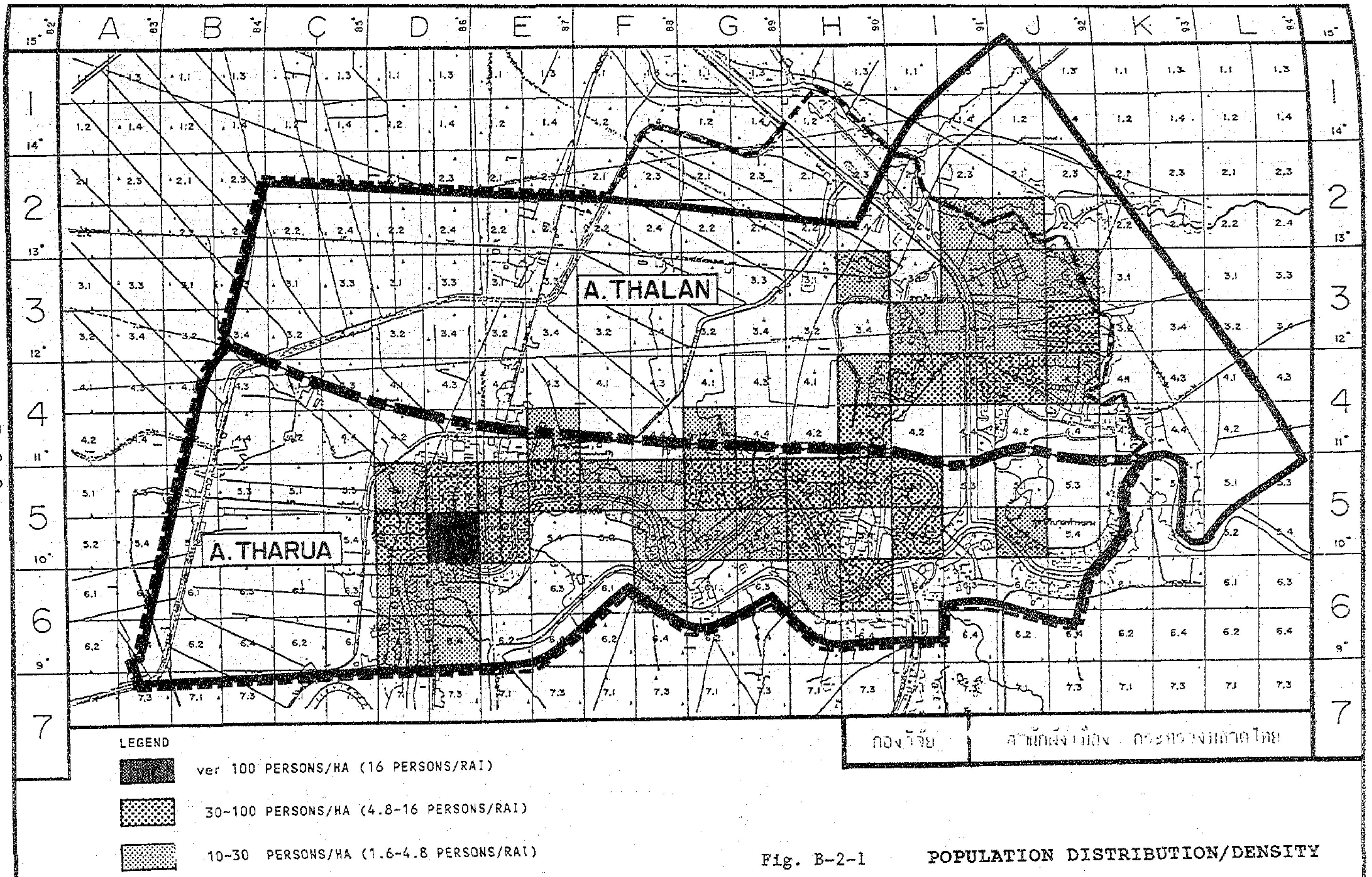


Fig. B-2-1 **POPULATION DISTRIBUTION/DENSITY**

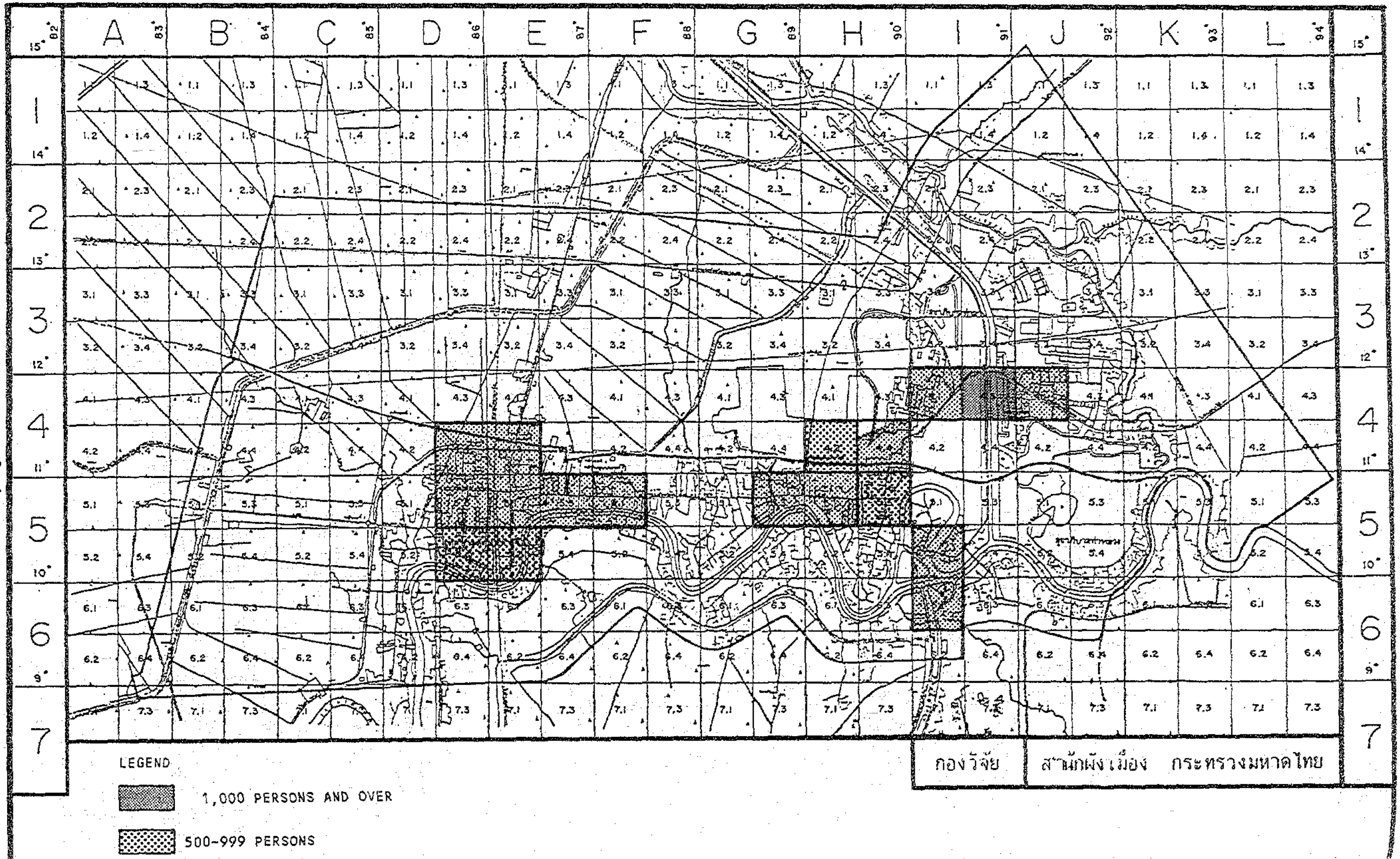


Fig. B-2-2 EMPLOYMENT DISTRIBUTION

With respect to the distribution of population, the following observations can be made (referring to Figure B-2-1):

1) The most populated grid cell is D554 (the center of Tha Rua Municipality), with a population of about 2,700 persons and a density of 107.5 persons per hectare.

2) The other urban areas (grid cells with a population density from 30 to 70 persons per hectare) are concentrated in the central parts of Tha Rua Municipality, Tha Luang Sanitary District, and Tha Lan Sanitary District. The total population of these areas is about 18,200.

3) Urbanizing areas (zones with a population density from 10 to 30 persons per hectare) are located at the fringes of the three built-up areas. Tha Rua and Tha Luang are being connected, forming a conurbation. The population of these urbanizing areas is approximately 11,300.

Regarding the distribution of employment, the following observations can be made (referring to Figure B-2-2):

1) The cell with the greatest employment density is I443 in the Tha Lan Sanitary District. More than 2,000 persons are employed in this cell; 56% are production workers.

2) Nearly 1,000 persons are working in both D554 and E552, which are located in the central part of Tha Rua Municipality. They are principally sales workers and service workers.

3) Grid cell H553 is the center of the Tha Luang Sanitary District, where about 500 persons are working. Most are sales workers.

4) Grid cell H442 is inside the Siam Cement Factory. Therefore, most of the approximately 700 employed persons are production workers.

Table B-2-1 shows commuting patterns by showing workplace and place of residence. The following observations can be made:

1) About 1,200 persons (8% of the total employed population living in the study area) commute to jobs outside the area.

2) About 3,500 employed persons live in the Tha Lan Sanitary District and about 500 persons commute to jobs outside. But about 4,800 persons work in the zone, 35% more than the number of zone residents with jobs. This zone has the largest employment in the study area; it attracts workers from every zone, especially from the Tha Luang Sanitary District.

3) Tha Rua Municipality also has more jobs than residents. However, commuters to the municipality are limited to two zones in Ayutthaya Province.

4) The Tha Luang Sanitary District has the largest labor force (5,600). This zone has 1,800 fewer jobs than workers, with 2,300 commuting to other zones, and only 500 commuting to the zone.

Table B-2-1 WORKING POPULATION BY PLACE OF RESIDENCE AND WORKPLACE

Workplace / Place of residence	Tha Rua M.	Tha Luang S.D.	Tha Lan S.D.	Tha Rua R.	Tha Lan R.	Outer Zone	Total
Tha Rua M.	3253	50	90	17	0	130	3540
Tha Luang S.D.	378	3234	1344	28	140	434	5558
Tha Lan S.D.	35	133	2819	6	19	526	3538
Tha Rua R.	202	286	379	1190	0	94	2151
Tha Lan R.	0	22	128	0	53	23	226
Totals	3868	3725	4760	1241	212	1207	15013

Population and Employment Projections

Due to data limitations, only the geometric growth model and the simple economic model were examined. The former projects total population, while the latter can be used for the simultaneous projection of population and employment.

Application of the Geometric Growth Model. Table B-2-2 shows the recent trend toward a reduced population growth rate in the municipality and sanitary district areas in the study area. The data indicate that these areas are reaching their point of maximum population density. The present situation of the study area is shown in Figure B-2-3.

Table B-2-2 TOTAL POPULATION OF MUNICIPALITY AND SANITARY DISTRICT AREAS

Year	Population	Growth Rate*
1967	20,470	
1972	24,934	4.02%
1977	26,596	1.30%
1982	29,704	2.23%
1987	31,790	1.37%

*Average annual growth rate equals 2.23%.

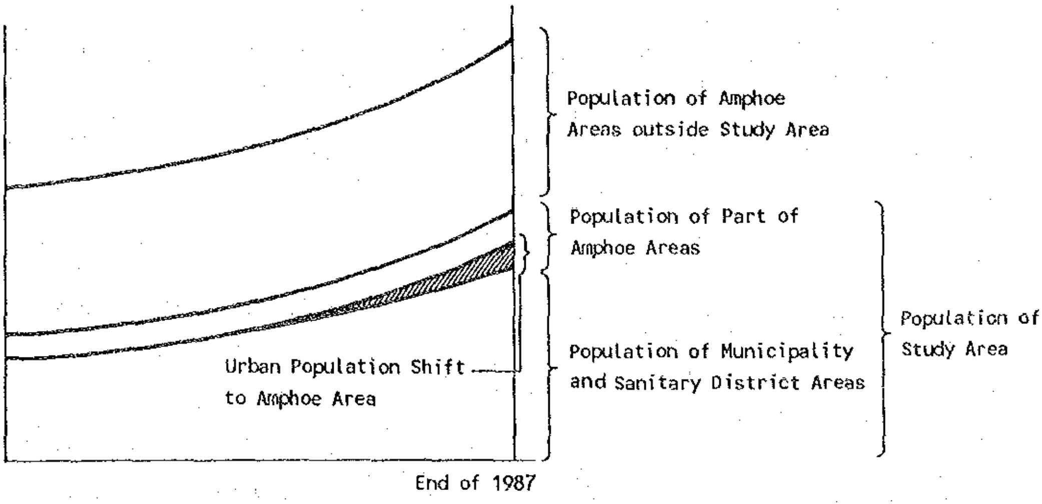


Fig. B-2-3 POPULATION GROWTH INSIDE AND OUTSIDE THE STUDY AREA

The population of the Tha Rua and Ban Moh amphoes (including municipal and sanitary district areas) is growing at a steady average rate of 1.20% annually, as shown in Table B-2-3. The population growth rate of the study area is not available directly, but it is assumed to be midway between the urban population growth rate and the amphoe growth rate.

Table B-2-3 POPULATION OF THE THA RUA AND BAN MOH AMPHOES (Including Municipal and Sanitary District Areas)

Year	Population	Growth Rate*
1972	81,239	
1977	88,598	1.75%
1982	91,669	0.68%
1987	97,188	1.18%

Average annual growth rate equals 1.20%.

The population growth rate for urban areas may be higher than the 1.37% average annual increase in municipal and sanitary districts from 1982 to 1987. If the annual growth rate of urban population is assumed to have been 2.23%, the urban population can be estimated at 33,167 in 1987. The difference of 1,377 between the registered population (31,790) and the estimated one could be considered to be the portion of urban population that "spilled over" to rural areas.

According to the household survey, 4,157 persons lived in the rural part of the Study Area at the beginning of 1988. Therefore, about 2,800 persons (4,157 - 1,377 = 2,780) are estimated to have been rural. Assuming that the rural population of the Study Area has not changed very much, the total population of the Study Area is estimated to have been about 32,500 (29,700 + 2,800) in 1982 and about 35,900

(31,800 + 4,100) in 1987. In this case, the average annual population growth rate of the Study Area would have been 2.01%.

Applying this growth rate to the future, population projections for the Study Area can be generated, as shown Table B-2-4.

Table B-2-4 POPULATION PROJECTIONS FOR THE STUDY AREA

Year	Population
1988	36,657
1993	40,500
1998	44,700
2003	49,400
2008	54,600

*Average annual growth rate equals to 2.01%

Application of Simple Economic Model. Approximately 1,000 persons commute from the study area to jobs outside the area, while approximately 800 persons from outside work in industrial firms in the area. Considering that other employers such as administrative offices, schools, and hospitals also attract employees from outside the study area, the net difference between outbound and inbound movements is assumed to be nearly zero. The following model can be applied in such a case:

$$P_t = \frac{\alpha}{1-\alpha\beta}(E_{bt} + E'_{bt})$$

$$E_{st} + E'_{st} = \frac{\alpha\beta}{1-\alpha\beta}(E_{bt} + E'_{bt})$$

$$P_t = \alpha E_t$$

$$E_{st} + E'_{st} = \beta P_t$$

$$E_t = E_{bt} + E''_{bt} + E_{st} + E''_{st}$$

$$E''_{bt} + E''_{st} = E'_{bt} + E'_{st}$$

where:

P_t: Population in year t

E_t: Total number of employed persons living in the study area in year t

E_{bt}: Population employed in basic economic sectors living and working in the study area in year t

E'_{bt}: Population employed in basic economic sectors, working in the study area, and commuting from outside in year t

E''_{bt}: Population employed in basic sectors living in the study area and commuting outside in year t

E_{st} : Population employed in the local service sector living and working in the study area in year t

E'_{st}: Population employed in the local service sector, working in the study area, and commuting from the outside in year t

E''_{st}: Population employed in the local service sector living in study area and commuting outside in year t

α : Population provided for by one employed person

β : Employment in the local service sector generated by one person

The basic industries in the study area are considered to be rice production in the primary sector and cement production in the secondary sector. Assuming that all employed persons classified as agricultural workers (1,556 persons) are engaged in rice production and that the production workers in the Thalua Sanitary District (2,640 persons) and all incoming industrial employees (824 persons) are engaged in cement production, the 1988 values of the variables in the economic model specified above are as follows:

$$P_{88} = 36,657$$

$$E_{88} = 14,830$$

$$E_{b88} = 1,556 + 2,640 = 4,196$$

$$E'_{b88} = 824$$

$$E''_{b88} + E''_{s88} = E'_{b88} + E'_{s88} = 1,066$$

$$E_{s88} = 14,830 - 1,066 - 1,556 - 2,640 = 9,568$$

$$E'_{s88} = 1,066 - 824 = 242$$

$$\alpha = \frac{36,657}{14,830} = 2.47$$

$$\beta = \frac{9,568 + 242}{36,657} = 0.268$$

Then:

$$P_t = \frac{2.47}{1 - 2.47 \times 0.268} (E_{bt} + E'_{bt})$$

$$= 7.31 (E_{bt} + E'_{bt})$$

$$E_{st} + E'_{st} = \frac{2.47 \times 0.268}{1 - 2.47 \times 0.268} (E_{bt} + E'_{bt})$$

$$= 1.96 (E_{bt} + E'_{bt})$$

The value of E_{bt} and E'_{bt} depend on the future prospects of rice and cement production. Assuming that the area devoted to rice fields will be reduced by 20% and that the ratio of agricultural workers to rice field area will not change, the number of employed persons engaged in rice production will decrease in proportion to the rice field area. Assuming that cement production in the study area will increase by 5% per year and that labor productivity in that industry will increase by 2% per year, employment will grow by 2.9% per year.

If these assumptions are applied to a target year set 20 years later (2008), the values in the equation would be as follows:

$$P_{20} = 7.31 \times [(1,556 \times 0.8) + (2,640 + 824) (1 + 0.029)]$$

$$= 53,954$$

$$E_{s20} + E'_{s20} = 1.96 \times [(1,556 \times 0.8) + (2,640 + 824) (1 + 0.029)]$$

$$= 14,466$$

Improvement of the Pilot Database

In Case Study I, the JICA Study Team developed a basic tabulation system for socioeconomic data using the dBASE III PLUS language. However, the processing speed of this system was too slow to be practical. Therefore, the JICA Study Team had to redevelop the whole system. The same programming language was employed, the JICA Study Team used the Basic language in cases in which dBASE III PLUS was inappropriate.

After completion of a new Basic tabulation system, the JICA Study Team prepared operations manuals for this system to facilitate technical transfer. As a result, staff members from DTCP's Research and Analysis Division understood how to operate this system.

APPENDIX B-3

LAND USE PLANNING

Appendix B-3

LAND USE PLANNING

Case Study Areas

Case Study I (Chiang Mai)

The city of Chiang Mai serves as the administrative, business, and cultural center of its changwat as well as of the northern region. Chiang Mai's existing plan was prepared in 1984 and is now under revision. Because of the ready availability of data at the time of the study, the Chiang Mai Case Study dealt with the original (1984) planning area of approximately 100 square kilometers and an estimated population of 218,000 (1987). The planning area has since been expanded to 400 square kilometers.

Case Study II (Tha Rua/Tha Lan)

The Tha Rua/Tha Lan Case Study was conducted in an area covering two changwats about 130 kilometers north of Bangkok. The Tha Rua general plan area (18.37 square kilometers), is located in Changwat Phranakorn Si Ayutthaya and has a population of 26,000 (1987). The Tha Lan general plan area (20.66 square kilometers), also included in this case study, is located in Changwat Saraburi and has a population of 10,000 (1987). Major economic activities include the manufacturing of building materials such as cement, gypsum boards, and steel bars; agro processing; and distribution via rail, road, and river transport.

Study Issues

As mentioned above, the main subject of study was the application of quantitative approaches to land use planning analysis. Such applications can be applied to the demand side (land use) as well as the supply side. Development can be measured more objectively by scores (digital form) reflecting the views of several interested groups in order to guide, select, and allocate the optimum space and location to meet a specific demand. This technique can readily be applied when a microcomputer is available for information processing.

LAND USE FORECASTING (Case Study I)

Since the data collection and field surveys were conducted in 1987, the target year was set at 2007, 20 years later. The forecasting of each category of land use in 2007 was conducted as shown in Figure B-3-1. Of course, future population is a key parameter in land use planning. Here, it must be estimated taking into consideration the expected future role of the Chiang Mai area in local, regional, and national development as well as socioeconomic changes. Due to time constraints, however, a population projection (341,000) made by DTCP's Research and Analysis Division was used. Notable demographic characteristics of the Chiang Mai municipal area are its very high rate of natural population growth and out-migration. These characteristics can be explained by Chiang Mai's role as a health care

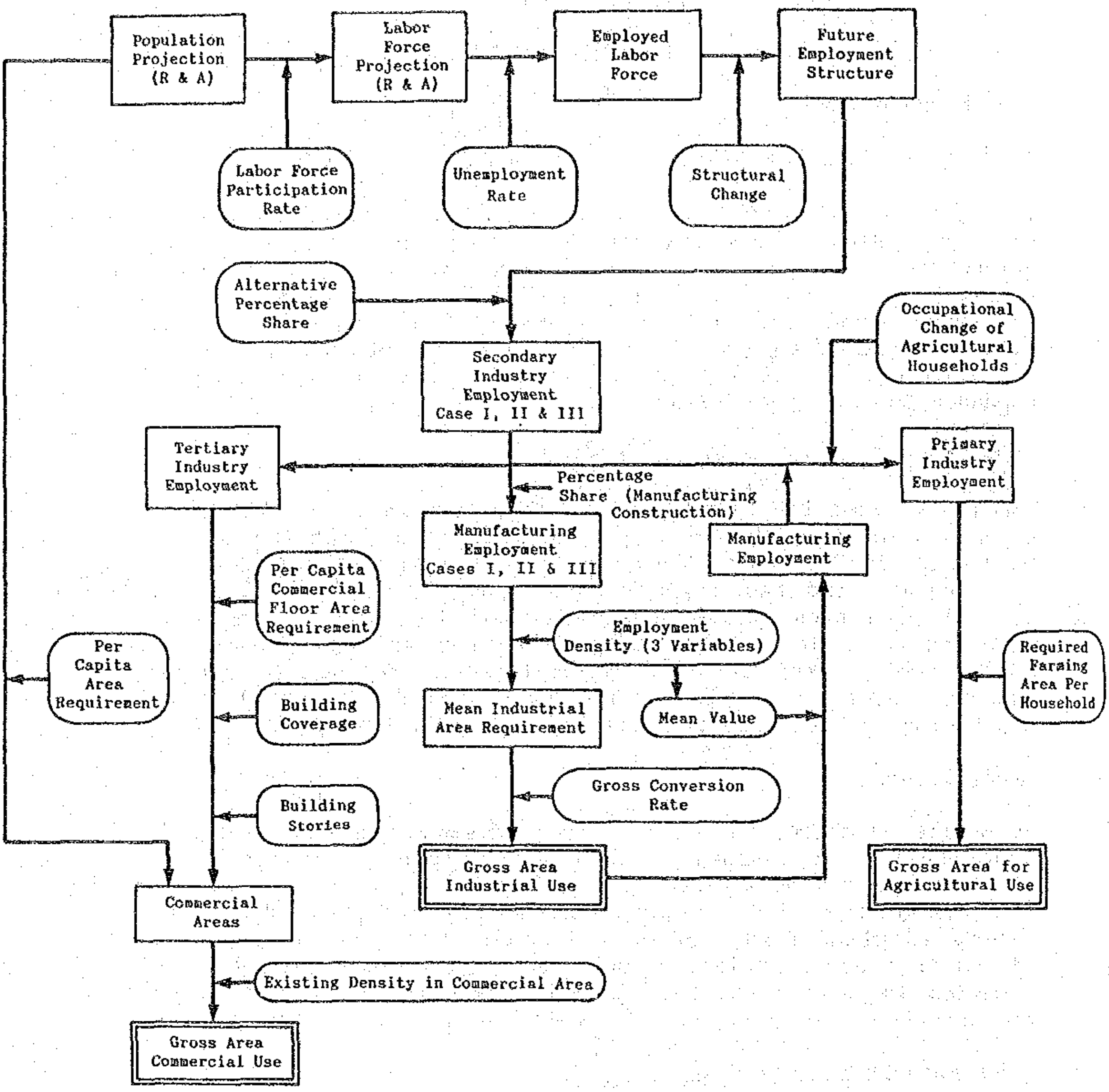


Fig. B-3-1 APPROACHES TO LAND USE FORECASTING service center at the changwat and regional levels.

Similarly, Chiang Mai is a center of higher education, attracting a large number of students from all over Thailand. Indeed, only half of the students in Chiang Mai are registered residents of the planning area.

