AN ABSTRACT OF THE THESIS OF

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(Name) (Degree) (Major)

Date thesis is presented January 4, 1963

Title AN ECONOMIC ANALYSIS OF THE KANG KRACHAN MULTI-PURPOSE WATER DEVELOPMENT PROJECT, PETCHBURI, THAILAND

Abstract approved Redacted for Privacy
(Major professor)

The Petchburi Irrigation Project was built in the southern part of the Central Plain of Thailand in 1942. The purpose of the project was to divert water from the Petchburi River to irrigate the principal part of the Petchburi Plain where lands were used for rice and upland crop production.

At present, however, a serious water shortage both for agricultural and domestic uses occurs in the areas outside of the project. The lands on the northern part of the plain are seriously in need of water for irrigation because the available inflow of the river is not sufficient to irrigate these lands in the wet season. As the river decreases its flow in the dry season, there is practically no water delivered to the southern part of the plain for domestic use. The water shortage becomes more serious every year due to population growth

and the expansion of cash crop production during the dry season.

Water conservation through dam construction and extension of the existing irrigation system is considered a feasible way of increasing the amount of water required in the areas where the people are suffering from a desperate shortage of water. The additional works to the existing Petchburi Project under the name of "Kang Krachan Project" is proposed to fill the water requirements of the area. This project is designed as multi-purpose and will provide supplementary water for the existing Petchburi Project, water to irrigate new lands, and will provide for flood control, water for domestic use, and hydroelectric power.

The objectives of this study are: (1) to determine the general economic feasibility of the proposed Kang Krachan Project through an analysis of costs and benefits, (2) to recommend a possible method of allocating reimbursable costs, (3) to allocate costs to various purposes.

The U. S. Bureau of Reclamation methods with some modification of computing direct, indirect, and public benefits were used as the basis of analysis.

The average total project benefits per rai are found to be 566 bahts of which direct benefits account for 329 bahts, indirect benefits 147 bahts, public benefits 73 bahts, benefits from preventing flood damage 5 bahts, and benefits from domestic water amount to 12 bahts per rai.

The analysis indicates the total project benefit-cost ratio to be 6.4, while the total irrigation benefit-cost ratio is 6.3, and the direct irrigation benefit-cost ratio is 3.8. These benefit-cost ratios are very favorable. The project is, therefore, considered economically feasible.

For the allocation of the multi-purpose project costs in Thailand, the separable costs-remaining benefits method is applicable. Because all required data are not available, the cost allocation of the Kang Krachan Project is not shown in the analysis.

The problem of repayment by direct beneficiaries has thus far never occurred in Thailand. The costs of all previous projects have been repaid by the federal taxpayers. Thai farmers have not been charged for repayment of construction costs of primary facilities. However, the government proposed to use a land tax for the Kang Krachan Project area. Repayment of construction costs of this project is proposed from a land tax, municipal tax on domestic water use and revenues derived from the differential in the domestic and export price of rice.

In the future, all water development projects in Thailand should be multi-purpose. Benefit-cost analysis by the U. S. Bureau of Reclamation methods and the allocation of project costs by the separable costs-remaining benefits method will be useful in determining economic feasibility and allocation of reimbursable costs to direct beneficiaries.

AN ECONOMIC ANALYSIS OF THE KANG KRACHAN MULTI-PURPOSE WATER DEVELOPMENT PROJECT, PETCHBURI, THAILAND

by

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A THESIS

submitted to

OREGON STATE UNIVERSITY

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1963

APPROVED:

Redacted for Privacy

Professor of Agricultural Economics

In Charge of Major

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Date thesis is presented: January 4, 1963

Typed by Jolene Wuest

ACKNOWLEDGEMENTS

I wish to express special thanks and sincere appreciation to members of my graduate committee, Dr. Henry P. Hansen, Dean of Graduate School; Dr. G. B. Wood, Head of Department of Agricultural Economics; Dr. Lyle D. Calvin, Head of Department of Statistics; Dr. Gordon R. Sitton, Professor of Agricultural Economics for their guidance and recommendations.

I am deeply indebted to Dr. Grant E. Blanch, the Major Professor, who spent much time to read critically this thesis, and made helpful suggestions. I also thank him for his English editing and correcting of the thesis writing. I know this thesis has been completed only through his assistance.

I desire also to express thanks to many other individuals. Among them are Mr. Chune Luamudhai, Dr. Bhochana Panyadhibya and some engineers of the Royal Irrigation Department, Thailand, who supplied the writer with essential data, literature, and maps used in the preparation and writing of the thesis.

The writer, however, is alone responsible for any errors and omissions in this thesis.

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CHAPTER 1

INTRODUCTION

Brief History of Petchburi Irrigation Project

Thailand, a rice growing country, is situated on the Southeast Asia Peninsula within the latitudes 6 and 20 north and longitudes 97 and 106. The total area of the country is about 200,000 square miles or 512,000 square kilometers with a population of about 22 million (12, p. 36). Because Thailand is almost exclusively an agricultural country, the most important source of income of the people stems from rice cultivation. Rice is not only the main staple food for Thai people but also the export commodity which earns the largest share of foreign currency annually for Thailand.

Some sixty years ago, fluctuations in the rice export first caused the Government to realize the need for a water control system. Rice production in those days was uncertain because yields depended upon rainfall or natural water.

As the annual rate of population growth in Thailand is about 2 percent (12, p. 36) and the world rice-eating people increase greatly every year, the necessity for Thailand to produce more rice becomes an essential problem.

It has been found that as more land is opened up for cultivation, the rice yield per unit area becomes less. The reason is that rain water alone is not adequate for rice growing. Irrigation, therefore, is a necessary means for increasing and stabilizing rice production.

The South Pasak was the first irrigation project built in the Central Plain of Thailand. This project was constructed in 1915 and completed in 1924. After the completion of this project, many other modern irrigation projects have been constructed in all parts of the country. Among these projects is the Petchburi Irrigation Project.

Table 1. State Irrigation Projects, Thailand