Due to its climate and scenic attractions, the Chiang Mai area attracts seasonal residents (principally from Bangkok) with high incomes. In addition, both domestic and foreign tourists come to Chiang Mai, with the total number of visitors in one year exceeding the population of the planning area by a factor of 10. Chiang Mai's population of seasonal residents and tourists must be taken into account when planning housing and transport facilities.

Assumptions Underlying the Residential Land Use Forecasts

Since the data collected in the field were limited, various assumptions (see Table B-3-1) were made considering the results of reconnaissance surveys of current housing construction in and around BMA; information from BMA and NHA; information on land prices and income levels in the study area; and goals for the study area in the future. Also, assumptions were made regarding income group and zonal distribution (Table B-3-2), type of housing and zonal distribution (Table B-3-3), and density by housing type and plot size (Table B-3-4).

Table B-3-1 BASIC ASSUMPTIONS

Assumptions	1987	2007
Urban/rural population ratio (10% of agricultural households switch occupations per year)	86:14	98:2
Household size (Reduction of 0.5 persons per household in 10 years)	5.35 persons	4.35 persons
Income structure (Goal of having large middle income group)	unknown	high: 10% medium: 60% low: 30%
Housing Type (larger share of multifamily units; goal of compact, functional city)	unknown	55%

Table B-3-2 INCOME GROUP AND ZONAL DISTRIBUTION

Zone / Income Group	Low Density	Medium Density	High Density	Totals
Low		20%	80%	100%
Medium	30%	60%	10%	100%
High	80%	10%	10%	100%

Table B-3-3 TYPE OF HOUSING AND ZONAL DISTRIBUTION

Zone / Type	Low Density	Medium Density	High Density
Single family unit	85%	50%	0%
Multifamily unit	15%	50%	100%
Totals	100%	100%	100%

Table B-3-4 DENSITY BY HOUSING TYPE AND PLOT SIZE
(Gross conversion rate: 1.43 to 1.67)

Net Wah^2	Gross Wah^2	Density/Rai
Multifamily Plot		
20	33-29	53-60
30	50-43	35-40
40	67-57	26-31
50	83-71	21-25
70	117-100	15-17
100	167-143	10-12
Single Family Plot		
50	83-71	21-25
70	117-100	15-17
100	167-143	10-12
135	225-192	8-9
175	292-250	6-7
300	500-428	3.5-4

For the assumptions regarding housing plot size, housing affordability was analyzed based on income. According to NHA classifications, low income households have monthly incomes ranging from 3,500 to 7,700 baht. Therefore, for simplicity of calculation, an average monthly income of 6,000 baht was used. Assuming that 30% of household income is allocated to housing, 1,800 baht would be spent. If 50% of that amount goes to an installment payment for land for 10 years at 6% annual interest, the present value of that land would be approximately 60,000 baht. The lowest land values surveyed by the Research and Analysis Division range from 30,000 to 999,000 baht per rai. Affordable plot sizes can thus be calculated, as in Table B-3-5. Density classes are shown in Table B-3-6.

Table B-3-5 CALCULATION OF AFFORDABLE PLOT SIZES

Land Value	Plot Size
2,500 baht/wah^2 (1 million baht/rai)	24 wah^2
2,000 baht/wah^2 (800,000 baht/rai)	30 wah^2
1,000 baht/wah^2 (400,000 baht/rai)	60 wah^2

Table B-3-6 DENSITY CLASSES

Density Class	Range of Densities
Low density	5 persons/rai
	7 persons/rai
	9 persons/rai
Medium density	11 persons/rai
	15 persons/rai
	17 persons/rai
High density	23 persons/rai
	26 persons/rai
	31 persons/rai

Residential Land Requirements

To calculate residential land requirements, the first step was to estimate urban population by subtracting the agricultural population from total projected population and then distributing by income group and zonal density according to the assumptions stated in Table B-3-2. The results were as follows:

Low density areas	12,958 rai
Medium density areas	9,283 rai
High density areas	3,575 rai
Total	25,816 rai

Recognizing that some area is used for second homes and there is now a housing shortage of 10%, the total residential area requirement was adjusted to 28,400 rai, which is approximately 16,000 more than is available currently.

Industrial Land

The manufacturing sector is at present insignificant in terms of land use (0.96%) and employment (7%). Factories are generally small in scale, serving only limited local demand. Since Chiang Mai is the principal city in the Northern Region, the industrial sector should be promoted to balance the current orientation toward tourism. Since data on industrial output or value added were not available, the forecasting of industrial land demand was approached by estimating the share of employment in the manufacturing sector and the density of workers. The share of manufacturing employment will depend on the future economic structure, which was forecast by examining the experience of inland Japanese provincial capitals that had a similar population in 1975. Three scenarios were developed, and density standards from IEAT and DTCP/Ritchfield were used for calculation.

Scenario 1: Balanced Structure, manufacturing share=20%
Scenario 2: More industry oriented, manufacturing share=23%
Scenario 3: Most industry oriented, manufacturing share=26%

The industrial land requirement was estimated to be 2,100 rai, or adjusted for gross area, 3,000 rai. A new requirement would be 2,400 rai.

Commercial Land

Since data on sales per unit of commercial floor space and per employee are not available, attempts were made to employ a unit space method using population and commercial employment with the following assumptions:

- 80% of the tertiary sector employees will work in commercial zones;
- the gross commercial land per capita in regional cities is 15 m^2;
- the amount of commercial floor area per employee is 20 m^2;
- the buildings have two stories; and
- the building coverage ratio is 60%.

LAND USE FORECASTING (Case Study II)

Though the study area is divided into two general planning areas (Tha Rua and Tha Lan) for administrative reasons, it is a physically, economically, and socially unified community. The study area is in the middle of the Central Plain and functions as an important hub for road, rail, and water transportation. The location has attracted resources-oriented industrial developments, such as agro-processing plants and building materials factories.

The development plan for the Central Region calls for the area to play the role of a third-level community in the regional urban hierarchy. Industrial growth will be necessary if the study area is to fulfill this role. Since the Siam Cement Group, one of the largest industrial groups in Thailand, has large industrial facilities in Tha Lan, their future investment plans will have a significant impact on the future growth of the community.

Population Projections

In Case Study II, two population forecasting methods were applied. The first one was basically a trendline projection, as was used in Case Study I. The second was based on acquisitions of vacant industrial land by the Siam Cement Group, as shown in Figure B-3-2.

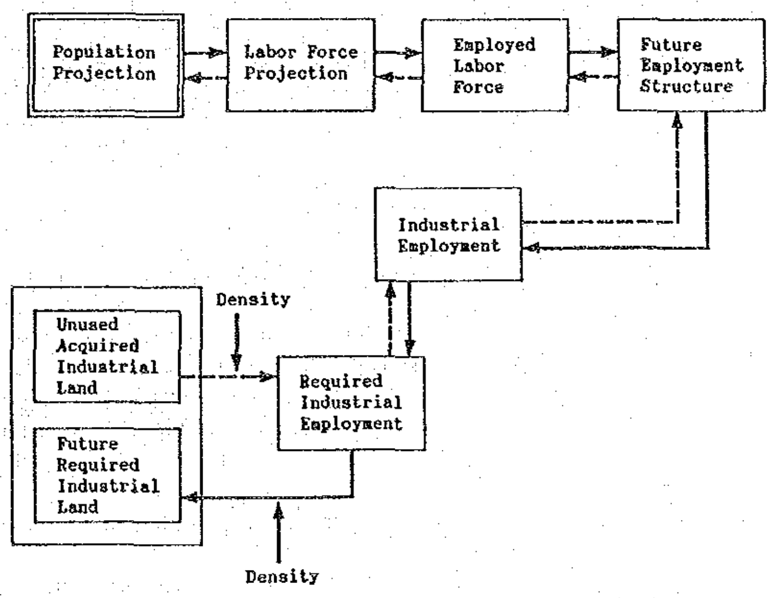


Fig. B-3-2 POPULATION PROJECTION METHOD BASED ON VACANT ACQUIRED INDUSTRIAL LAND

A future growth rate of 2% was estimated based on analysis of short-, medium-, and long-term growth rates; changwat and regional shares; and current regional policies. The resulting projections are shown in Table B-3-7.

Table B-3-7 CASE STUDY II POPULATION PROJECTIONS

	1987	2007
Tha Rua general plan area	26,055	39,000
Tha Lan general plan area	11,703	17,000
	37,758	56,000

Employment Projections

Currently, 52.5% of the population of Tha Rua is in the labor force, and of the total population, 39.6% are employed and 12.9% unemployed. Since reducing unemployment is a main objective of economic development, it is assumed that it will be reduced to 3%. On the other hand, enrollment in higher educational institutions will increase as family income goes up; therefore, it is assumed that the ratio of employed workers will increase to 45%. Assumptions on employment structure are shown in Table B-3-8.

Table B-3-8 EMPLOYMENT STRUCTURE ASSUMPTIONS FOR CASE STUDY II

	1980 Kingdom Municipal	2007 Tha Rua, Tha Lan
Primary Industry	11%	5%
Secondary Industry	24%	30%
Tertiary Industry	65%	65%

Assuming that the manufacturing sector will provide 20% of all jobs, future employment will be 5,040. As present manufacturing employment is estimated at approximately 3,600, there will be 1,440 new jobs added.

Future Industrial Land Use and Vacant Acquired Industrial Land

Based on projected employment in the manufacturing sector, industrial land use will be approximately 130 rai. While the Siam Cement Group owns approximately 3,100 rai, including 926 rai outside of the planning area, the area presently occupied amounts to 1,250 rai, including a 150-rai golf course. Therefore, the unused area is about 1,800 rai. Assuming that 30% of this area is used for manufacturing activity, it will provide an additional 410 rai of industrial land over the above land use forecast, thereby creating an additional 4,600 jobs.

Adjusted Future Population

Based on the projection of manufacturing employment, the previous population projection (56,000) was increased by 14,000. Thus, the total future population was adjusted to 70,000. It is assumed that the average household size for the above additional manufacturing employees will be only three due to a disproportionately large percentage of unmarried workers.

Residential Land Use

The Tha Rua-Tha Lan area is much smaller in population and area than Chiang Mai and has less variation in occupation and income level. Therefore, only two categories of population density (low and medium) were considered. The assumptions made on household size and housing type are shown in Table B-3-9.

Table B-3-9 ASSUMPTIONS ON HOUSEHOLD SIZE AND HOUSING TYPE

	1987	2007
Average Household Size		
Urban Households	4.74	4.0
Rural Households	6.0	5.0
Housing Type		
Detached House	88.6%	68%
Row House (Multifamily Unit; an annual increase of 1% was assumed)	11.4%	32%

The new residential land use requirement was calculated as follows:

- Future urban population = Target population - rural population
- Rural population = rural employment ÷ 2 x rural household size
- Future urban population = 70,000 - (1575 ÷ 2 x 5) = 66,062
- Future urban housing units = 16,516 units
  - Detached type = 11,230 units
  - Multifamily type = 5,286 units
- Present stock = 6,471 units
  - Detached type = 5,261 units
  - Multifamily type = 1,210 units
- New housing units required = 10,045 units
  - Detached type = 5,969 units
  - Multifamily type = 4,070 units
- Gross Wah^2 requirement = Detached 150
  = Multifamily 80

New residential land requirement = 763 rai

DEVELOPMENT POTENTIAL ANALYSIS (Case Study I)

The area development potential for residential, commercial, and industrial uses in Chiang Mai was examined using PSA with the following grid size, factors, and factor measurement.

Grid Cell Size

A suitable grid cell size is dependent upon the size of the study area. Since the Chiang Mai study area is 100 square kilometers, a cell size of 200 m x 200 m (25 rai) was selected, with 58 rows and 54 columns, forming a total of 2,675 cells.

Factors and Measurement of Factors

Various factors derived from location theory were considered. Indicators, measurement ranges, and scores are presented in Table B-3-10. The measurement of each factor is considered below.

Built-Up Area

The density of an area will generally indicate the importance or opportunity of developing the area. An area with a low density will have a higher chance of being developed than a high density area, other factors being equal. Scores were assigned based on the percentage of vacant area, with four levels identified.

Road Accessibility

Accessibility by road is another important factor. Therefore, the walking distance to the nearest road was considered, with a distinction made between major and minor roads. The score was zero at a distance of 500 meters or more. For a given distance, proximity to a major road was accorded twice the score than for proximity to a minor road. In all, six levels of road accessibility were identified.

Land Price

The price of land is an important economic factor. Assessed land values were used in this study. Low to moderate land prices were deemed suitable for residential and industrial categories, while a higher price was deemed suitable for commercial categories considering the higher returns from such land. The scores for land prices included eight levels.

Conservation Area

A conservation area is an area that is of importance for the arts, culture, history, architecture, or scenic values, and that is controlled and maintained by a governmental agency. Since conservation areas are not suitable for development of any other type, the scores assigned were low, classified into three levels.

Table B-3-10 DETAILS OF FACTORS, INDICATORS, MEASUREMENT RANGES, SCORES, AND SOURCES OF MAPS FOR PSA

Series	Factor	Computer Code	Indicator	Range of Measurement	Normalized Score		Maps, Scale, Source
1	Built up Area	FAC1.DAT	Rank size of vacant area	0-25(%)	10		- Map of Built Up Area
				26-50(%)	7		- Scale 1:20,000
				51-75(%)	3		- Mapping Division
				76-100(%)	0		
					Minor Road	Major Road	- Right of Way, Road Surface & Traffic Lanes Map
2	Road Accessibility	FAC2.DAT	Rank of accessibility to minor and major roads	0-100 (m)	5	10	- Traffic Volumn Map
				101-200 (m)	4	8	- Scale 1:20,000
				201-300 (m)	3	6	- Engineering Division
				301-400 (m)	2	4	
				401-500 (m)	1	2	
				>500 (m)	0	0	
					RI	C	- Land Price Map
3	Land Price	FAC3RI.DAT	Land price assessment for residences and industry	30,000-999,999 (Baht/Rai)	10	0	- Scale 1:20,000
				1,000,000-2,999,999 (Baht/Rai)	9	1	- Research & Analysis Division
				3,000,000-4,999,999 (Baht/Rai)	7	3	
				5,000,000-6,999,999 (Baht/Rai)	6	4	
				7,000,000-8,999,999 (Baht/Rai)	4	6	
		FAC3C.DAT	Land price assessment for commerce	9,000,000-10,000,000 (Baht/Rai)	3	7	
				11,000,000-12,000,000 (Baht/Rai)	1	9	
				13,000,000-15,000,000 (Baht/Rai)	0	10	
4	Conservation Area	FAC4.DAT	Conservation or preservation area for art, cultural, historical, architectural, natural, governmental or public reasons	- Preservation area for art, cultural, historical, architectural, or natural reasons	0		- Map of Tourist Attractions & Facilities - Scale 1:20,000 - Research & Analysis Division and Mapping Division
				- Conservation area for governmental or public reasons	5		
				- Other area	10		
5	Water Supply	FAC5.DAT	Service Area	- Completed Service Area within 200 m from major water pipeline	10		- Water Supply Map - Scale 1:20,000 - Engineering Division
				- Service Area	5		
				- Other Area	0		
6	Drainage System	FAC6.DAT	Service Area	- Completed Service Area within 200 m from drainage line	10		- Drainage System Map - Scale 1:20,000 - Engineering Division
				- Service Area	5		
				- Flooded Area & Other Area	0		

Table 3-10 DETAILS OF FACTORS, INDICATORS, RANGES, SCORES, AND SOURCES OF MAPS FOR PSA (CONT.)

Series	Factor	Computer Code	Indicator	Range of Measurement	Normalized Score	Map, Scale, Source
7	Market Places	FAC7.DAT	Service Area	0-400 (m)	10	- Map of Market Places
				401-800 (m)	9	- Scale 1:20,000
				801-1,200 (m)	8	- Research & Analysis Division
				1,201-1,600 (m)	6	
				1,601-2,000 (m)	5	
				2,001-2,400 (m)	4	
				2,401-2,800 (m)	3	
				2,801-3,200 (m)	1	
				>3,200 (m)	0	
8	Recreation Area or	FAC8.DAT	Service Area	Small Size / Large Size		
	Open Space		(Small size recreation	/ 0-700 (m)	10	- Recreation Area & Open
			area)	/ 701-1,400 (m)	8	Space Map
			&	0-250 (m) / 1,401-2,100 (m)	5	- Scale 1:20,000
			(Large size recreation	251-500 (m) / 2,101-2,800 (m)	3	- Research & Analysis Division
			area)	>500 (m) / >2,800 (m)	0	
9	Educational Institution	FAC9.DAT	Service Area	K-P / S-U		- Map of Educational Institutional
			(Kindergarten-Primary)	0-200 (m) / 0-400 (m)	10	- Scale 1:20,000
			&	201-400 (m) / 401-800 (m)	8	- Research & Analysis Division
			(Secondary-University)	401-600 (m) / 801-1,200 (m)	6	
				601-800 (m) / 1,201-1,600 (m)	4	
				801-1,000 (m) / 1,601-2,000 (m)	2	
				>1,000 (m) / >2,000 (m)	0	
10	Hospital or Health Clinic	FAC10.DAT	Service Area	0-400 (m)	10	- Map of Hospital & Health Clinic
				401-800 (m)	8	- Scale 1:20,000
				801-1,200 (m)	5	- Research & Analysis Division
				1,201-1,600 (m)	3	
				>1,600 (m)	0	
					RC / I	- Map of Existing Land Use
11	Environment	FAC11RC.DAT	Distance from Industrial	0-200 (m)	0 / 10	- Scale 1:20,000
		FAC11I.DAT	Sites & Polluted Area	201-400 (m)	3 / 8	- Research & Analysis Division
				401-600 (m)	5 / 5	
				601-800 (m)	8 / 3	
				>800 (m)	10 / 0	

Water Supply

The water network is another key factor. Areas within a water supply service area and on a pipeline, river, or canal were assigned the highest score, while areas within the service network but with no water-pipes, river, or canal within 200 meters received a lower score. Three classification levels were used.

Drainage System

Water drainage is also an important factor in the development of land. The highest score was given to land within a drainage service area and located 200 meters or less from drainage pipes. Three levels were used for this factor.

Market Places

Market places such as business and commercial centers and department stores are directly relevant to the location of commercial activities. The scoring system was based on the service area within 3.2 km, with nine classifications used.

Recreation Area and Open Space

Recreation area and open space are social factors with direct relevance to the location of residential areas. The scoring system was based on walking distance to recreation areas and open space. Recreation areas and open space were divided into two sizes, "small" and "large" (more than 10 rai). The minimum score was received at a distance of 500 meters from a small recreation area, and 2,800 meters from a large recreation area. Five classification levels were employed.

Educational Institution

The presence of an educational institution is an important factor in the location of residential activity. The scoring system was based on service area, with two categories of educational institutions identified: kindergarten-primary level and secondary-university. The service area for the former was set at one kilometer, and the latter at two kilometers. The scores were classified into six levels.

Hospital or Health Clinic

The presence of a hospital or health clinic also has direct relevance to the location of residential activity. The scoring system was based on a service area of 1.6 km., with five levels identified.

Environment

Environment is an important physical factor having direct relevance to the location of urban activities. The scoring system was based on distance from industrial sites and polluted areas. Note that while residential and commercial activities are most suitably located in areas with high environmental quality, manufacturing activities may be attracted by other similar activities, from which agglomeration economies can be achieved. The scoring system for environmental quality has four levels.

Results

Table B-3-11 shows the selected factors and weighted scores indicating importance for residential, commercial, and industrial land use. Table B-3-12 and Figures B-3-3 through B-3-5 show the results of an evaluation of the development potential of the three types of land use, leading to the formulation of a land use plan (Figure B-3-6).

DEVELOPMENT POTENTIAL ANALYSIS (Case Study II)

Some changes were made in applying potential surface analysis to the Tha Rua-Tha Lan area, and these changes are described below. The changes reflect the area's unique socioeconomic background, history, and physical setting, as well as the different formatting of the data for this area.

Grid Cell Size

The Tha Rua study area is 39.73 square kilometers, smaller than Chiang Mai. However, a cell size of 250 m x 250 m (40 rai) was used. The number of rows and columns were 45 and 28, respectively. The number of total cells was 718.

Factors and Measurement of Factors

The factors along with their indicators, measurement range, scoring, and map sources are shown in Tables B-3-13 and B-3-14.

Two factors--population density and flood area--were newly employed for Case Study II, while the land price factor was excluded. The two new factors are described below.

Population Density

The population density of an area indicates the opportunity for developing the area for various activities. This factor is related to trends in the growth of urban areas, urban facilities, and the transportation network. An area with low density provides more opportunities for residential and industrial development, but a high density area provides more opportunities for commercial development. The scores were classified into six levels.

Flood Area

The presence of a flood area is another important factor since such areas are not suitable for development. All other areas are assigned a higher score.

Results

Table B-3-15 *shows the selected factors and weighted scores indicating* their importance for residential, commercial, and industrial development. Table B-3-16 and Figure B-3-7 show the results of an evaluation of the development potential of the three types of land use, leading to the formulation of a land use plan (Figure B-3-8). DTCP's Comprehensive Planning and Engineering Divisions have collected data on a grid basis for use in the analysis of development potential. In this study a PSA program written in FORTRAN was written to facilitate calculation and to clearly show the step-by-step PSA process, from actual factor scores, to weighted normalized scores, to potential development scores. The result of the analysis is in map form, providing decisionmakers with various alternatives for consideration in preparation of the general plan.

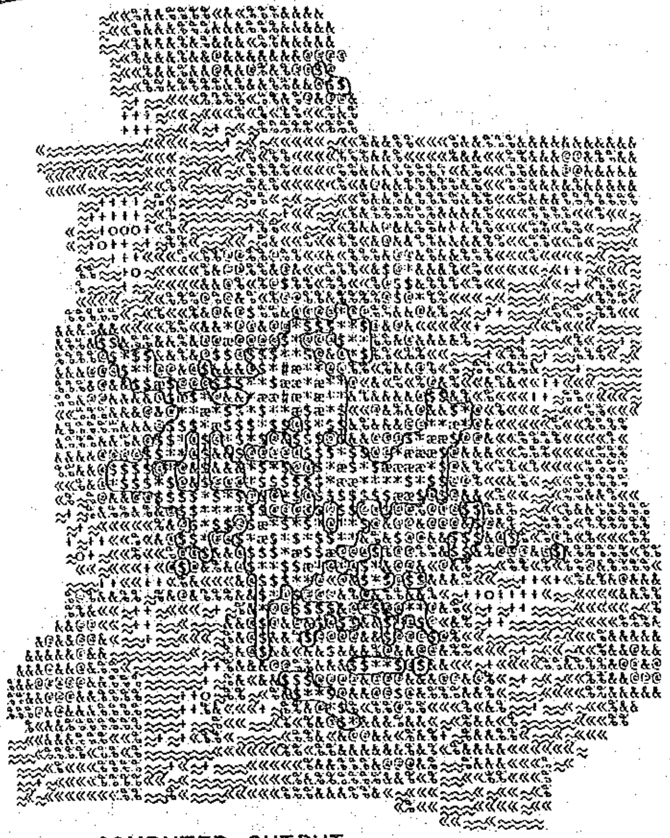
Table B-3-11 *FACTORS INDICATING LAND USE ACTIVITIES* AND WEIGHTED SCORES (Chiang Mai City, Case Study I)

Series	Factors	Weighted Scores of Land Use Activity		
		Residential	Commercial	Industrial
1	Built-up Area	2	3	1
2	Road Accessibility	3	4	4
3	Land Price	3	4	3
4	Conservation Area	2	2	2
5	Water Supply	4	4	4
6	Drainage System	3	4	4
7	Market Places		4	
8	Recreation Area & Open Space	3		
9	Educational Institution	3		
10	Hospital or Health Clinic	3		
11	Environment	5	4	4
	Total Number of Factors	10	8	7

Note: "5" indicates "most importance and highest direct relevance to land use activities".

Table B-3-12 POTENTIAL SURFACE ANALYSIS: DEVELOPMENT POTENTIAL OF LAND USE ACTIVITIES

Land Use Activities	Rank Development Potential	Percent		Interval Score	
		Correlation Matrix Weighting	Factor Rankings	Correlation Matrix Weighting	Factor Rankings
Residential	Lowest	1.98	3.89	<=27.95 - <=33.85	<=88.50 - <=107.50
	Low	23.86	34.10	<=39.75 - <=45.65	<=126.50 - <=145.50
	Moderate	44.23	38.51	<=51.55 - <=57.45	<=164.50 - <=183.50
	High	24.15	18.17	<=63.35 - <=69.25	<=202.50 -<=221.50
	Highest	5.75	5.34	<=75.15 - >81.05	<=240.50 - >259.50
Commercial	Lowest	5.53	7.06	<=16.75 - <=22.25	<=55.55 - <=76.65
	Low	33.80	46.58	<=27.75 - <=33.25	<=97.75 - <=118.85
	Moderate	44.90	31.97	<=38.75 - <=44.25	<=139.95 - <=161.05
	High	12.90	11.21	<=49.75 - <=55.25	<=182.15 - <=203.25
	Highest	2.88	3.18	<=60.75 - >66.25	<=224.35 - >245.45
Industrial	Lowest	4.78	18.24	<=15.60 - <=20.80	<=45.65 - <=62.95
	Low	26.51	32.15	<=26.00 - <=31.20	<=80.25 - <=97.55
	Moderate	42.25	26.20	<=36.40 - <=41.60	<=114.85 - <=132.15
	High	22.92	15.85	<=46.80 - <=52.00	<=149.45-<=166.75
	Highest	3.55	7.55	<=57.20 - >62.40	<=184.05 - >201.35



PERCENT OF POTENTIAL

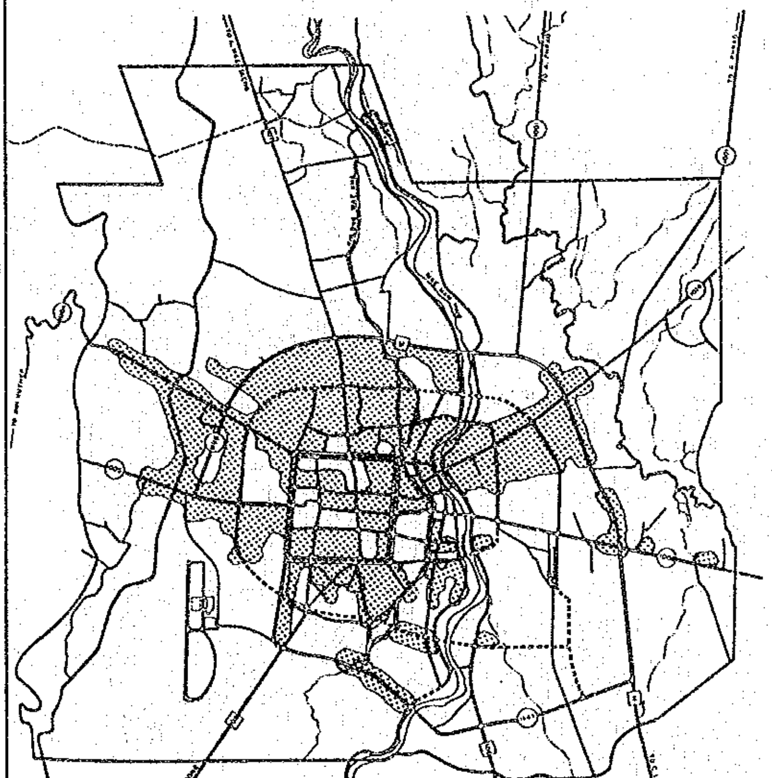
O = 0.30 PERCENT
+ = 3.59 PERCENT
≈ = 14.17 PERCENT
« = 19.93 PERCENT
% = 21.50 PERCENT
& = 17.46 PERCENT
@ = 10.54 PERCENT
$ = 7.63 PERCENT
* = 3.96 PERCENT
æ = 1.31 PERCENT
= 0.07 PERCENT

SCORE

O ≤ 88.50 , + ≤ 107.50
≈ ≤ 126.50 , « ≤ 145.50
% ≤ 164.50 , & ≤ 183.50
@ ≤ 202.50 , $ ≤ 221.50
* ≤ 240.50 , æ ≤ 259.50
# > 259.50

COMPUTER OUTPUT

CARTOGRAPHIC INTERPRETATION



LEGEND

SUITABLE LOCATION FOR DEVELOPMENT OF RESIDENTIAL ACTIVITY
(HATCHED AREA SHOWS THE FOUR HIGHEST RANKS OF POTENTIAL)

Fig. B-3-3 RESIDENTIAL POTENTIAL BY FACTOR RANKING APPROACH (CHIANG MAI, CASE STUDY I)

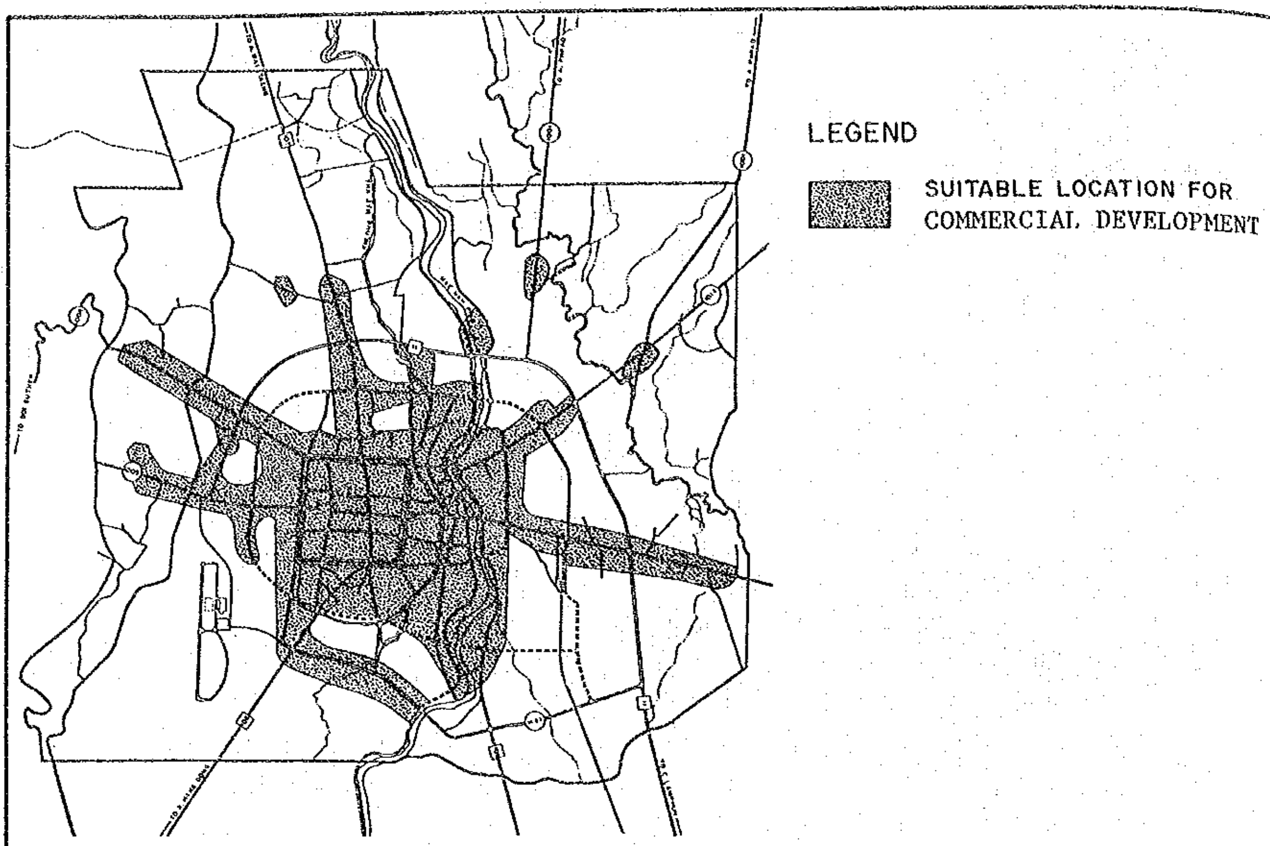


Fig. B-3-4 COMMERCIAL POTENTIAL BY FACTOR RANKING APPROACH

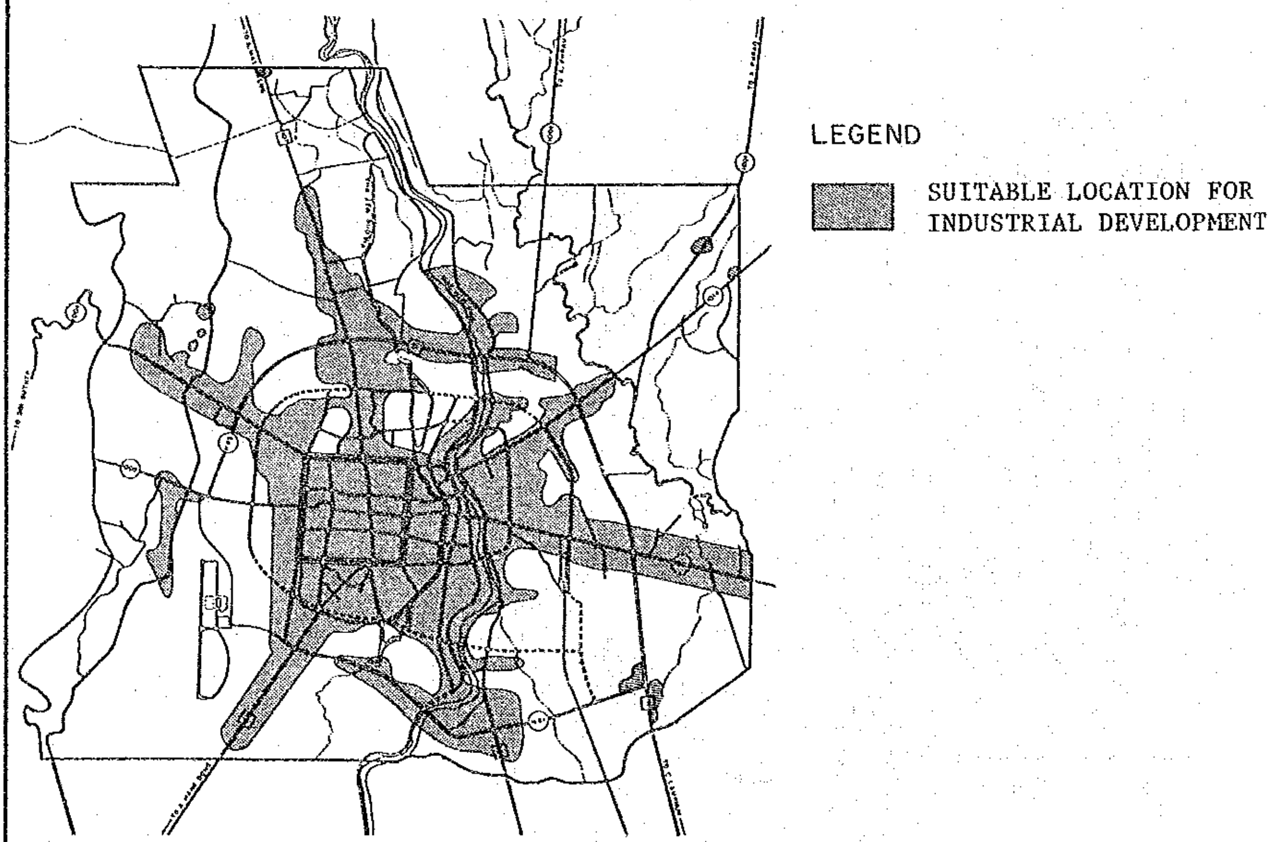


Fig. B-3-5 INDUSTRIAL POTENTIAL BY FACTOR RANKING APPROACH

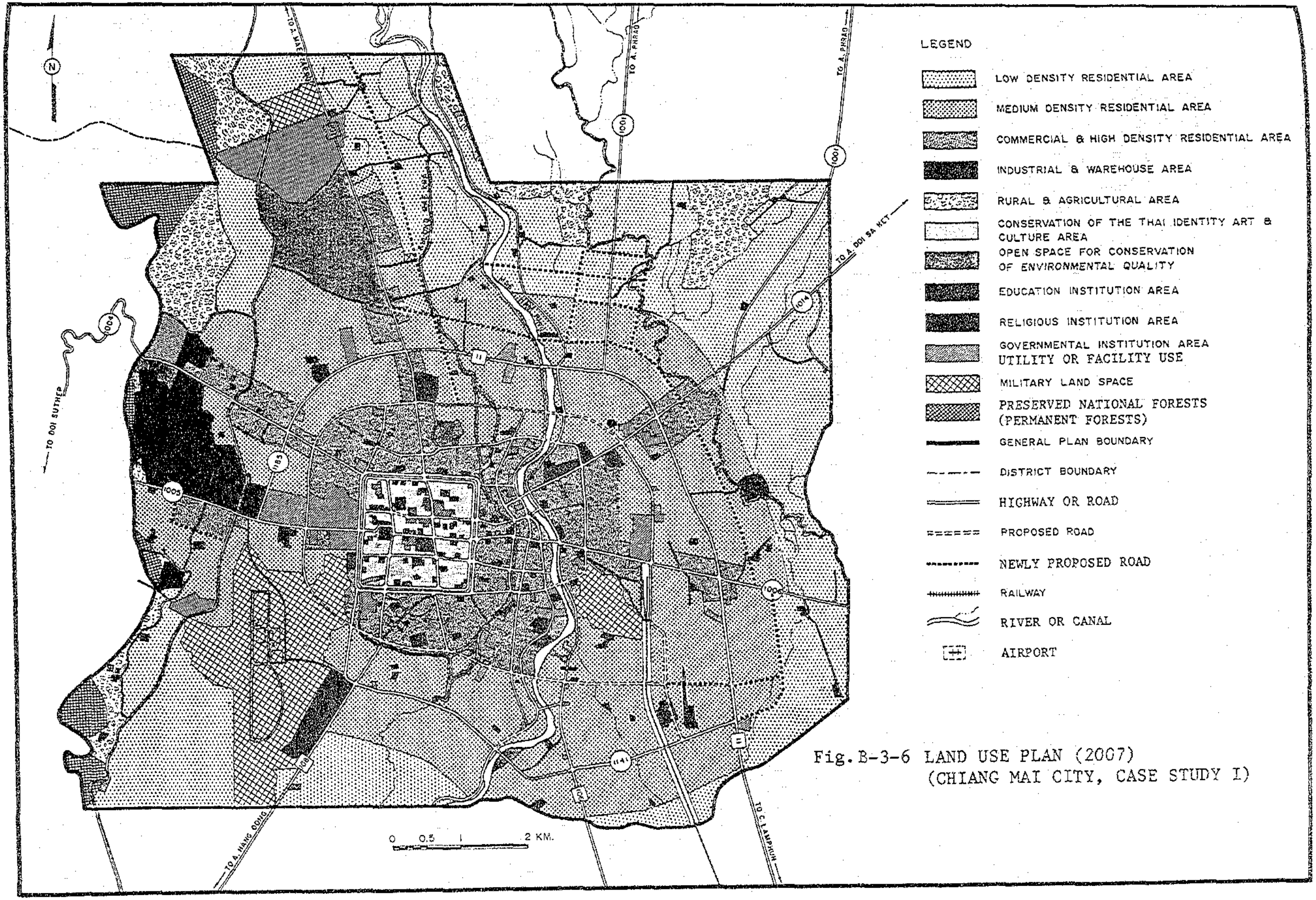


Fig. B-3-6 LAND USE PLAN (2007)
(CHIANG MAI CITY, CASE STUDY I)

Table B-3-13 DETAILS OF FACTORS, INDICATORS, MEASUREMENT RANGES, SCORES, AND SOURCES (THA RUA, CASE STUDY II)

Series	Factor	Indicator	Range of Measurement	Score: Actual		Score: Normalized		Map Sources
				R,I	C	R,I	C	
1	Population Density	Rank size of population density	- < 1 (person/rai)	6	1	10	0	- Population Density Map
			- 1- 5 (person/rai)	5	2	8	2	- Scale 1:20,000
			- 6-10 (person/rai)	4	3	6	4	- R & A Div.
			- 11-15 (person/rai)	3	4	4	6	
			- 16-20 (person/rai)	2	5	2	8	
			- >20 (person/rai)	1	6	0	10	
2	"Urban Vacant Area"	Rank size of occupancy rate	- 0-25 (%)	4		10		- Land Use Map
			- 26-50 (%)	3		7		- Scale, 1:20,000
			- 51-75 (%)	2		3		- Mapping Div.
			- 76-100(%)	1		0		
3	Conservation Area	Conservation or preservation are for art, cultural, historical, or architectural government & public aspects	- Preservation area for art, culture, historical, architectural reasons	1		0		- Land Use Map
			- Conservation area for government or & public reasons	2		5		- Scale, 1:20,000
			- Others	3		10		- Mapping Div.
4	Road Accessibility	Rank of accessibility to roads	- 0-250 (m)	5		10		- Right of Way, Road Surface and Traffic Lanes Map
			- 251-500 (m)	4		8		- Scale 1:20,000
			- 501-750 (m)	3		5		- Engineering Div.
			- 751-1,000 (m)	2		3		
			- >1,000 (m)	1		0		
				R,C	I	R,C	I	
5	Environment	Distance from industrial sites & polluted area	- 0-250 (m)	1	5	0	10	- Land Use Map
			- 251-500 (m)	2	4	3	8	- Scale 1:20,000
			- 501-1,000 (m)	3	3	5	5	- Mapping Div.
			- 751-1,000 (m)	4	2	8	3	
			- >1,000 (m)	5	1	10	0	

Table B-3-13 DETAILS OF FACTORS, INDICATORS, RANGES, SCORES, AND SOURCES (THA RUA, CASE STUDY II)(CONT.)

6	Flood Area	Flood area	- Flood area		1	0	- Flood Area Map
			- Others		2	10	- Scale 1:20,000
							- Mapping Div.
7	Water Supply	Service area	- Completed service area		3	10	- Water Supply Map
			- Service area, irrigated area & river effect area		2	5	- Scale 1:20,000
							- Engineering Div.
			- Others		1	0	
8	Market Place & Shopping Center	Service area	Large Size	Small Size			- Land Use Map
			- 0-250 (m)		6	10	- Scale 1:20,000
			- 251-500 (m)		5	8	- Mapping Div.
			- 501-1,000 (m)	- 0-250 (m)	4	6	
			- 1,000-2,000 (m)	- 251-500 (m)	3	4	
			- 2,001-3,000 (m)	- 501-1,000 (m)	2	2	
			- >3,000 (m)	- >1,000 (m)	1	0	
9	Park & Recreation Area	Distance from the park & recreation area	- 0-500 (m)		4	10	- Land Use Map
			- 501-1,500 (m)		3	7	- Scale 1:20,000
			- 1,501-3,500 (m)		2	3	- Mapping Div.
			- >3,500 (m)		1	0	
10	Educational Institution	Service area (Kindergarten-Primary) (Secondary-Vocational)	K - P	S & V			- Land Use Map
			- 0-250 (m)	- 0-500 (m)	5	10	- Scale 1:20,000
			- 251-500 (m)	- 501-1,000 (m)	4	8	- Mapping Div.
			- 501-750 (m)	- 1,001-1,500 (m)	3	5	
			- 751-1,000 (m)	- 1,501-2,000 (m)	2	3	
			- >1,000 (m)	- >2,000 (m)	1	0	
11	Hospital & First Aid Center	Service area	Hospital	First Aid Center			- Land Use Map
			- 0-250 (m)		6	10	- Scale 1:20,000
			- 251-500 (m)		5	8	- Mapping Div.
			- 501-1,000 (m)	- 0-250 (m)	4	6	
			- 1,001-1,500 (m)	- 251-500 (m)	3	4	
			- 1,501-2,000 (m)	- 501-1,000 (m)	2	2	
			>2,000 (m)	- >1,000 (m)	1	0	

Note: R= Residential, C= Commercial, I= Industrial

Table B-3-14 FACTORS INDICATING LAND USE ACTIVITIES AND WEIGHTED SCORES (Tha Rua: Case Study II)

Series	Factors	Weighted Scores of Land Use Activity								
		Residential			Commercial			Industrial		
		*	**	***	*	**	***	*	**	***
1	Population Density	4	3	5	4	3	5	3	1	4
2	Urban Vacant Area	3	4	4	3	3	5	3	3	4
3	Conservation Area	3	2	5	3	3	5	4	3	5
4	Road Accessibility	4	3	4	4	3	5	4	3	4
5	Environment	4	3	4	3	2	2	3	3	5
6	Flood Area	4	3	3	4	3	3	3	3	3
7	Water Supply	4	3	3	4	3	3	4	3	4
8	Market Place or Shopping Center	3	2	3	4	3	4			
9	Park & Recreation Area	3	3	4						
10	Educational Institution	3	2	2						
11	Hospital or First Aid Center	3	2	2						
	Total Number of Factors	11			8			7		

Note: "1" indicates "Least importance and lowest direct relevance to land use activities".

* Mean Weighted Score

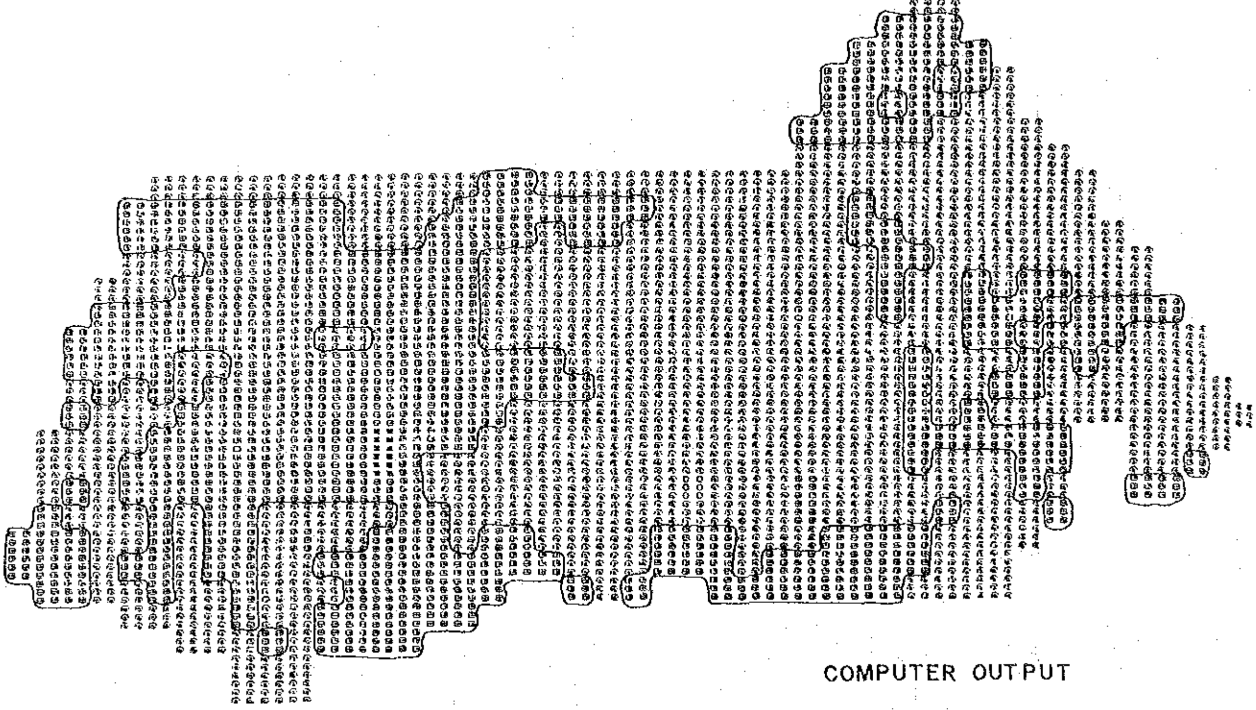
** Weighted by "Nishita"

*** Weighted by "Kobkaew"

Table B-3-15 POTENTIAL SURFACE ANALYSIS (THA RUA, CASE STUDY II)

Land Use Activities	Rank Development Potential	Factor Ranking								
		(1)			(2)			(3)		
		Internal Score	Percent	No. of Grid	Internal Score	Percent	No. of Grid	Internal Score	Percent	No. of Grid
Residential Potential	Low	38.83	0.14	1	37.83-39.83	0.42	3	36.58-39.57	0.42	3
	Moderate	40.16-60.00	56.82	408	40.50-59.94	39.42	283	40.77-59.91	26.04	187
	High	60.02-79.41	42.76	307	60.00-79.72	59.61	428	60.00-79.23	72.84	523
	Highest	82.78-85.71	0.28	2	80.50-86.83	0.56	4	80.00-85.64	0.70	5
Commercial Potential	Low	23.36-39.92	5.01	36	23.48-39.57	5.0	36	24.52-39.78	4.60	33
	Moderate	40.00-59.92	76.46	549	40.00-59.13	65.32	469	40.11-60.00	61.00	438
	High	60.17-79.66	18.52	133	60.00-79.13	29.67	213	60.00-78.06	34.26	246
	Highest	-	-	-	-	-	-	80.43-80.43	0.14	1
Industrial Potential	Low	38.50	0.28	2	35.79-39.74	0.70	5	35.17-39.77	0.56	4
	Moderate	41.44-59.92	13.51	97	41.05-59.74	15.04	108	42.47-59.89	13.65	98
	High	60.13-79.75	69.78	501	60.53-79.21	67.83	487	60.06-79.89	68.52	492
	Highest	80.15-94.46	16.43	118	80.26-95.00	16.43	118	80.17-93.10	17.27	124

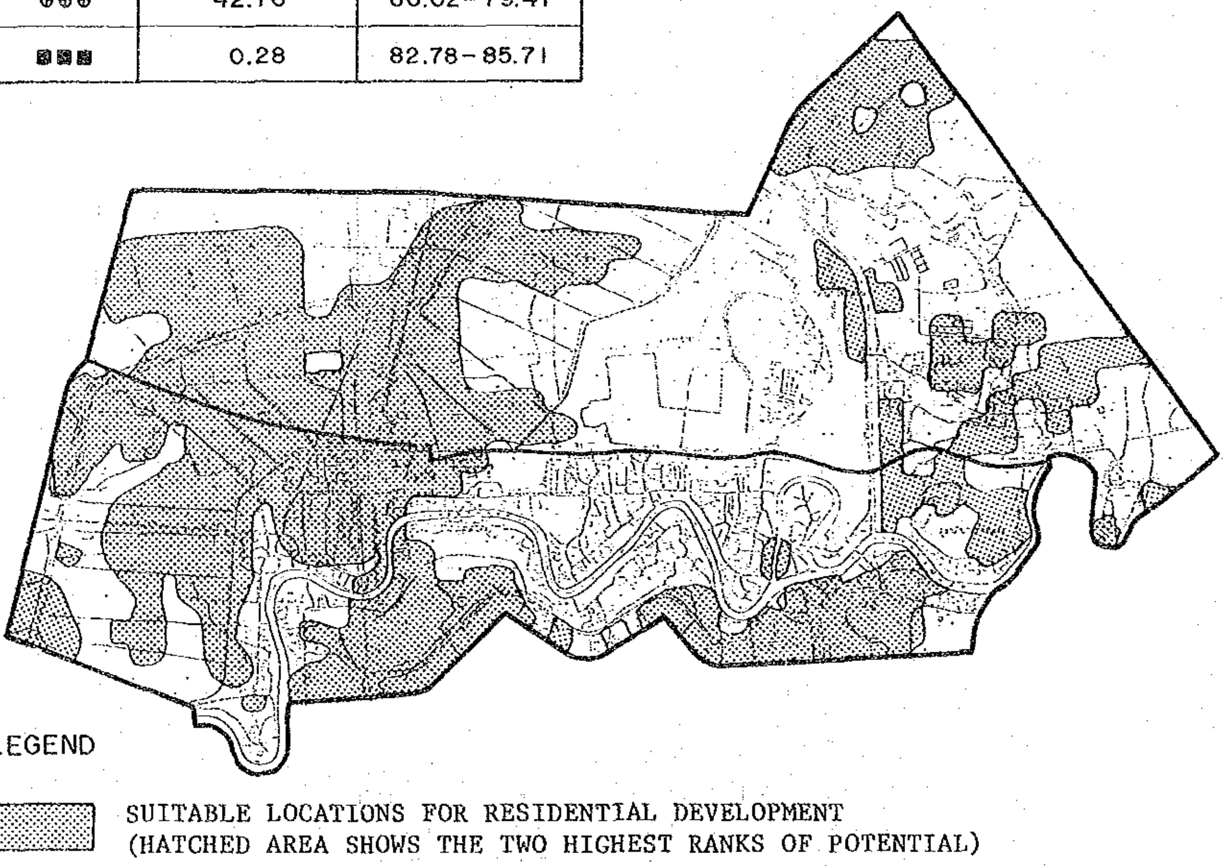
Note : (1) = Mean Weighted Score
(2) = Weighted by "Nishita"
(3) = Weight by "Kobkaew"



COMPUTER OUTPUT

CARTOGRAPHIC INTERPRETATION

LEGEND	PERCENT OF POTENTIAL	SCORE
OOO	0.14	38.83
@@@	56.82	40.16-60.00
⊕⊕⊕	42.76	60.02-79.41
■■■	0.28	82.78-85.71



LEGEND

SUITABLE LOCATIONS FOR RESIDENTIAL DEVELOPMENT
(HATCHED AREA SHOWS THE TWO HIGHEST RANKS OF POTENTIAL)

Fig. B-3-7 RESIDENTIAL POTENTIAL (MEAN WEIGHTED SCORE)
(THA RUA - THA LAN CASE STUDY II)

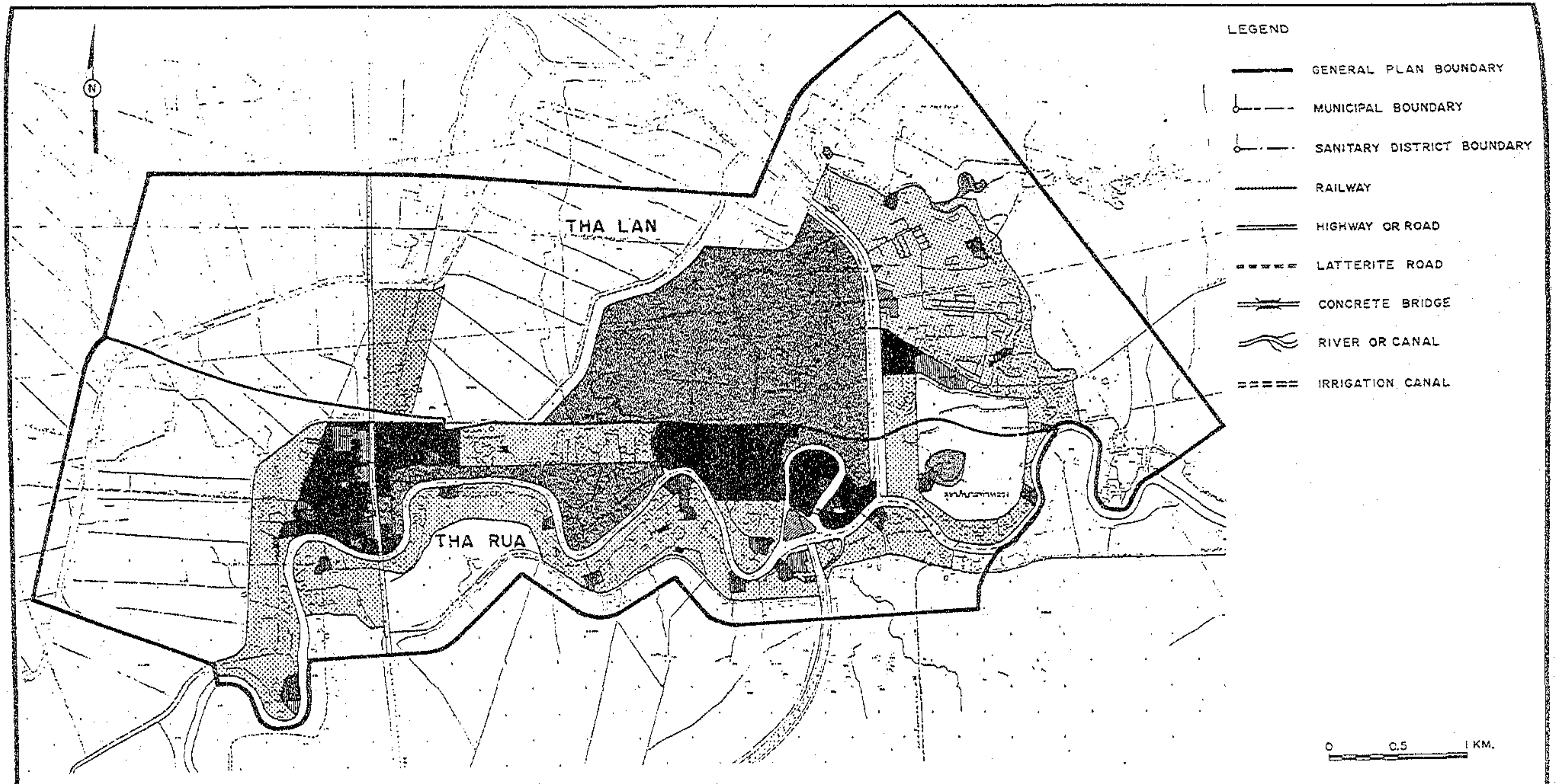


Fig. B-3-8 FUTURE LAND USE PLAN (A.D. 2001) (THA RUA - THA LAND GENERAL PLAN, CASE STUDY II)

APPENDIX B-4

TRANSPORT PLANNING

Appendix B-4

TRANSPORT PLANNING

Study Subjects and Study Areas

The major objective of the transport planning case studies was to evaluate the proposed techniques in practical planning environments. Study issues were chosen to cover the major areas of technical improvement at the different stages of the planning process. The final recommendations of this report took into account the results of the case studies.

The case studies had to be conducted in accordance with the DTCP's statutory planning schedule. Although DTCP was prepared to make some changes in its existing schedule (fiscal year 1987-1988), major modifications were not possible. The scale of the city as well as the cost and accuracy of the proposed methods also had to be considered. Taking all of this into account, Chiang Mai (1987 population, 218,000; a regional city) and Tha Mai (1987 population, 9,000; a municipality) were selected.

The study issues for each site are shown in Table B-4-1.

TRANSPORT PLANNING IN CHIANG MAI (PHASE I)

The case study in Chiang Mai was divided into two phases. In Phase I, the existing traffic flow pattern was simulated and the adequacy of assignment data was validated; in Phase II (Case Study II), the future volume of traffic on the proposed network was estimated, and the results were utilized in the plan design and evaluation process. The household interview and car O-D survey data were available at the outset of the case study but the data had not been analyzed. These data were used to build the present O-D matrix, which was then adjusted to reproduce the present link volumes. This approach required the construction of an assignment network and the preparation of link data for computer processing.

Most of the calculations were performed with the use of a commercial transport planning software package made available to this study by JICA. The package was run on an Acer 1100 series 32-bit computer operating with 16 MHz.

Case Study Areas and Initial Data

The original area of the Chiang Mai general plan, which covers 98.4 square kilometers, was chosen (see Figure B-4-1) for a case study. The area was divided into 35 zones, while the area outside was divided into seven zones, making 42 traffic zones altogether.

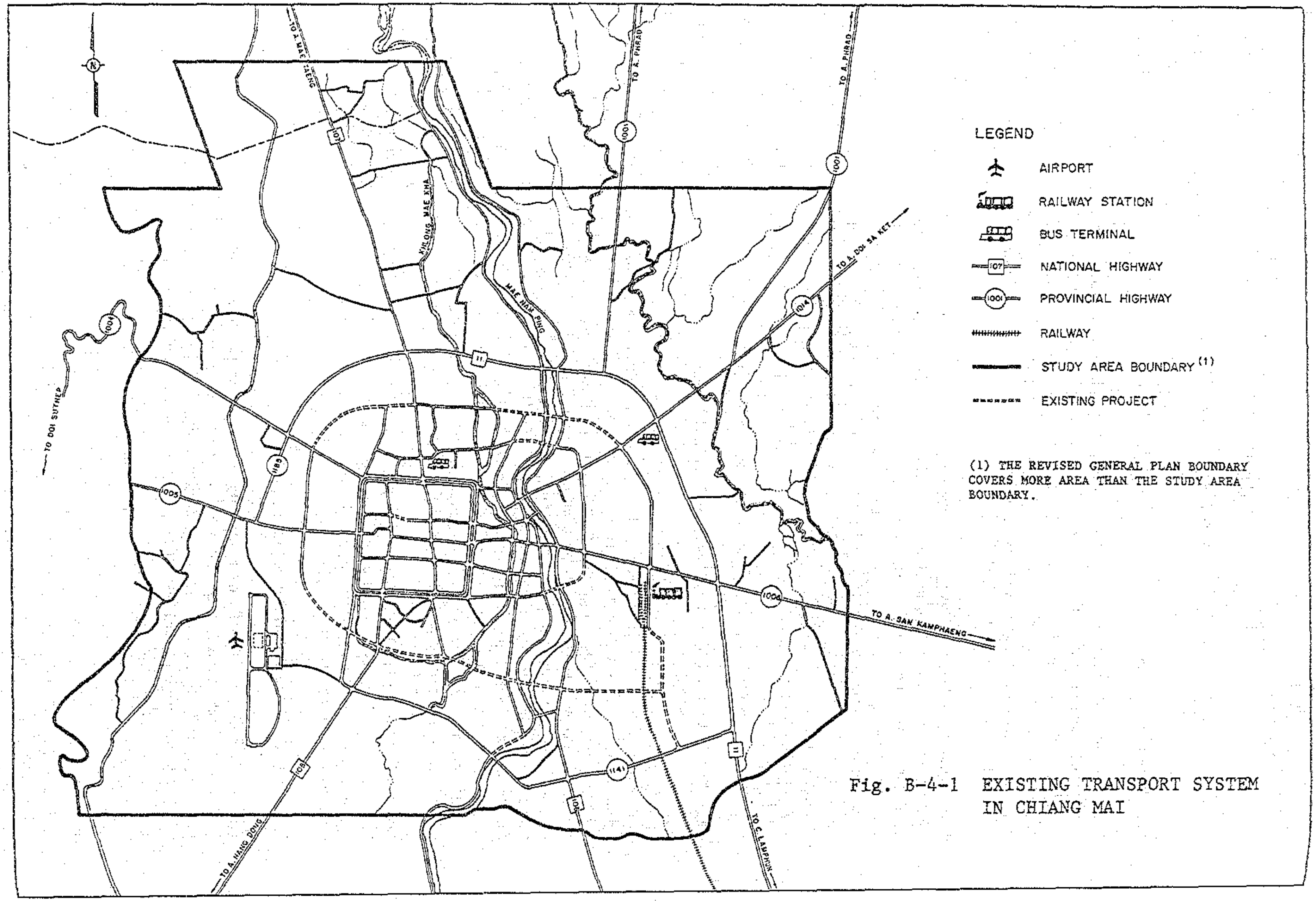


Fig. B-4-1 EXISTING TRANSPORT SYSTEM IN CHIANG MAI

TABLE B-4-1 CASE STUDY CITIES AND TRANSPORT PLANNING STUDY ISSUES

City	Study Issues
CASE STUDY I	
Chiang Mai (Phase I)	Quantitative Demand Analysis - Construction of O-D matrix from home interviews and car O-D survey (by using computer) - Estimation of O-D matrix from roadside traffic volume counts.
CASE STUDY II	
Chiang Mai	Network Design and Evaluation - Forecasting of future trip ends and O-D pattern - Traffic simulation and network evaluation - Graphic presentation of desire line pattern and network volumes
Tha Mai	Data Collection and Compilation - Testing of traffic counter - Compilation and analysis of traffic data collected by automatic counter with magnetic storage medium compatible with microcomputer

Traffic demand data had been collected in surveys conducted earlier in 1987. Two separate approaches, a home interview survey and a cordon survey, were used. The home interview survey collected data on the trip origins and destinations of persons residing inside the study area. Data on mode of transport (e.g., auto), trip purpose, and travel time were also collected. A random sample of 4.5% of the total population was taken. The cordon O-D survey was conducted through roadside interviews at seven entry-exit checkpoints. The purpose of this survey was to find out the origins and destinations of trips across the cordon line (i.e., the boundary of the study area). Items on the cordon O-D questionnaire included type of vehicle, purpose of journey, and type and volume of cargo transported. The average sampling rate in the cordon O-D survey was 7.7%.

Both an automatic and a manual traffic volume count was conducted. Automatic counters were installed at 25 points on the road network; manual counts were conducted at 158 points from 7 to 10 am and from 3 to 5 pm. The manual counts classified traffic into seven different modes.

Socioeconomic data and land use forecasts are also indispensable for planning and were supplied by the Research and Analysis Division and the Comprehensive Planning Division. The existing population by traffic zone was derived by converting existing population data, which is tabulated on the basis of "enumeration districts" (i.e., the zones used by DTCP's Research and Analysis Division). Existing employment by traffic zone were derived from employment statistics collected by the Research and Analysis Division.

Construction of O-D Matrix

As has been mentioned, a home interview survey of study area residents and a cordon survey of vehicle trips were conducted through roadside interviews. To construct an O-D matrix, raw data from these two surveys were integrated using the process shown in Figure B-4-2.

Table B-4-2 shows the sources of survey data for construction of a complete O-D matrix. The data obtained from the home interview and cordon surveys, however, are different in terms of measurement units; the former is in terms of person trips, while the latter is in terms of vehicular trips. In this study, focus was placed on vehicular trips; therefore, the data from the home interview survey had to be converted into vehicular trips by applying an appropriate conversion factor based on "occupancy rate" (i.e., the average number of passengers per vehicle). These rates vary by type of vehicle. For this reason, basic O-D matrices were constructed for each vehicle type. Four matrices from the home interview survey and six matrices from the cordon survey were constructed. Prior to the use of occupancy rates to convert person trips to vehicular trips, the basic matrices explained above were expanded to represent the whole population. (Recall that the data used was based on a random sample of the entire study area population.)

Table B-4-2 SOURCES OF SURVEY DATA FOR THE INTEGRATION OF A COMPLETE O-D MATRIX

Origin Zones	Destination Zones	
	Internal	External
Internal	II (Home Interview)	IE (Home Interview)
External	EI (Cordon Survey)	EE (Cordon Survey)

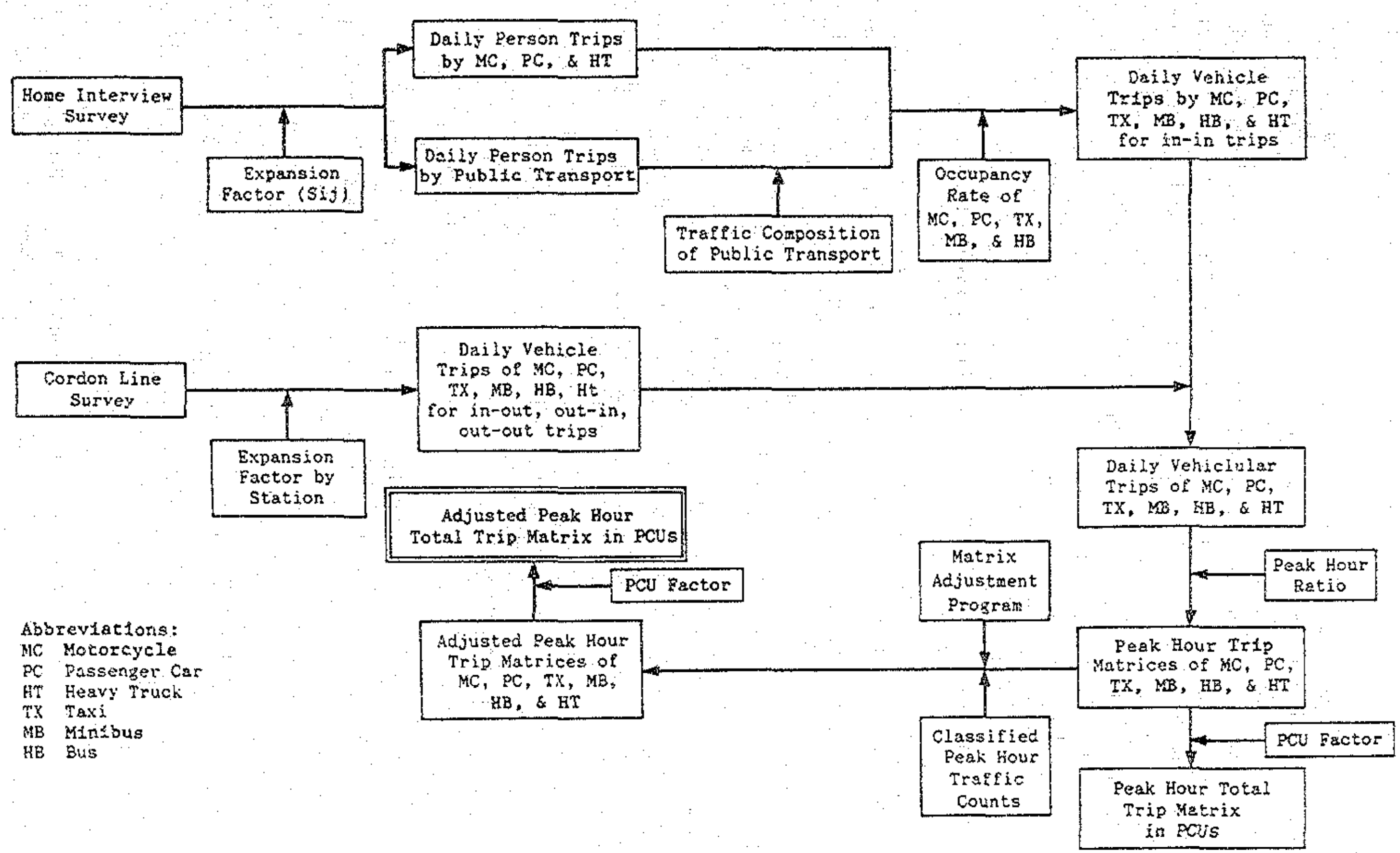


Fig. B-4-2 PROCESS OF CONSTRUCTING AN O-D MATRIX

Conversion of Person Trips to Vehicule Trips

Matrices constructed based on home interviews are in the unit of person trips. To convert these to vehicular trips, the occupancy rates obtained from the cordon survey were used and are displayed in Table B-4-3. However, the classification of vehicle types in the cordon survey did not correspond to the classification in the home interview survey; "public transport" in the home interview survey corresponded to "heavy bus," "minibus," and "taxi" in the cordon survey. Conversion of "public transport" trips into vehicle trips was done by considering the public transport mode share in Chiang Mai, which was also collected in the cordon survey (see Table B-4-4).

Table B-4-3 **AVERAGE VEHICLE OCCUPANCY RATES**

Vehicle Type	Occupancy Rate (Passengers/Vehicle)
Passenger Car	2.25
Motorcycle	1.37
Minibus	9.0
Heavy Bus	20.0
Taxi	2.71

Table B-4-4 **PUBLIC TRANSPORT MODE SHARE (TRAFFIC COMPOSITION) IN CHIANG MAI**

Public Transport	Traffic Composition
Taxi	21.28
Minibus	72.99
Heavy Bus	5.73
Total	100.00%

The basic matrices represent daily vehicle trips (i.e., on a 24-hour basis), but the traffic assignment must be made for the peak hour. Peak-hour traffic movements were estimated by applying an average peak hour rate of 16% to the basic matrices; the rate was derived from 24-hour traffic data collected in Chiang Mai with automatic traffic counters. Using passenger car units (PCUs) as a common demoninator, these matrices can be combined into one integrated matrix to form an original O-D matrix.

O-D Matrix Adjustment with Traffic Counts

The O-D matrix constructed with interview survey data does not necessarily reproduce observed traffic counts when it is assigned on the existing road network. Reasons for such a discrepancy include inadequate sampling and expansion methods, and erroneous conversion factors. Since traffic counts are a record of actual traffic movements on the existing road network, they are credible in the sense that they do not rely on any theoretical assumptions. Indeed, this is the major rationale for the matrix adjustment method employed in this study. Based on an entropy maximizing theory, the matrix adjustment method adjusts the O-D matrix to closely reproduce observed link flow. [1] This process was applied to the O-D matrix for each traffic mode. The results were then combined into one matrix expressed in terms of passenger car units (PCUs).

Goodness of fit can be evaluated by comparing simulated traffic volumes with actual counts. In the case of cars, simulated traffic volumes were found to vary between 82 and 102% of actual counts, reflecting a degree of accuracy that was considered accurate enough for the purposes of this case study.

TRANSPORT PLANNING IN CHIANG MAI (PHASE II)

Phase II of the Chiang Mai transport study concentrated on the forecasting of travel demand. The principal purpose of Phase II was to forecast future trip ends, O-D patterns, and link volumes by applying quantitative methods and computer techniques, and to evaluate the practicality of this quantitative approach in the context of transport planning in Chiang Mai and other Thai cities.

Trip Generation Process

The process of forecasting travel demand starts with the estimation of trip production and attraction in each zone. Trip generation models were first calibrated to reproduce existing trip ends (i.e., trip production and trip attraction for each traffic zone). Various methods are available; a linear multiple regression model was used in this study. The model was estimated by stratifying by six modes of vehicular traffic and using as the dependent variable the number of vehicle-trips produced and attracted during the peak hour. Population and employment were used as explanatory factors (i.e., independent variables). No other socioeconomic indices were available. The results of the regression analysis showed relatively low R^2's, indicating comparatively low explanatory power, which was likely due to the lack of sufficient socioeconomic factors in the model and the lack of a variable incorporating vehicle ownership levels. Nevertheless, the calibrated models had sufficient explanatory power to use to predict the future level of trip generation.

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[1] Willnemsen (1987) "Estimation of An O-D Matrix from Traffic Counts: A Review," Institute for Transport Studies Working Paper 99, Leeds University.

Trip Distribution Process

After travel demand was forecast, the next step was to attribute this demand to particular origin and destination pairs. This can be achieved through the use of trip distribution models. In this case study, the gravity and growth factor models of trip distribution were used. The sequence of steps in the analysis of trip generation was the same as that use in the calibration and simulation of trip generation, in which analyses were made based on classifications of vehicle types or transport modes. Finally, the results of the analyses were combined to express the trip distribution of all vehicles in terms of passenger car units.

The gravity model was tested using standard methods, but application of this method to the available data set proved difficult. Therefore, the Fratar method was employed in the trip distribution process. The calculation was carried out through the use of a computer program to estimate trip distribution matrices classified by vehicle type.

Network Assignment

Network assignment involves the estimation of traffic volume on each segment of the road network; the future O-D table is "loaded" onto the road network using a computer. Figure B-4-4 illustrates how this process was implemented in the case study.

Link length data were obtained by making measurements along the actual road alignments on the map. Link speed, capacity, and travel time together with capacity class determine the Q/V curve, which is used to account for congestion effects in a capacity-constrained assignment (see Figure B-4-3 and Table B-4-5). In contrast, in an "all-or nothing" assignment, all the traffic between two zones is assigned to the shortest path (in terms of travel time).

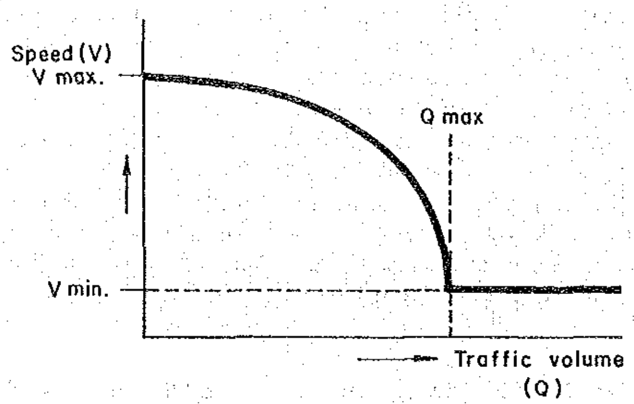


Fig. B-4-3 Q/V CURVE USED IN THIS STUDY

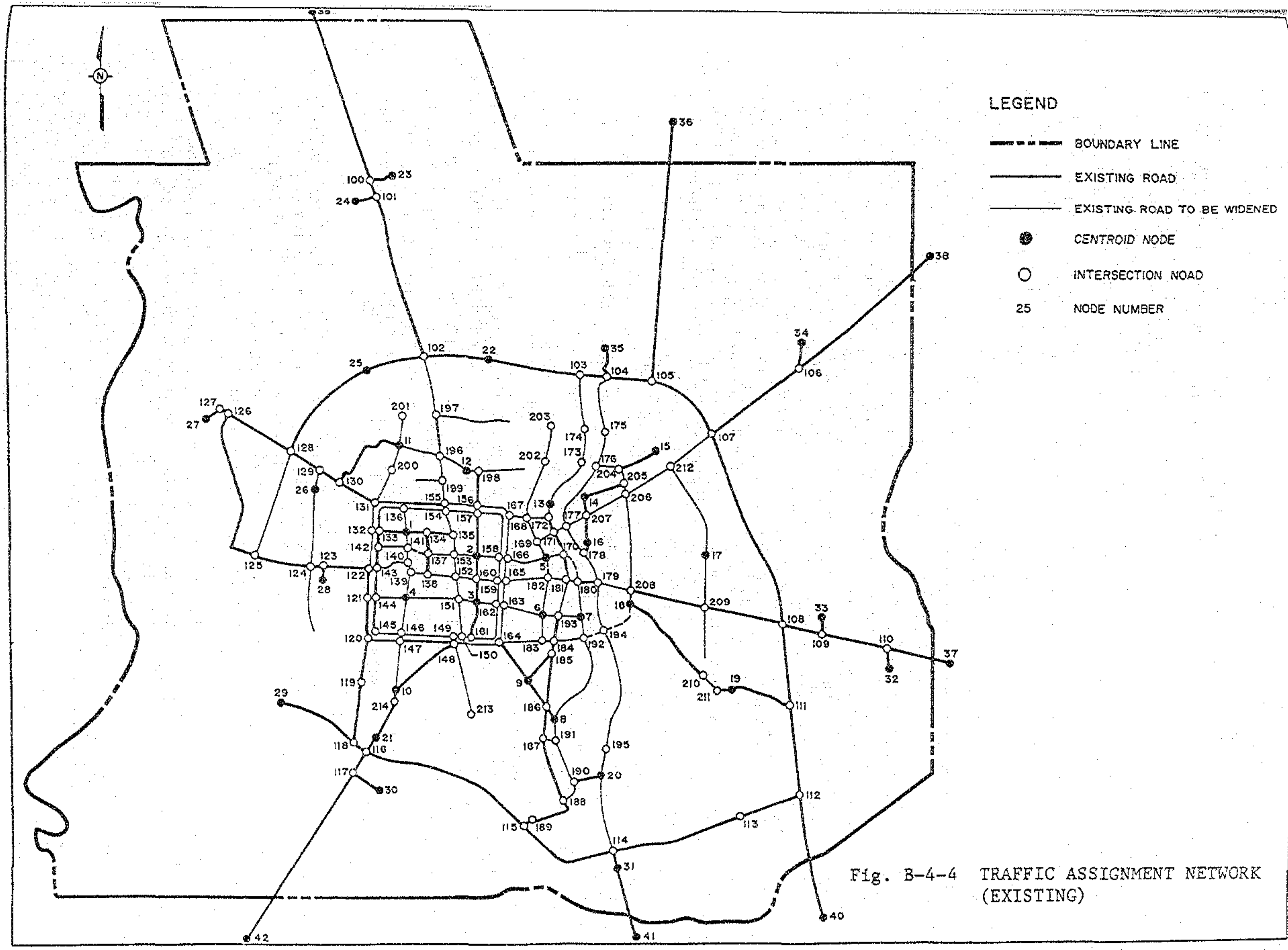


Fig. B-4-4 TRAFFIC ASSIGNMENT NETWORK (EXISTING)

Table B-4-5 Q/V CLASSIFICATIONS USED IN THE CHIANG MAI TRAFFIC ASSIGNMENT

Q/V Category Number	Qmax (PCU/direction/hr)	Vmax (Kph)	Vmin (Kph)
1	800	40	4
2	1200	50	4
3	1600	60	4
4	3600	80	4
5	5400	80	4

The forecasted O-D matrix was loaded on the existing network to examine whether it would be possible to handle future traffic demand with the "do-nothing" option. The calculations were performed with both the capacity-constrained and the all-or-nothing approaches. The results from the former approach showed that the capacity of the existing network was too low to accommodate future travel demand, indicating that network improvement is necessary to accommodate future demand. Three alternative plans were formulated, each representing varying levels of improvement. Descriptions of the three alternatives are presented in Table B-4-6. A capacity-constrained assignment was performed for the three alternative plans.

Table B-4-6 ALTERNATIVE PLANS FOR NETWORK IMPROVEMENT

Alternative Plan	Description
I	- 78.1 km of new road would be built. Most of the proposed links would form additional ring roads. In addition, a "semi-ring-road" is proposed around the expected commercial development along Route 1006. Also, street widening was proposed. - Six new bridges crossing the Ping River are proposed.
II	- 73.3 km of new roads would be built but a more complete multi-ring road pattern would be pursued compared with alternative I. A "semi-ring-road" along Route 1006 was dismissed in this case. - Six bridges are proposed.
III	- An outer ring road is proposed in addition to alternative II. The new roads would add 86.0 km to the existing network, 12.7 km more than in alternative II. - Eight new bridges are proposed.

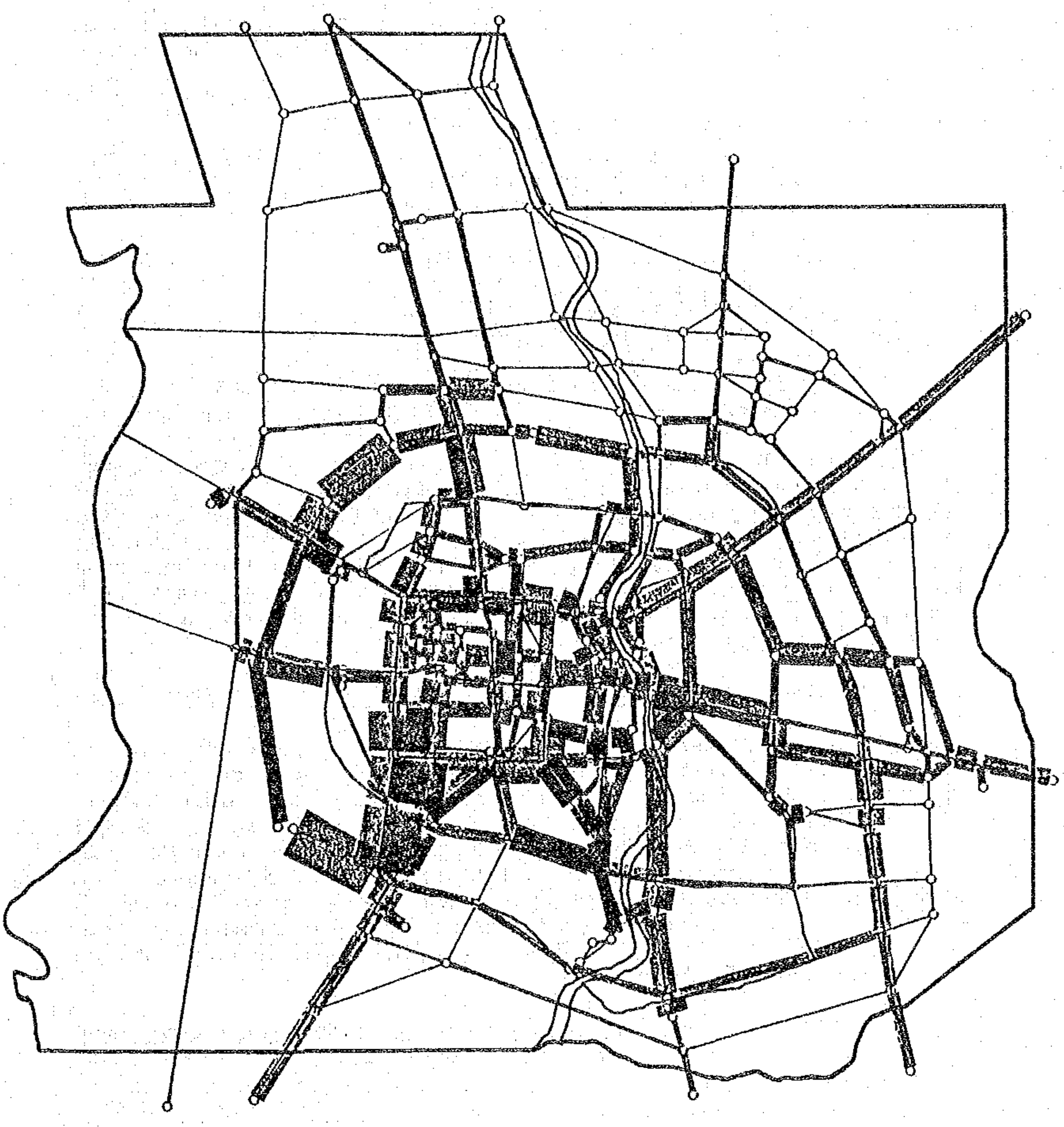


Fig. B-4-5 GRAPHIC REPRESENTATION OF TRAFFIC ASSIGNMENT RESULT (CHAING MAI)

Network Evaluation

Most basic evaluation indices were calculated based on the traffic assignment for the three alternative network patterns. The indices used were:

- total vehicle kilometers (km);
- average trip length (km);
- total vehicle hours (hours);
- average travel time (min);
- total vehicle operating cost (baht/hour);
- unit operating cost (baht/trip);
- average speed (km/hour);
- number of links with V/C >.7;
- number of links with V/C >.9;
- average V/C ratio;
- additional road sections to be constructed (km); and
- number of bridges across the Ping River.

The relative advantages and disadvantages of the alternatives were discussed based on these indices, and the final road network plan was selected by modifying Alternative II. The modification was made with the aid of computer graphics produced by an X-Y plotter based on the traffic assignment result (Figure B-4-5). These graphics can show visually the magnitude of traffic volume and congestion levels (by V/C ratios), thereby providing valuable information for the preparation of a transport network plan.

THE THA MAI CASE STUDY (THE USE OF THE CLASSIFICATION RECORDER)

The automatic counter made available for the case study was the TrafiCOM 241 Classification Recorder (produced by Streeter Richardson), which has the capability of recording the traffic volumes of 13 different vehicle classes. It can also measure spot speeds and record and classify them by six speed classes. All recording was performed in the recorder's internal memory, which has a capacity of 64 K-bytes; under normal recording conditions (a 15-minute interval, 8 vehicle classes, 1 direction), the machine can store information for a continuous count of up to 52 days. [1] The specifications of the machine are shown in Table B-4-7.

The magnetically stored data can be retrieved directly by a computer and analysis can then be performed immediately. The major study items were:

- checking the accuracy of the vehicle classification function (a manual survey was also conducted to count the same traffic stream for comparison purposes);
- evaluation of the advantages and disadvantages of the equipment; and
- assessment of the improvement in efficiency compared to manual counting.

[1] Note that this may exceed the life of a rechargeable battery.

Table B-4-7 MAJOR SPECIFICATIONS OF THE CLASSIFICATION RECORDER USED IN THE THA MAI CASE STUDY

Item	Features
Size and Weight	6.5 x 9.5 x 10 inches (16.5 x 24.1 x 25.4 cm) and 15 lbs (6.8 kg), including batteries and detectors
Functions	Volume counting and speed, length, vehicle type, and headway (or gap) classification. Any three classifications (or any two related to lane or direction) may be related and recorded simultaneously
Power Source	One 10-ampere-hour, 6-volt battery
Temperature	- 40 F to 158 F (-40 C to 70 C)
Maximum Count Rate	20 counts per second, 150 vehicles per minute, 9,999 vehicles per count period
Memory Storage	32K bytes standard, 64K optional
Recorder Connectors (some optional)	- connector for printer or computer - connector for 4- and 8- loop detectors - connectors for up to 8 external detectors or up to 8 piezo sensors - 2 air switch nipples for roadtubes (4 on special order)
Controls and Displays	1-16 key keyboard 1-32 character alpha numeric LCD display
Output	Baud rate user (selectable 300 to 9600)

Vehicle Classification Counting Experiment

The machine was installed on a road section near the town center of Tha Mai, where the traffic volume is relatively low (around 300 vehicles/hour) but where a sufficient mix of vehicle types is present. Several methods of connecting the two types of detectors are available depending on the combination of loop and tube detectors and their placement. The most basic arrangement is the use of two tubes, which while easy to install can also perform most of the functions listed in Table B-4-7. A few combinations involving loop detectors were tested but the classification accuracy was no better than for the more practical arrangement using two tube detectors. [1] The classification

[1] The manufacturer suggests two loops and one tube for the most accurate arrangement.

experiment was conducted by using this arrangement of detectors for one hour along with the manual counts using eight vehicle types (see Table B-4-8). The analysis was performed with a portable computer, with the recorded data retrived directly from the counter.

Table B-4-8 VEHICLE TYPES USED IN THE CLASSIFICATION EXPERIMENT

Category No.	Vehicle Type	Wheel Base (Meters) 1-2	Wheel Base (Meters) 2-3
1.	Motorcycle, Tuk-Tuk	0.03-1.83	
2.	Passenger Car, Pickup	1.86-3.11	
3.	Minibus, Light Truck	3.14-3.96	
4.	Heavy Bus	6.10-12.19	
5.	Bus, 6-Wheel Truck	3.99-7.01	
6.	10-Wheel Truck	1.86-7.01	0.03-1.83
7.	Trailer	More Than 3 Axles	
8.	Unclassified Vehicles		

[1] The manufacturer suggests two loops and one tube for the most accurate arrangement.

APPENDIX B-5

URBAN FACILITIES PLANNING CASE STUDIES

APPENDIX B-5

URBAN FACILITIES PLANNING

Drainage/Sewerage

CASE STUDY I (CHIANG MAI)

Present Conditions

Generally, the Chiang Mai study area consists of lowlands bisected by the meandering Ping River, which divides the city into the East and West Banks. The West Bank is characterized by a gradual downward slope from the foot of the nearby mountain to the river bank; the East Bank is less precipitous and lower in altitude.

The Natural Drainage System

The West Bank occupies the terrain adjoining Doi Suthep, with the Mae Taeng irrigation canal flowing from north to south. Three natural streams--the Mae Kha, the Mae Tha Chang, and the Lam Khu Wai--connect one another and serve as the city's principal drainage system. The Mae Kha Canal is the most important canal in the system; the Mae Tha Chang, Lam Khu Wai, and most of the wastewater from the West Bank flow into it. In addition, the old city moat serves a drainage function, receiving water from the irrigation canal and then releasing it to irrigate the farmland in the southern part of city.

The East Bank of the Ping River has many natural drains but they are mostly small and shallow. The principal drain of this area is the Muang Rin, which flows from north to south parallel to the Ping River.

Catchment Areas

The catchment areas are shown in Figure B-5-1. The catchment areas on the West Bank of the Ping River are divided into two parts by the Mae Taeng Irrigation Canal. The catchment area west of the Mae Taeng is located on the Doi Suthep ranges. The flood water produced by these catchment areas are not allowed to drain into the Mae Taeng. These discharges are drained into the principal drainage system through culverts, siphars, and flumes that connect the catchment areas on the West Bank with areas along the Mae Taeng. The eastern catchment areas of the Mae Taeng are normally flatter in slope than the western ones. The flood flows of these areas are drained directly into the principal drainage system, except for the areas in the city in which water is drained through the drainage/sewerage network before being discharged into the principal drainage system. The central catchment area for the Mae Kha Canal is 29.1 square kilometers. The catchment area for the irrigation canal is 54.6 square kilometers.

On the East Bank of the Ping River, seven major catchment areas with a total area of 9 square kilometers were identified from a topographic map. These areas drain run off into the Muang Rin.

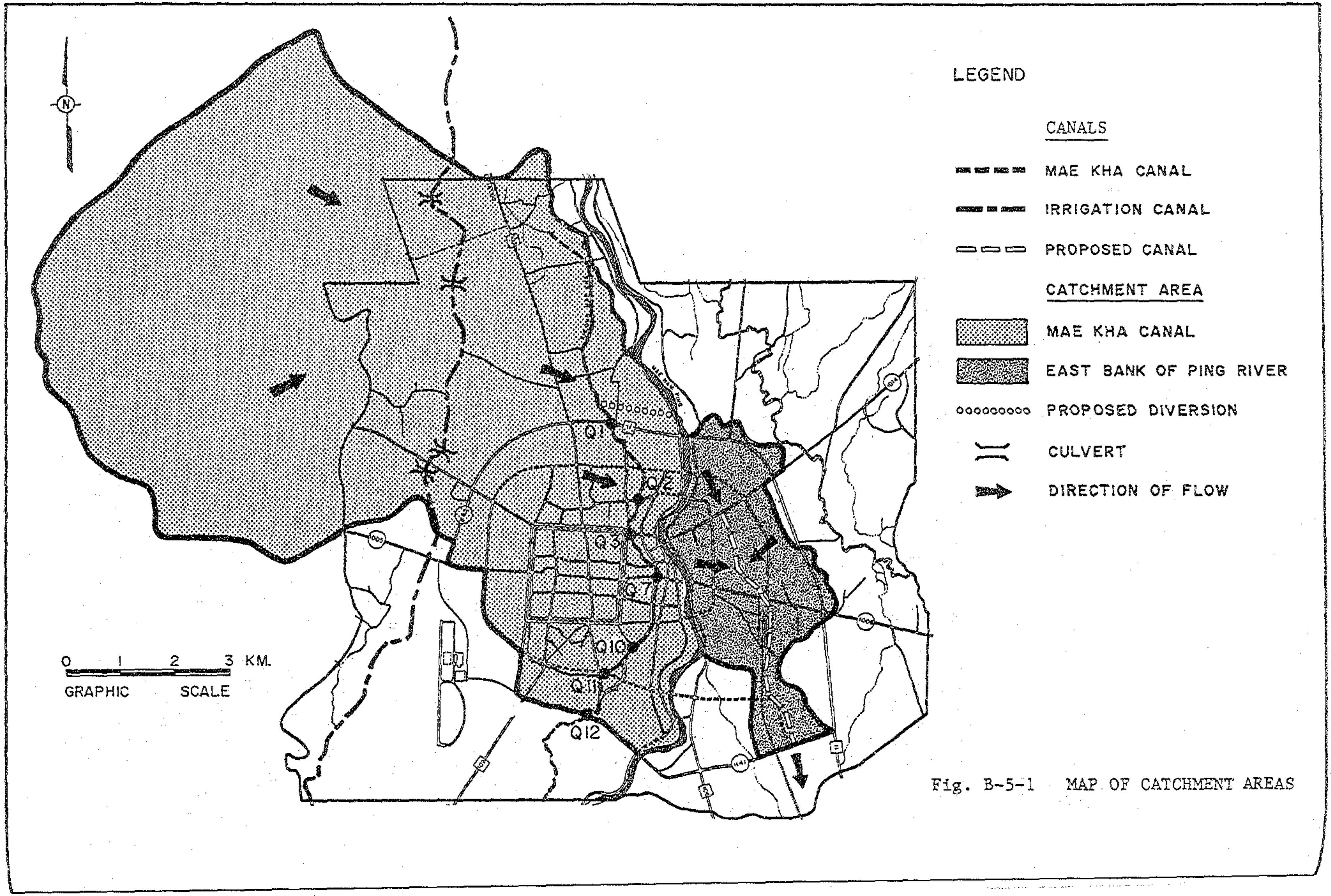


Fig. B-5-1 MAP OF CATCHMENT AREAS

Drainage/Sewerage Network

At present, the drainage system in the city of Chiang Mai is a combined system that drains rainwater and wastewater. A detailed description of the Chiang Mai drainage system is shown in Figures B-5-2 and B-5-3. The size of the drainage pipes are 0.50 m, 0.60 m, 0.80 m, and 1.00 m; the rest of the system uses an open channel with a cover. Wastewater is not treated but drained directly in the Khlong Mae Kha and Ping River.

Flood Area

The flood area is shown in Figure B-5-2. The inundation time is rather short, from one to five days. The principal causes of flooding are the flood routing from the Ping River, the Mae Kha, the Mae Tha Chang, the Lam Khu Wai, and seasonal overflows from storms in the city.

Financial Condition

The financial condition of Chiang Mai Municipality is shown in Figure B-5-4. From 1979 to 1986, Chiang Mai Municipality had revenues of 103,462,918.28 and expenditures of 93,878,022.85 baht per year on average. Revenues exceeded expenditures by 9,584,895.43 baht per year.

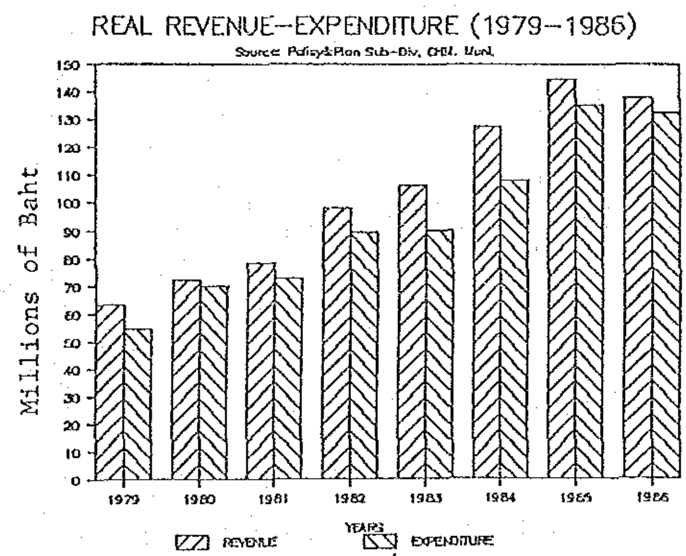
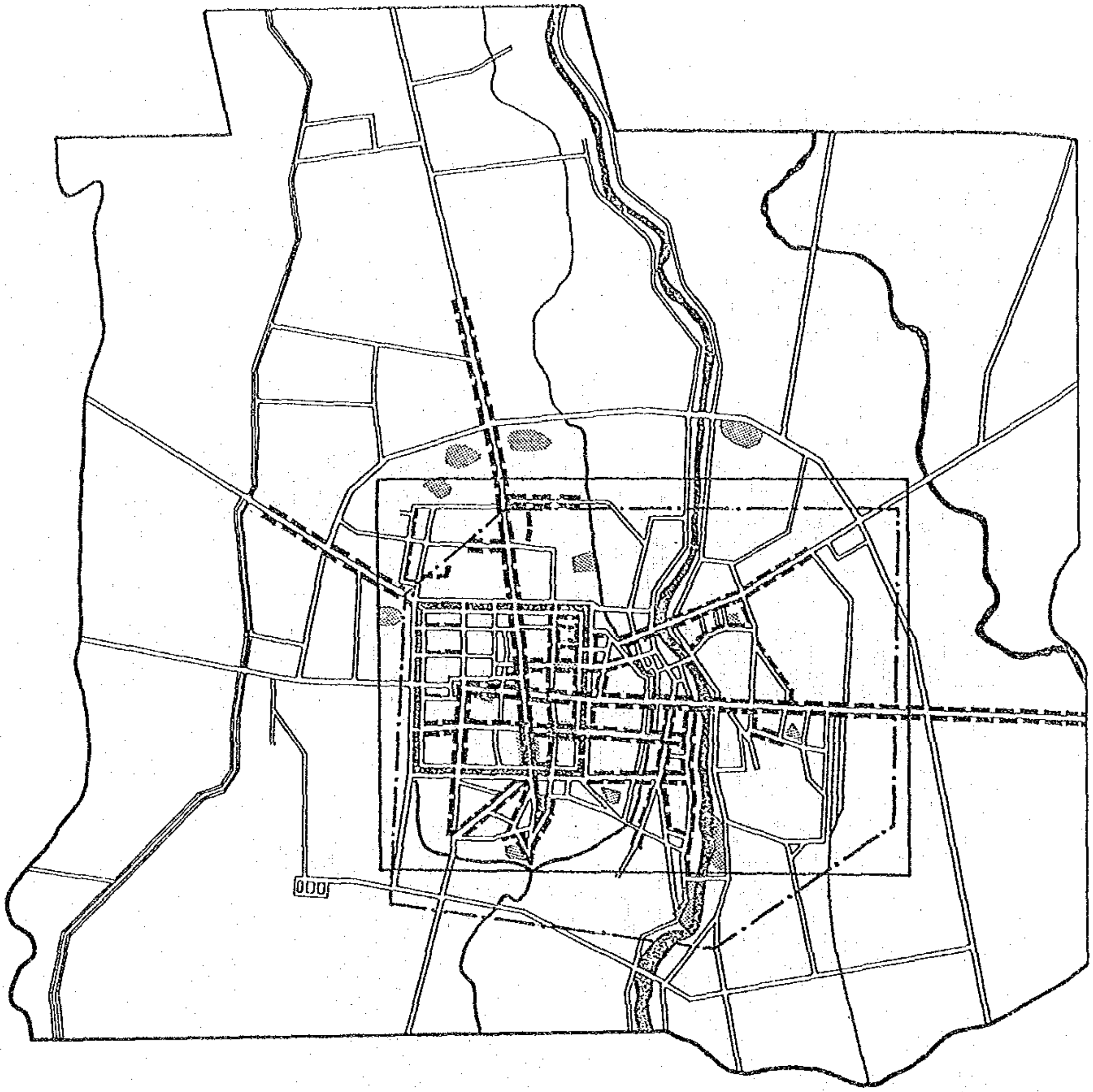


Fig. B-5-4 THE BUDGET OF CHIANG MAI MUNICIPALITY (1979-1986)



LEGEND

DRAINAGE LINE

MUNICIPAL BOUNDARY LINE

FLOOD AREA

INSET AREA (SEE Fig. B-5-3)

Fig. B-5-2 DRAINAGE SYSTEM

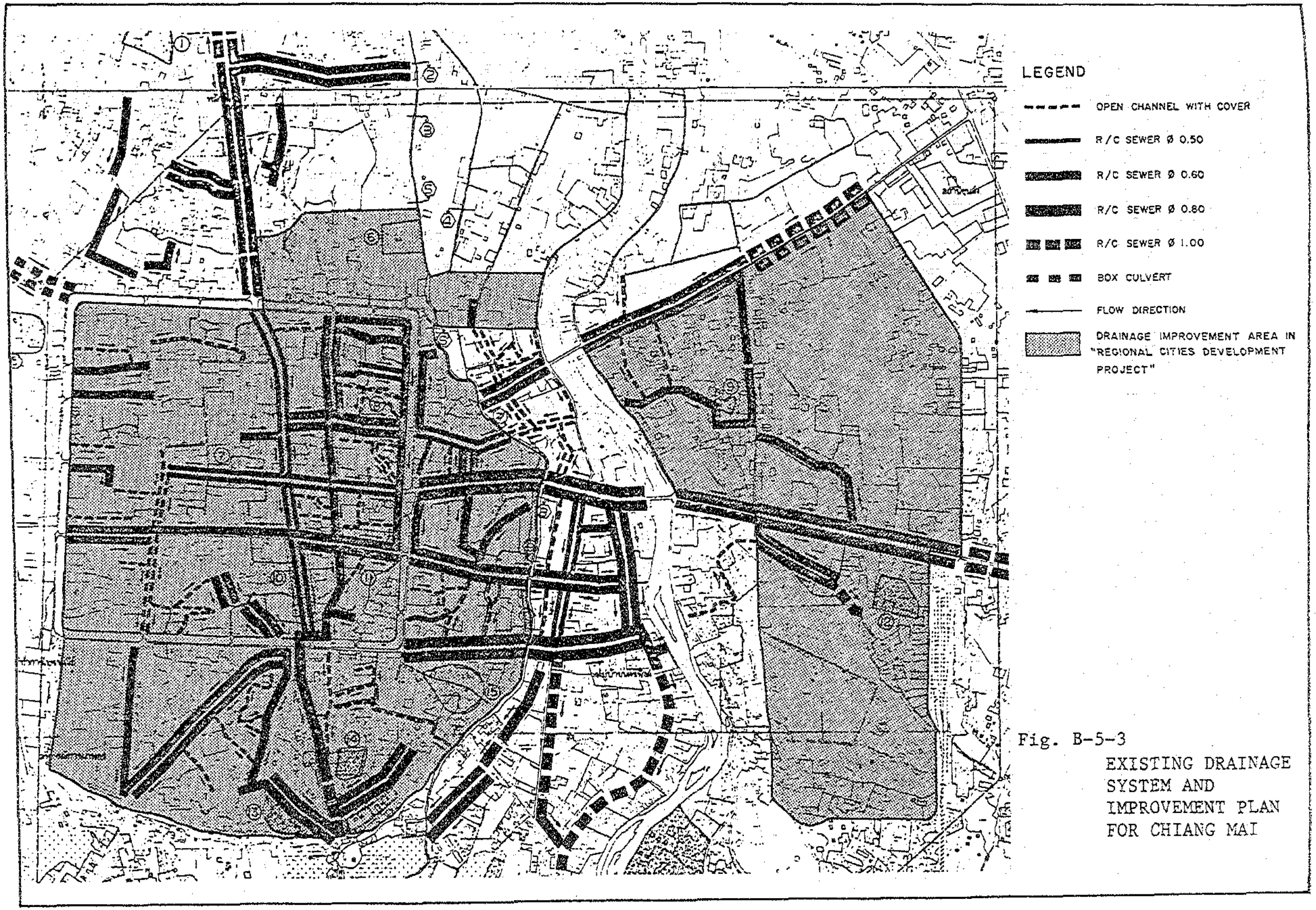


Fig. B-5-3
EXISTING DRAINAGE SYSTEM AND IMPROVEMENT PLAN FOR CHIANG MAI

Table B-5-1 shows the utility budget as a proportion of total expenditures. It indicates that about three to five percent of the municipality's expenditures are in the utilities sector.

Table B-5-1 CHIANG MAI'S UTILITY BUDGET AS A PROPORTION OF TOTAL EXPENDITURES

YEAR	TOTAL BUDGET	UTILITY BUDGET	PERCENT
1986	67287512.80	3173411.76	4.72
1987	75736853.51	3427824.70	4.53
1988	85628436.95	3701467.48	4.32
1989	97224017.48	3997584.88	4.11
1990	110853952.28	4317391.67	3.89
1991	126835740.45	4662783.01	3.68

Problem Identification

Drainage/Sewerage Network Problems

A comparison of the quantity of drainage water with the flow capacity of the pipes showed that most of pipes were inadequate. Many pipes are too small and their slope is insufficient. Further, the drainage system network is incomplete. Some pipes are not connected to the main drains, with floods caused as a consequence. The existing drainage system is shown in Figure B-5-2 and B-5-3.

Flooding and Drainage System Program

After heavy rains, flood problems arise in some areas as a result of the inadequate drainage system. Many pipes are too small and are therefore unable to drain water in time to prevent a flood. The overflowing Ping River and Mae Kha Canal add to the flooding. Such floods damage property and cause transportation problems. Further, because of the city's combined drainage system, any overflow may be unsanitary. However, Chiang Mai now has plans to solve these problems by improving the city's drainage system, as shown in Table B-5-2. In addition, with regard to the Ping River, the Royal Irrigation Department has planned several upstream development projects (e.g., the Mae Ngad dam) that will decrease flood problems in Chiang Mai.

Unfortunately, there is no comprehensive urban drainage/sewerage plan for the city. Such a plan would assign priorities to sewer construction projects, thereby facilitating budgetary planning.

Table B-5-2 PLANNED DRAINAGE/SEWERAGE AND FLOOD CONTROL PROJECTS

Project	Year			
	1988	1989	1990	1991
1. Construction of sewers and footpaths on Praprock Klaow Road	*			
2. Construction of sewers and footpaths, an expansion of Thung Hotel Road	*			
3. Improvement and expansion of roads, sewers, and footpaths on Kawonawarut Road	*			
4. Mae Kha Improvement (Phase I)	*			
5. Mae Tha Chang Improvement				*
6. Muang Rin Improvement				*
7. Construction of the Mae Kha diverting canal (Phase II)		*	*	*

Water Pollution

In the dry season (from November to April), water pollution is a problem in the Mae Kha Canal, which flows through densely populated sections of Chiang Mai. This problem results from the use of the canal to move untreated water out of the city. Since Chiang Mai has a combined drainage system, the wastewater that flows into Mae Kha Canal is not purified sufficiently during the dry season. As indicated in Table B-5-2, plans have been made to improve the Mae Kha Canal, the objective being to provide sufficient water from the irrigation system (e.g., from the Mae Thang Irrigation Canal or the Mae Ngod Dam) to flush out the putrid water. However, since the water from the irrigation system is provided principally for agriculture, at times there is no reserve for other purposes. In the future, a study of the feasibility of establishing a wastewater treatment plant should be conducted.

Demand Forecast

The peak discharges at various points of the Mae Kha Canal were estimated and are shown in Table B-5-3. The population of the area that discharges into the Mae Kha Canal is projected to be approximately 200,000 in 2007. Assiming liters of wastewater per day per capita is discharged, the total quantity of sewage produced would be 0.46 cubic meters per second (0.2 x 200,000 / 24 / 3,600).

Table B-5-3 ESTIMATED PEAK DISCHARGES INTO THE MAE KHA AFTER DIVERSION TO THE PING RIVER

Location	Peak Discharge (m^3/s)	
	2-year period	5-year period
Q1	9.59	13.39
Q2	18.74	24.68
Q3	20.69	26.37
Q4	20.69	26.37
Q5	20.69	26.37
Q6	20.69	26.37
Q7	20.69	26.37
Q8	20.69	26.37
Q9	20.69	26.37
Q10	23.58	30.06
Q11	30.17	38.41
Q12	30.17	38.41

Goals and Objectives

Goals

The goals related to the drainage/sewerage network are the following:

- to establish an appropriate drainage/sewerage/flood control system based on a comprehensive plan;
- to improve environmental quality, to promote tourism, and to protect the city's water resources; and
- to prevent drainage problems in future growth areas.

Objectives

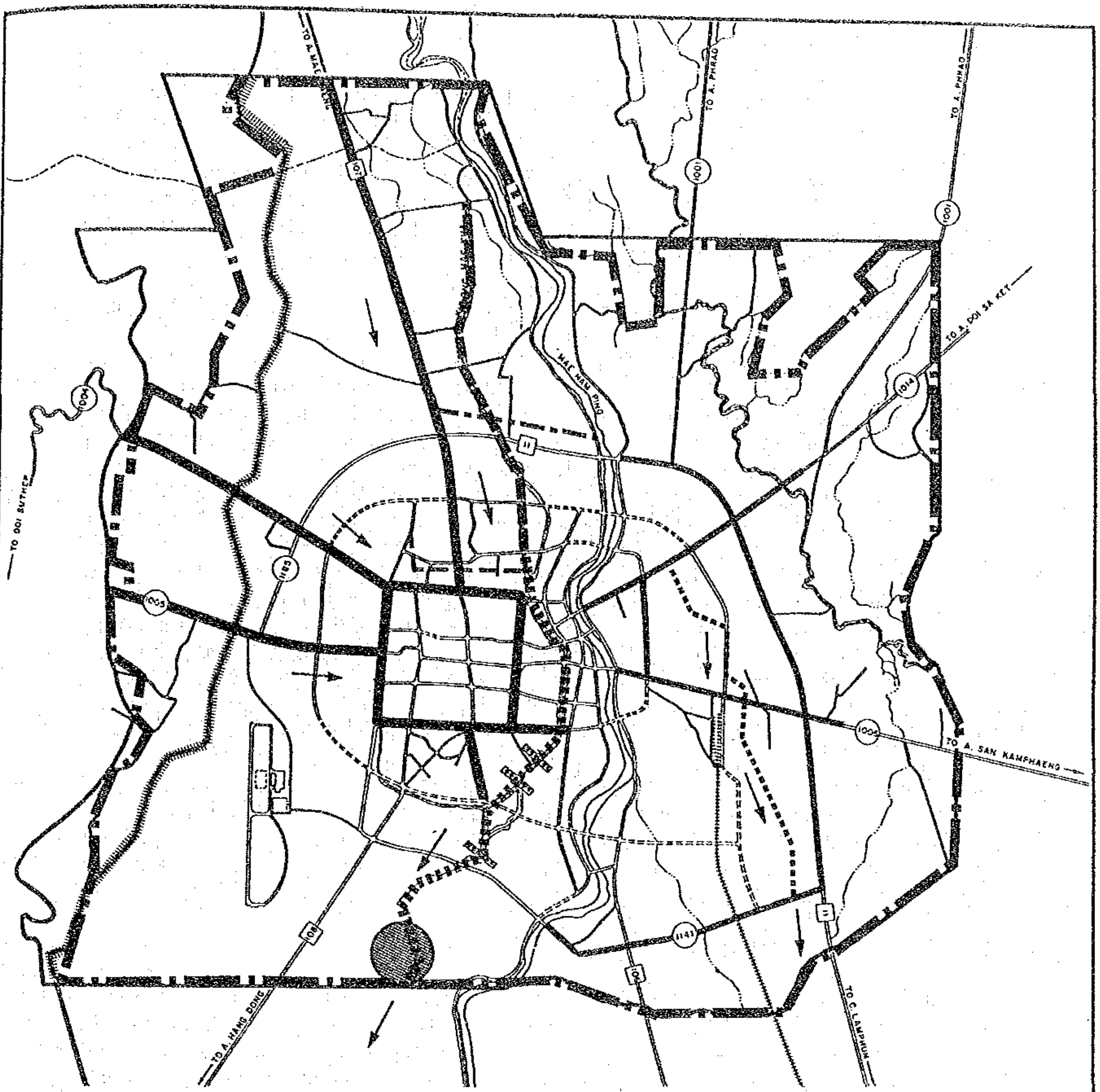
In order to reach the goals mentioned above, the following objectives were set:

- to expand the service area of the drainage network;
- to develop the drainage/sewerage system;
- to study the feasibility of a wastewater treatment system; and
- to acquire the budgetary resources to implement these plans.

Recommendations

The following recommendations were made by the Study Team:

- Detailed studies of improvements to the drainage/sewerage system (see Figure B-5-5) should be based on the latest land use and transportation data and plans.



LEGEND

- IMPROVEMENT OF MAE KAH CANAL WITH SEWER (RCD)
- EXISTING MAE KAH CANAL
- EXISTING IRRIGATION CANAL
- PROPOSED MAIN SEWER
- IMPROVEMENT OF CANAL (RCD)
- PROPOSED DRAINAGE
- IMPROVEMENT WITH SEWER (RCD)
- PROPOSED DIVERSION (RCD)
- PROPOSED WEIR (RCD)
- DRAINAGE / SEWERAGE SYSTEM BOUNDARY
- SUGGESTED TREATMENT PLANT LOCATION

Fig. B-5-5 PROPOSED DRAINAGE/SEWERAGE SYSTEM

- A sewage treatment plant should be constructed. The location suggested in Figure B-5-5 is at the southern end of the Mae Kha Canal.
- The authorities should strictly control industrial wastewater. The comprehensive plan calls for industrial firms to locate in the same area, making it possible to establish a plant for treating industrial wastewater and charging the firms for the service.
- An adequate budget maintaining and cleaning the drainage/sewerage system should be provided.
- Sewers should be cleaned during the dry season to improve the efficiency of flushing out wastewater during this period.
- At the southern end of the moat, landfill is required before the drainage system can be improved because land levels are lower than the level of the main drain.
- Drainage/sewerage system improvement should be divided into zones, and a phased implementation plan should be formulated based on the priority of the improvements.
- Budgetary resources will be required to implement the plan. The Municipality can provide the monies necessary to implement improvements within its boundaries, but it will be necessary to find supplementary budgetary resources to implement the comprehensive plan outside of the Municipality's boundaries.

CASE STUDY II (PHOTARAM)

The case study area (Figure B-5-6) was selected to cover only part of the plan area because time was limited. The case study focused on the application of computer-assisted technical methods. The study was divided into two parts, one for the measurement of drainage areas and the other for sewer design.

Measurement of Drainage Areas

A special program to reduce the time and increase the accuracy of the measurement of drainage areas was introduced. The program is described in detail in the mapping technical manual, in the sections on cartographic data processing and operational procedures. Sample output from the program is shown in Table B-5-4.

The drainage area measurement program has several advantages. It allows for more efficient measurement, especially for linear figures. In addition, accuracy is increased and the results are printed in an orderly fashion.

However, the drainage area measurement program has some disadvantages. The starting procedures are time-consuming, and the equipment required is much larger and heavier (and therefore less portable) than a digital planimeter.

Sewer Design

In the sewer design process, the size and inclination of pipes or conduits should be optimized depending on conditions such as rainfall intensity, flow velocity, and slope. Using "Lotus" software, a sewer

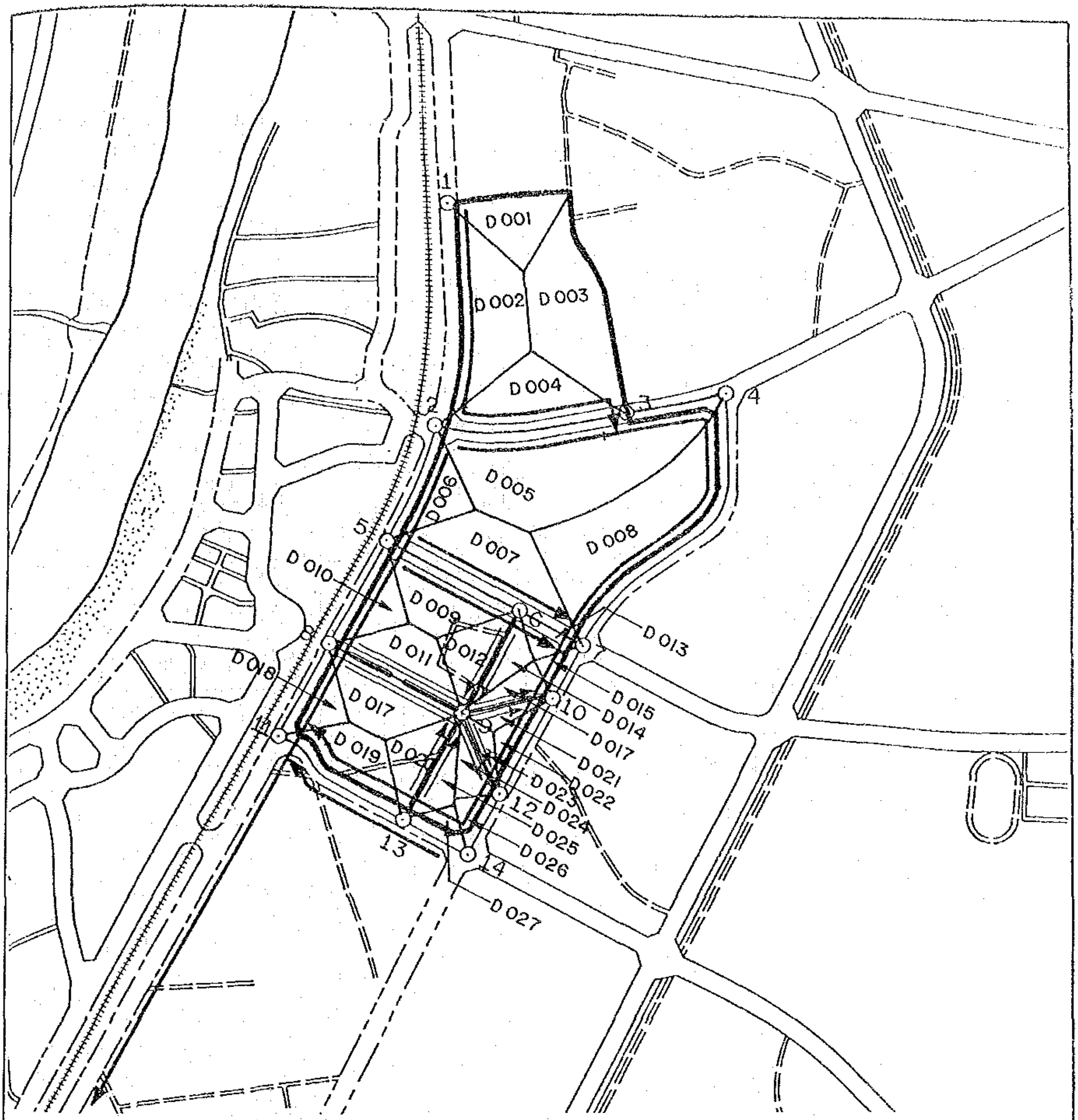


Fig. B-5-6 THE CASE STUDY AREA

Table B-5-4 OUTPUT OF AREA MEASUREMENT PROGRAM

2

Name	Area sq.km.	rai
d001	0.01155273	7.22
d002	0.03316797	20.73
d003	0.02975843	18.60
d004	0.02392822	14.89
d005	0.03641263	22.76
d008	0.04661318	29.13
d028	0.02726180	17.04
d029	0.19236260	120.23
d030	0.19115570	119.47
d031	0.04190832	26.19
d005-1	0.02435256	15.22
d005-2	0.01263195	7.89
d007-1	0.00039683	0.25
d007-2	0.00833879	5.21

3

Name	Area sq.km.	rai
d005-1	0.01612660	10.08
d007-1	0.02505989	15.66
d012	0.00708387	4.49
d006	0.01276709	7.98
d010	0.00177114	1.11
d011	0.01166708	7.29
d017	0.01492345	9.33
d018	0.00586714	3.67
d019	0.01625531	10.16
d020	0.00871853	5.45
d013	0.00051811	0.32
d015	0.00206872	1.29
d016	0.00057704	0.36

design program was developed to rationalize and standardize the sewer design process. The computer program provides both for automatic calculation and simulation. The ground and pipe elevation of a section is also presented graphically for easy understanding. The structure of the program is shown in Figure B-5-7.

The sewer design program includes many instructions that facilitate the design process. The set of commands are shown in Figure B-5-8. When a command is selected, the computer can provide clear explanations of what the command can accomplish.

Results

Figure B-5-9 shows the land use and road network plans on which the sewerage system design was based. The design of the sewerage system in central Photaram is presented in Figure B-5-10. Table B-5-5 shows some sample sewer design programs. During the course of this study, a manual for the program was prepared and the data input process has been systematized.

Recommendations

The following improvements are suggested:

- A warning should be issued when a system is inadequate (e.g., when the velocity is over 3.0 m/s.)
- Sewerage data should be input directly, thereby saving one step in the process.
- A complete graphical display of ground and pipe elevations should be presented.

PARKS/RECREATION AREAS

CASE STUDY I (CHIANG MAI)

The city of Chiang Mai, with an area of 100 square kilometers, was the site of Case Study I. The recreation and parks facilities planning process that was applied is illustrated in Figure B-5-11.

Present Conditions

First, an inventory of all parks and recreation areas was made, with the facilities classified based on location, size, characteristics, and function. Most of the open space is located inside the municipal boundaries of Chiang Mai and its area is 2,238.8 rai, or 10.2 rai per 1,000 population. The open space includes the sports grounds of various educational institutions as well as temple lawns and grounds.

Figure B-5-12 presents an open space classification system, and Table B-5-6 lists guidelines for parks and recreation areas. Figure B-5-13 shows the distribution of parks and recreation facilities in Chiang Mai, with more detailed data presented in Table B-5-7.

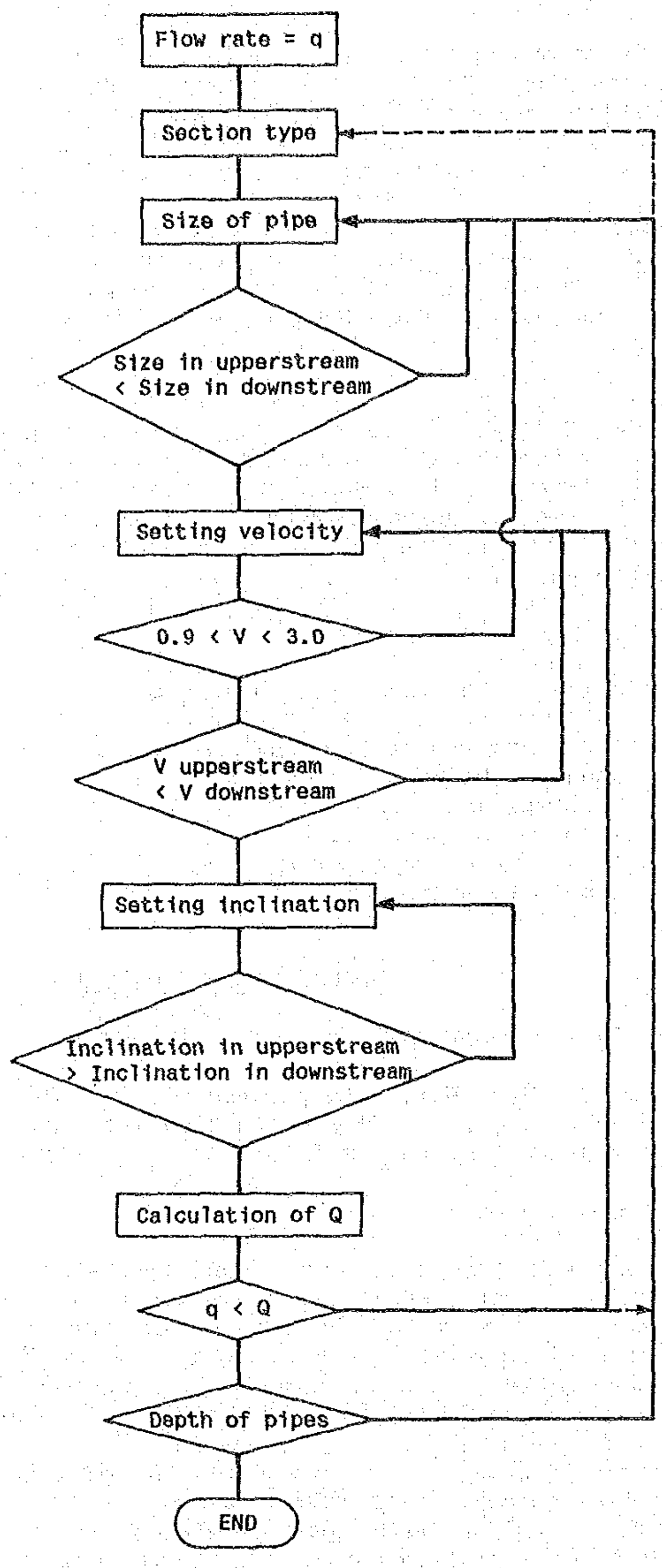


Fig. B-5-7 STRUCTURE OF PROGRAM TO DESIGN PIPING

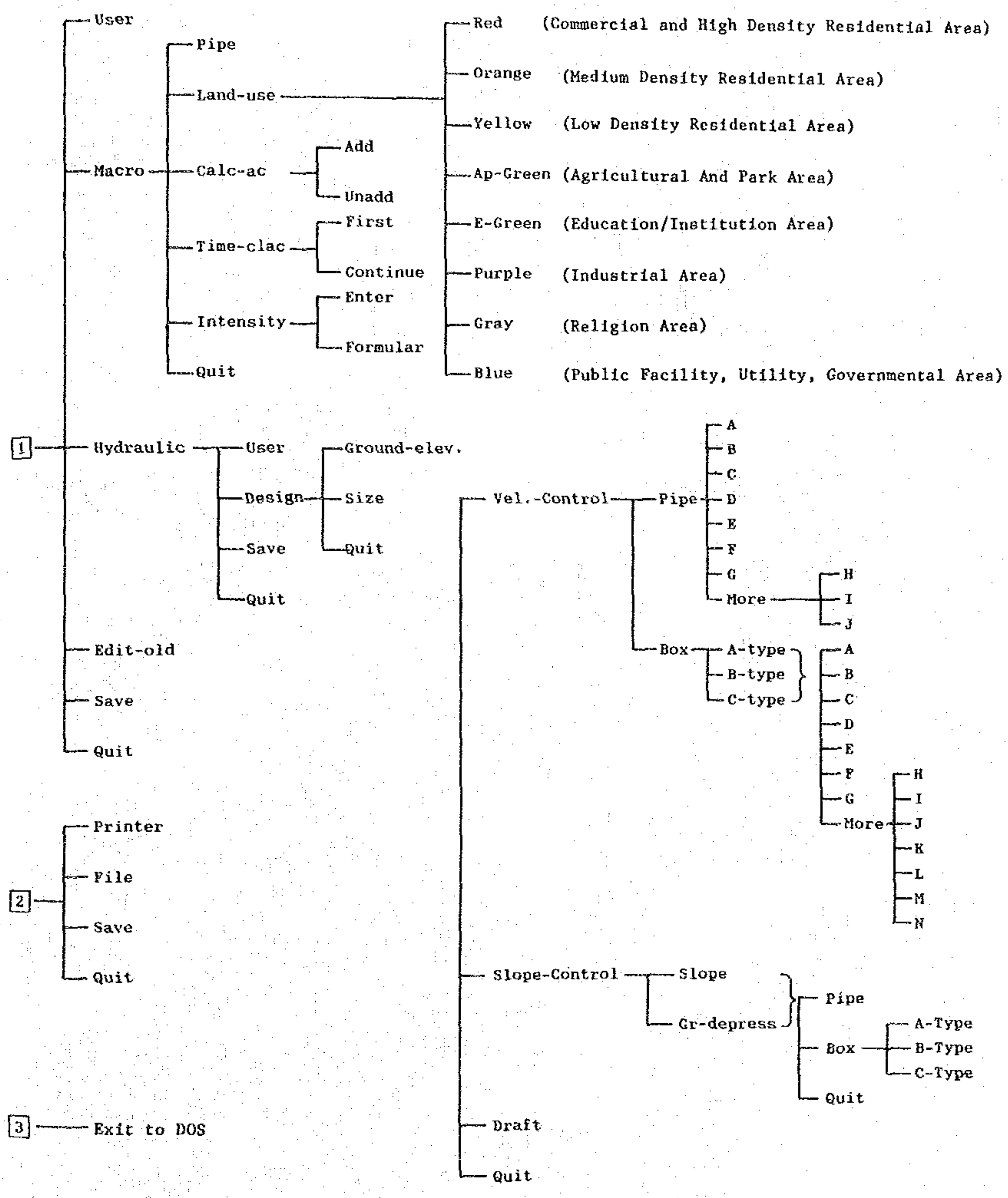


Fig. B-5-8 SET OF COMMANDS IN THE SEWER DESIGN PROGRAM

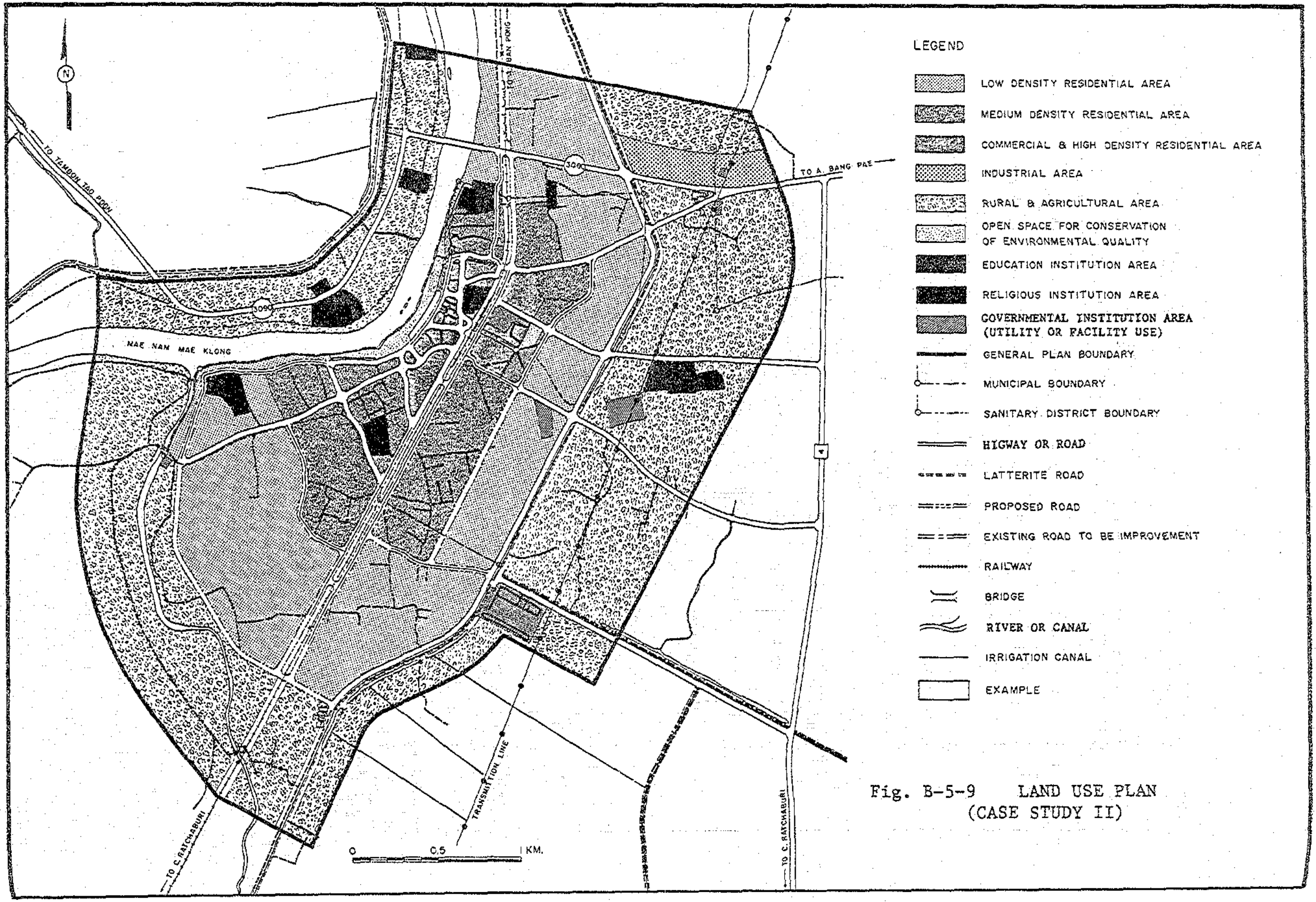


Fig. B-5-9 LAND USE PLAN (CASE STUDY II)

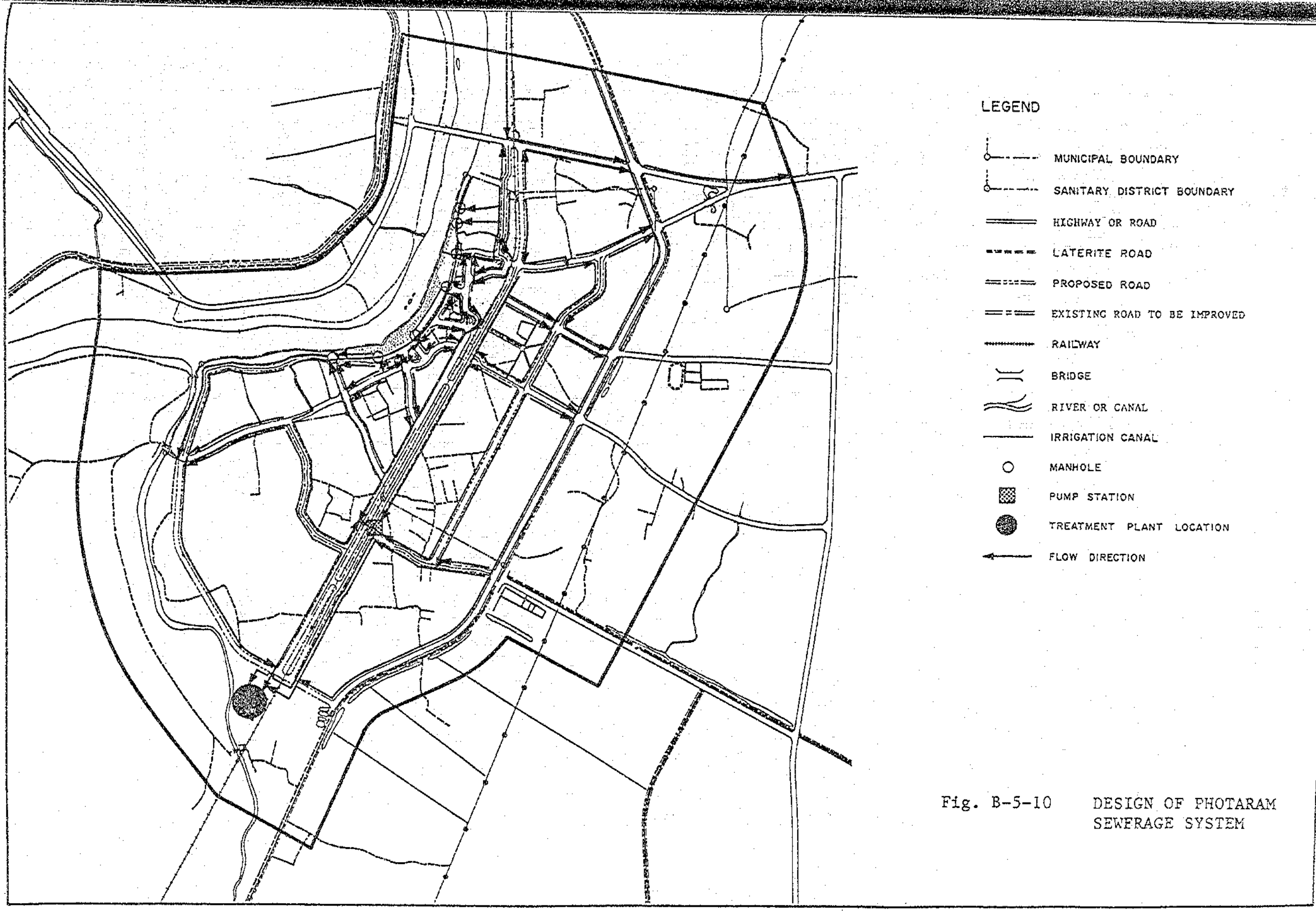


Fig. B-5-10 DESIGN OF PHOTARAM SEWERAGE SYSTEM

Table B-5-5 SAMPLE OUTPUT OF SEWER DESIGN PROGRAM

ROW NO.	PIPE NAME	LENGTH (m.)	AREA: AREA [a] (sq. km.)	AREA: LAND USE.	AREA: C [c] (coef.)	AREA: RETURN PERIOD	AREA: ac	AREA: Σ ac	TIME (min.): t	TIME (min.): T	INTENSITY (mm./hr.): i	RUN OFF (cms.): Q	STROM DRAIN: PIPE DIA.	STROM DRAIN: RECTANGULAR CONDUIT	HYDRALIC DESIGN: V	HYDRALIC DESIGN: S	HYDRALIC DESIGN: Q (design)	PROFILE: h	PROFILE: GROUND ELEV. upper	PROFILE: GROUND ELEV. lower	PROFILE: INVERT ELEV. upper	PROFILE: INVERT ELEV. lower
1	7R10	90	0.04377	red	0.575	5	0.02517	0.02517														
2		90	0.01469	blue	0.400	5	0.00587	0.03104														
3		90	0.00313	ap_green	0.300	2	0.00094	0.03198														
4		90	0.19064	orange	0.500	2	0.09532	0.12730	2	36	68.4	2.419		1.50x1.50	1.1	0.10	2.50	0.090	6.618	6.715	4.306	4.246
5	10R12	200	0.06320	red	0.575	5	0.03634	0.03634														
6		200	0.02745	blue	0.400	5	0.01098	0.04732														
7		200	0.01355	ap_green	0.300	2	0.00407	0.05139														
8		200	0.19064	orange	0.500	2	0.09532	0.14671	4	40	64.8	2.607		1.50x1.50	1.2	0.12	2.70	0.242	6.715	6.453	4.246	4.206
9	12R14	90	0.07192	red	0.575	5	0.04135	0.04135														
10		90	0.04061	blue	0.400	5	0.01624	0.05760														
11		90	0.01355	ap_green	0.300	2	0.00407	0.06166														
12		90	0.19064	orange	0.500	2	0.09532	0.15698	2	42	62.8	2.734		1.50x1.50	1.3	0.12	2.90	0.126	6.453	6.453	4.086	3.880
13	14R13	120	0.07192	red	0.575	5	0.04135	0.04135														
14		120	0.04434	blue	0.400	5	0.01774	0.05909														
15		120	0.01355	ap_green	0.300	2	0.00407	0.06316														
16		120	0.19064	orange	0.500	2	0.09532	0.15848	2	44	59.7	2.626		1.50x1.50	1.2	0.12	2.70	0.144	6.453	6.558	3.880	3.736
17	13R11	250	0.06818	red	0.575	5	0.03920	0.05070														
18		250	0.04434	blue	0.400	5	0.01774	0.06844														
19		250	0.01355	ap_green	0.300	2	0.00407	0.07250														
20		250	0.19064	orange	0.500	2	0.09532	0.16782	3	49	56.8	2.611		1.50x1.50	1.2	0.12	2.70	0.322	6.558	7.545	3.736	3.426

ROW NO.	PIPE NAME	LENGTH (m.)	AREA: AREA [a] (sq. km.)	AREA: LAND USE.	AREA: C [c] (coef.)	AREA: RETURN PERIOD	AREA: ac	AREA: Σ ac	TIME (min.): t	TIME (min.): T	INTENSITY (mm./hr.): i	RUN OFF (cms.): Q	STROM DRAIN: PIPE DIA.	STROM DRAIN: RECTANGULAR CONDUIT	HYDRALIC DESIGN: V	HYDRALIC DESIGN: S	HYDRALIC DESIGN: Q (design)	PROFILE: h	PROFILE: GROUND ELEV. upper	PROFILE: GROUND ELEV. lower	PROFILE: INVERT ELEV. upper	PROFILE: INVERT ELEV. lower
1	1L2	370	0.03317	orange	0.500	2	0.01658	0.01658	15	15	107.7	0.496	0.80		1.0	0.19	0.50	0.703	0.000	0.000	-1.110	-1.820
2	2L3	380	0.05700	orange	0.500	2	0.02850	0.02850	6	21	93.1	0.737	0.80		1.7	0.54	0.84	1.620	6.736	7.121	7.616	5.996
3	2R3	300	0.02435	orange	0.500	2	0.01218	0.01218														
4		300	0.01613	red	0.575	5	0.00927	0.02145	15	15	128.3	0.765	0.80		1.7	0.54	0.84	1.620	6.736	7.121	7.616	5.996
5	3R4	160	0.01613	red	0.575	5	0.00927	0.00927														
6		160	0.13529	orange	0.500	2	0.06764	0.07692	5	24	86.8	1.837	1.20		1.7	0.32	1.91	0.512	7.121	7.204	5.496	4.984
7	4R7	520	0.01613	red	0.575	5	0.00927	0.00927														
8		520	0.18190	orange	0.500	2	0.09095	0.10022	10	34	78.9	1.974		1.50x1.50	0.9	0.07	2.02	0.348	7.204	6.818	4.684	4.336
9	5L6	240	0.00040	orange	0.500	2	0.00020	0.00020														
10		240	0.02506	red	0.575	5	0.01441	0.01461	15	15	126.3	0.521	0.80		1.2	0.27	0.59	0.636	7.563	6.946	6.463	5.827
11	6L7	110	0.02506	red	0.575	5	0.01441	0.01441														
12		110	0.00874	orange	0.500	2	0.00437	0.01878	2	17	131.8	0.531	0.80		1.2	0.27	0.59	0.292	6.946	6.818	5.827	5.536
13	5R6	240	0.01469	blue	0.400	5	0.00587	0.00587	15	15	128.3	0.209	0.50		1.1	0.43	0.21	1.032	7.563	6.946	6.763	5.731
14	6R7	110	0.01469	blue	0.400	5	0.00587	0.00587														
15		110	0.00052	red	0.575	5	0.00030	0.00617														
16		110	0.00313	ap_green	0.300	2	0.00094	0.00711	2	17	101.8	0.201	0.50		1.1	0.43	0.21	0.473	6.946	6.818	5.731	5.258
17	2L5	200	0.01277	red	0.575	5	0.00734	0.00734	15	15	126.3	0.262	0.50		1.4	0.78	0.27	1.400	6.736	7.563	7.916	6.516
18	5L8	200	0.01454	red	0.575	5	0.00836	0.00836														
19		200	0.00748	blue	0.400	5	0.00299	0.01135	4	19	117.4	0.370	0.60		1.3	0.49	0.37	0.930	7.563	7.736	6.416	5.486
20																						

ENGINEERING DIVISION

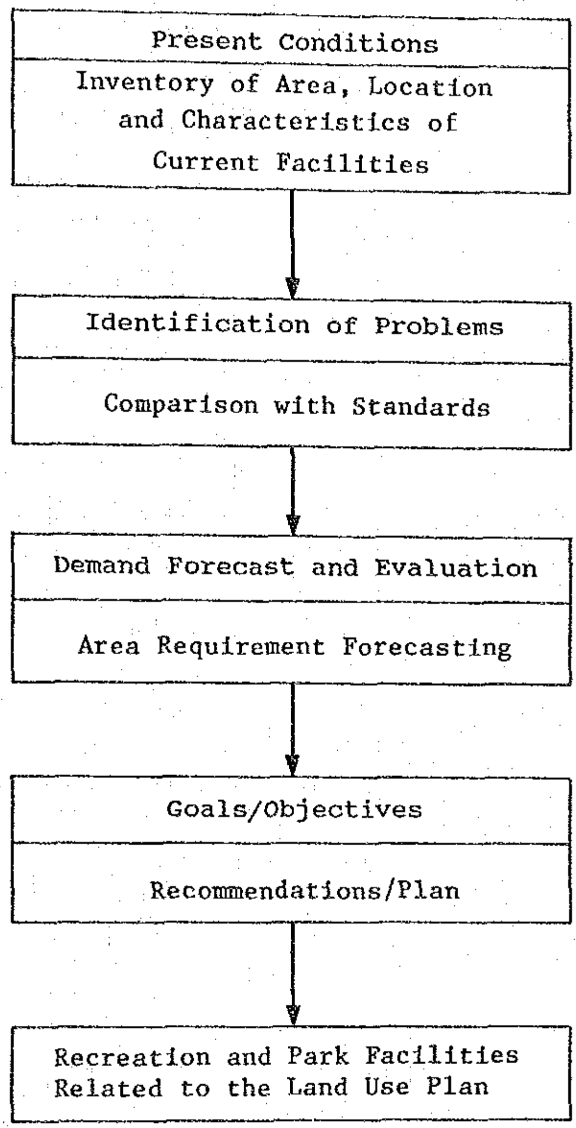


Fig. B-5-11 RECREATION AND PARK FACILITIES PLANNING PROCESS (CHIANG MAI CITY, CASE STUDY I)

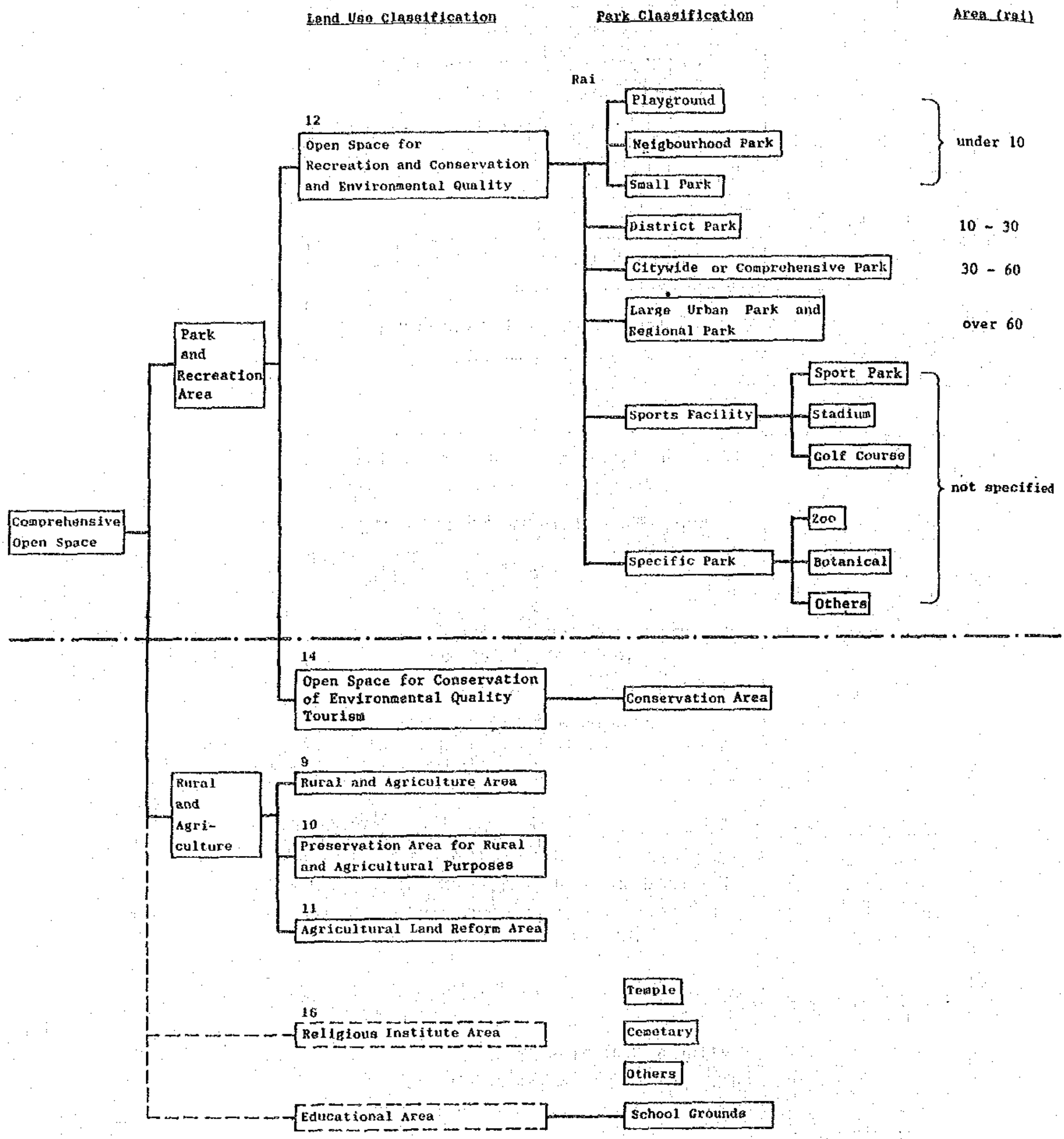


Fig. B-5-12 OPEN SPACE CLASSIFICATION SYSTEM

Table B-5-6 GUIDELINES FOR PARKS AND RECREATION AREAS

Park	Guideline: Characteristics	Guideline: Location
Playground, Neighbourhood Park, Small park	- Center of outdoor play for kindergarten; also offering some recreational opportunities for young people and adults. - Includes a playlot for pre-school children, an enclosed playground equipment area for elementary school children, an area for field games, circulation and buffer space, etc.	**Playground** - Should be readily accessible from and conveniently related to the housing area served. - Should be within 150 to 300 m of every family housing unit. **Neighbourhood Park** - Should be provided for each neighbourhood. - Located for easy access. - Near center of residential area, near or adjacent to other neighbourhoods.
District Park	- Serving persons of all ages in the community. - Designed to provide a wide variety of activities (e.g., area set aside for passive recreation such as picnicking and passive water sports.)	- Located in the center of the district and accessible to public transportation. - Site selection depends on various factors.
Citywide or Comprehensive Park	- Serving persons of all ages and whole city - Designed to provide a wide variety of activities both passive and active. (including sports facilities)	- Accessible to public transportation. - Sometimes serves as a buffer between residential and industrial areas.
Large Urban Park or Regional Park	- Serving persons of all ages and the whole region. - Designed to provide a wide variety of activities. - Present symbolism and attractiveness of the region.	- Accessible to public transportation.
Sports Park	- Provide various sports facilities such as stadiums, sports grounds, swimming pools and tennis courts.	- Should be close to the center of the population served.
Specific Park	- A park for a specific purpose, such as a zoological park, botanical garden or historical park.	- Variable.

Table B-5-7 CLASSIFICATION OF PARK AND RECREATION AREAS (CHIANG MAI CITY, CASE STUDY I)

Series	Type/Function	Categories	Existing Area (Rai)	Existing Area Sq.m.
1	Playground, Small Park or Neighbourhood Park	1.1 Pratu Tha Phae Public Park	3.3	5,280
		1.2 Pratu Tha Phae Children Playground	0.5	800
		1.3 Somphet Intersection Park	0.5	800
		1.4 Nawarat Bridge Park	1.4	2,240
		1.5 Pratu Chiang Mai Playground	0.2	320
		1.6 Three Kings Monument Mini Park	1	1,600
		1.7 Somdej Phra Srinakarin Garden	4	6,400
	TOTAL		10.9	17,440
2	District Park	2.1 Nong Puak Hat Public Park	13.5	21,600
		2.2 Flower Gardens	10	16,000
	TOTAL		23.5	37,600
3	Citywide or Comprehensive Park	3.1 Haiya Flower Seeding Center	35.25	51,600
	TOTAL		35.25	51,600
4	Large Urban Park Regional Park, or Large Open Space	4.1 Open Space along City Moat	90.7	145,120
	TOTAL		90.7	145,120
5	Sports Facility and Specific Park	5.1 Chiang Mai Zoological Park	50	80,000
		5.2 Chiang Mai Municipal Sport Ground	71	113,600
		5.3 Huai Kaew Botanical and Fitness Park	530	848,000
		5.4 Nong Hod Military Sports Field and Lan Na Golf Course	1,427.5	2,284,000
	GRAND TOTAL		2,238.8	3,577,360

Remarks : Park, open space & recreation areas are classified in the following categories:

1. Area less than 10 Rai : Playground/Small Park/Neighourhood Park (Less than 16,000 m^2)
2. Area 10-30 Rai : District Park (16,000 - 48,000 m^2)
3. Area 31-60 Rai : Citywide/Comprehensive Park (48,000 - 96,000 m^2)
4. Area more than 60 Rai : Large Urban Park or Regional Park. (more than 96,000 m^2)

Identification of Problems

The inventory of existing open space showed that parks were needed at the periphery of the municipality and outside the city limits, especially to the east of the city. However, the shortage of recreational areas is not a very serious problem since opportunities exist to create new public parks or recreational areas (e.g., the city moats have not yet been utilized for recreation).

Demand Forecast and Evaluation

Park area requirements were forecast based on standards established by other agencies such as BMA and NHA in Thailand, and by agencies in other countries such as Japan and Indonesia. The forecasts were based on a projected population of 341,000 in the target year, 2007. The park standards underlying the forecast are shown in Table B-5-8, and the forecasts themselves in Table B-5-9.

Goals and Objectives

The development of new public parks and recreation areas is necessary to accommodate the rapidly increasing population of Chiang Mai. Consequently, the city should improve and expand its park and recreation area network to enhance the local living environment and improve the quality of life. The city will then continue to be an attractive tourist destination.

Recommendations for the Park and Recreation Area Plan

Currently, playgrounds and small parks such as neighborhood and district parks are not located near residential areas. Therefore, the parks and recreation plan should emphasize not only the development of new parks, but also their location near park users. Since most parks are now located in the center and west of Chiang Mai, additional parks should be developed east of the Ping River. New park space can be created by areas by utilizing governmental land, by purchasing it from the public sector, or by receiving private donations.

The Relation Between Recreation and Park Facilities and the Land Use Plan

The presence of a recreational facility is a social factor of moderate importance affecting the residential location decision. Therefore, this factor helps determine an area's potential for residential development. In applying the potential surface analysis (PSA) technique to the analysis of residential development potential, a five-level system is employed based on walking distance to a recreational facility and the size of the recreational facilities. Details were provided in Appendix B-3.

CASE STUDY II (THA RUA-THA LAN)

Case Study II in the Tha Rua-Tha Lan area focused on area requirement forecasting and area potential analysis. The results of the former are shown in Tables B-5-10 and B-5-11. The latter was carried out

Table B-5-8 STANDARDS FOR PARKS

Type of Park	Area		Standard		Area per capita		Radius of Area Served (m)	Service Catchment Area		Service Population		
	rai	ha	rai	ha	rai/1000 persons	m²/person		rai	ha	Persons	Applied Density Persons/rai	Persons/ha
Playground, Neighbourhood park, Small park	0.18-10	0.03-1.6	6	1	3	4.8	300 (Walking distance of children)	225	36	2,000	9	55
District Park	10-30	1.6-4.8	24	4	3	4.8	900 (Walking distance: 10-15 min.)	2,000	324	8,000	4	25
City wide or Comprehensive Park	30-60	4.8-9.6	50	8	1	1.6	2,700 (10-15 min. by bus or bicycle)	18,000	3,000	50,000	3	19
Large Urban Park or Regional Park	Over 60	Over 9.6	-	-	-	-	-	-	-	-	-	-

Table B-5-9 DEMAND FORECAST FOR CHIANG MAI

Type of Park	Per Person Standards		Area Demand (1987)		Area Demand (2007)		Present Area		Ratio
	sq. m.	rai/ 1,000	ha	rai (A)	ha	rai	ha	rai (B)	% (B/A)
Playground, Neighbourhood Park, or Small Park	4.8	3	104.9	655.6	163.7	1,023	1.74	10.9	1.7
District Park	4.8	3	104.9	655.6	163.7	1,023	3.76	23.5	3.4
Citywide or Comprehensive Park	1.6	1	35.0	218.5	54.6	341	5.64	35.25	16.1
Large Urban Park Regional Park	-	-					14.5	90.7	
Sports Park Specific Park	-	-					322.6	2076.5	
Total							357.7	2238.8	

Table B-5-10 PARKS AND RECREATION AREAS IN THA RUA CASE STUDY II

Park & Open Space	Location	Area (rai)	ha	Cassification
1. Municipal Public Park	Located on Municipal Rd. No.2, behind Tha Rua Railway Station	0.5	0.08	Small Park
2. Municipal Playground	Located on Municipal Rd. No.2, behind the Rua Railway Station	0.25	0.04	Playground
3. Royal Park (Park provided to honor the King)	Located along the Pa Sak River	0.59	0.09	Small Park
4. Mini Park (Slap Area)	Located along the Pa Sak River	0.63	0.10	Small Park
Total		1.97	0.31	
5. Private Sports Ground (1)	East bank of irrigation canal	10	1.6	
6. Private Sports Ground (2)	East bank of irrigation canal	15	2.4	
7. Private Sports Ground (3)	East bank of irrigation canal	17.5	2.8	

Table B-5-11 PARK DEMAND FORECAST FOR THA RUA

Type of Park	Per Person Standards		Area Demand (1987) (37,000 persons)		Area Demand (2007)		Present Area		Ratio
	sq. m.	rai/ 1,000	ha	rai (A)	ha	rai	ha	rai (B)	% (B/A)
Playground, Neighbourhood Park, or Small Park	4.8	3	17.8	111			0.3	1.97	1.8
District Park	4.8	3	17.8	111				-	
City wide or Comprehensive Park	1.6	1	5.9	37				-	
Sports Park or Specific Park	-	-							
Private Sports Ground							(6.8)	(42.5)	
Totals							0.3	1.97	

Table B-5-12 DETAILS OF FACTORS, INDICATORS, MEASUREMENT RANGE, SCORING, AND MAP SOURCES (THA RUA: CASE STUDY II)

Series	Factor	Indicator	Range of Measurement	Score		Weighted Score	Map Source
				Actual	Normalized		
1	Population Density	Rank size of population density	- < 1 (person/rai) - 1-5 (person/rai) - 6-10 (person/rai) - 11-15 (person/rai) - 16-20 (person/rai) - >20 (person/rai)	1 2 3 4 5 6	0 2 4 6 8 10	4	- Population Density Map - Scale 1:20,000 - Research and Analysis Division
2	Urban Vacant Area	Rank size of occupancy rate	- 0-25 (%) - 26-50 (%) - 51-75 (%) - 76-100 (%)	4 3 2 1	10 7 3 0	3	- Land Use Map - Scale 1:20,000 - Mapping Division
3	Parks & Recreation Area	Distance from the park & recreation area	- 0-500 (m) - 501-1,500 (m) - 1501-3,500 (m) - >3,500 (m)	1 2 3 4	0 3 7 10	2	- Land Use Map - Scale 1:20,000 - Mapping Division
4	Waterfront	Area adjacent to a river bank	- Totally pass through the area - Partially pass through the area - In land area	3 2 1	10 5 0	3	- Land Use Map - Scale 1:20,000 - Mapping Division
5	Road Accessibility	Rank of accessibility to roads	- 0-250 (m) - 251-500 (m) - 501-750 (m) - 751-1,000 (m) - >1,000 (m)	5 4 3 2 1	10 8 5 3 0	3	- Map of Right of Way, Traffic Surfaces & Traffic Lanes - Traffic Volume Map - Scale 1:20,000 - Engineering Division

through the application of the PSA technique for measuring the development potential of an area for park and recreational facilities. The application of the PSA technique is described in detail below.

(1) Setting the Size of Grid Cells

A grid cell size of 250 m x 250 m was used. A total of 718 cells, distributed over 45 rows and 28 columns, was required to cover the 39.05-square-kilometer study area.

(2) Selection and Measurement of Factors

The factors selected for the study area were selected on the basis of locational theory. Table B-5-11 lists these factors along with their indicators, measurement ranges, scoring, and map sources.

Five major factors were analyzed to gauge the recreational potential of a piece of land. One factor, population density, is directly related to the demand for park facilities. A second factor, "urban vacant area," shows the availability of land that can be readily developed at relatively low cost. A third factor, parks and recreation areas, is based on the premise that there is a "demand" for a recreation facility in areas distant from an existing park. A fourth factor is the presence of waterfront property, which is particularly attractive for recreational uses. A final factor, road accessibility, was selected. Of course, the importance of road accessibility varies with the size of the park. Playgrounds or small parks require only minor roads for access, while large parks should have convenient access to major roads.

The weighted score for each factor was based on weightings made by park and recreation facility planners. Population density was found to have the "highest significance" and most "direct relevance to the demand or supply of park and recreation areas." The presence of existing park and recreational facilities was found to have the least significance.

(3) Evaluation of Potential

The result of the area potential analysis is shown in Figure B-5-14. An area of approximately 2,750 rai (11.0% of the entire study area) was identified as most suitable for the development of parks. This area of high potential has public transportation and other public services. Most of the high potential area is located along the Pa Sak River, in the Tambon Tha Rua municipal community and the Tha Luang sanitary community. Also, areas of high potential are located along the irrigation canal. An area of approximately 19,185 rai (76.7% of the entire study) area was identified as having moderate potential for the development of parks and recreation areas. Most of this area is along the Pa Sak River. Most of the low potential area (3,604 rai or 12.3% of the study area) is located in the agricultural district in the western part of the Tha Lan Sanitary District and on the present site of the Siam Cement Company.

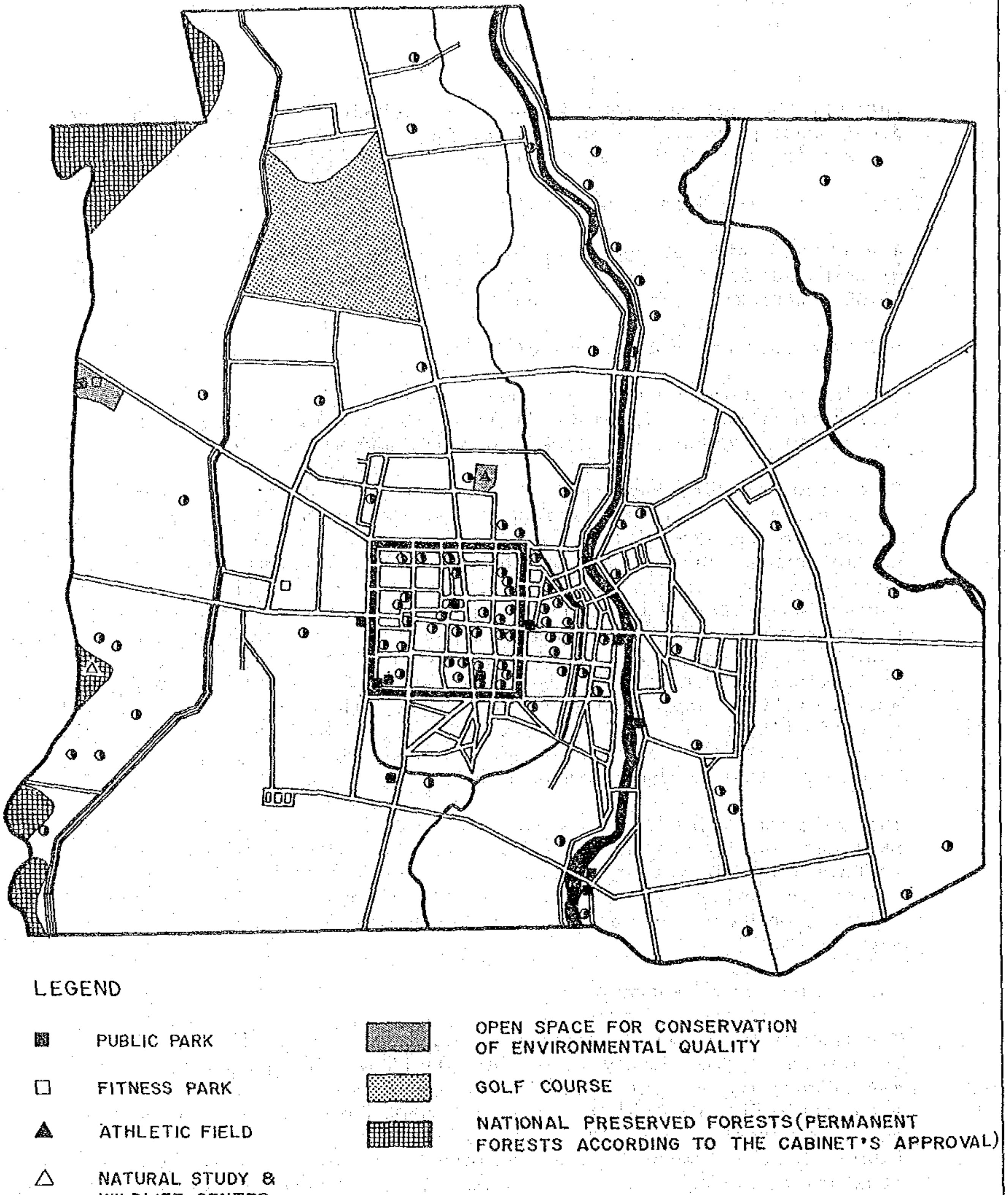
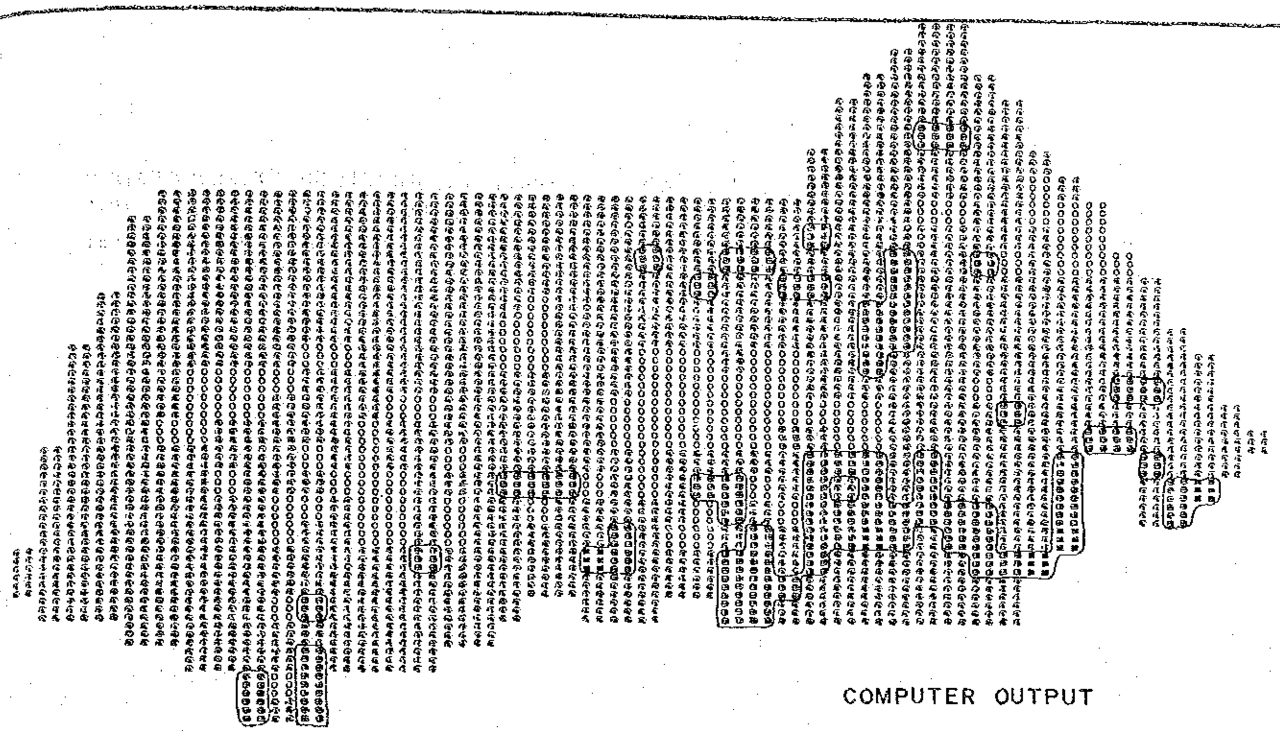
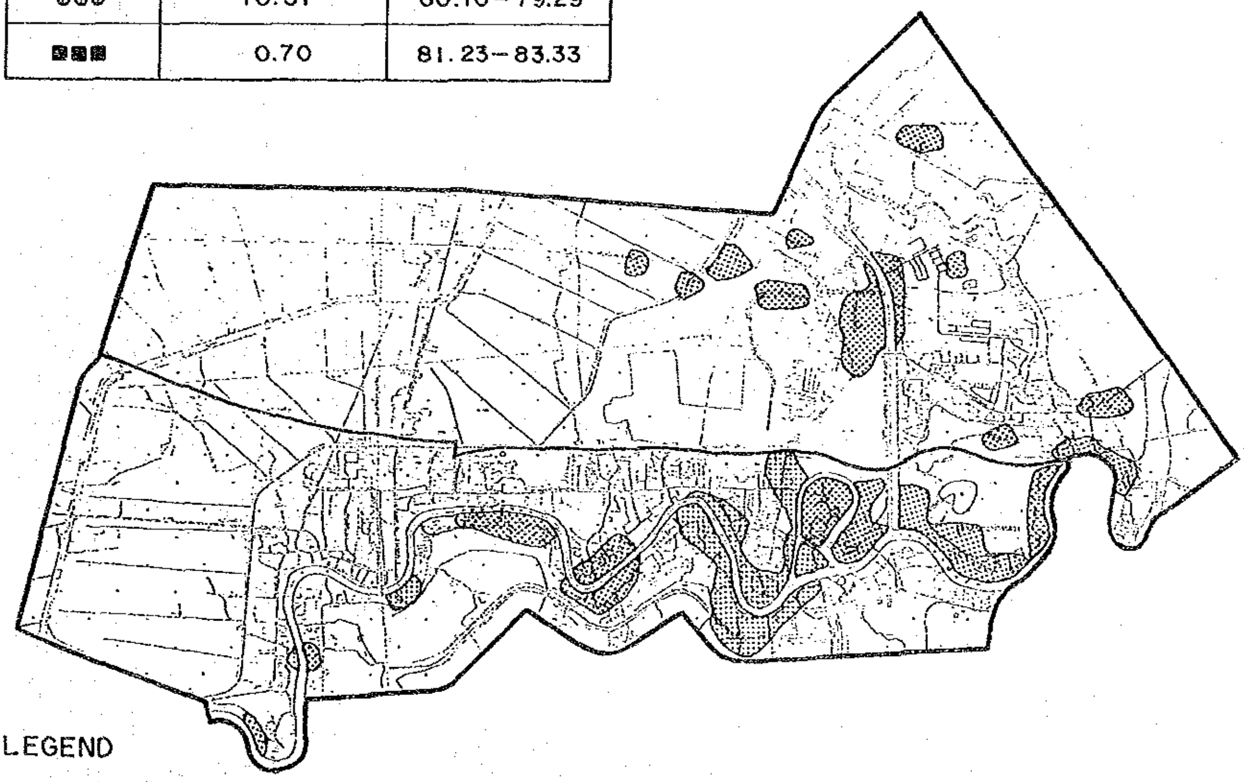


Fig. B-5-13 RECREATION AREAS AND OPEN SPACE IN CHIANG MAI



LEGEND	PERCENT OF POTENTIAL	SCORE
OOO	12.26	23.23 – 39.90
@@@	76.74	40.40 – 59.60
⊕⊕⊕	10.31	60.10 – 79.29
■■■	0.70	81.23 – 83.33



LEGEND

SUITABLE LOCATION FOR DEVELOPMENT OF PARK & RECREATION AREA
(HATCHED AREA SHOWN THE HIGH & HIGHEST TWO RANKS OF POTENTIAL)

Fig. B-5-14 PARK & RECREATION AREA POTENTIAL (MEAN WEIGHTED SCORE) THA RUA - THA LAND (CASE STUDY II)

New public parks and recreation areas should be provided in locations suitable to accommodate the increased future population. The PSA technique allows the planner to evaluate alternative locations so that the sites most suitable for park development can be selected.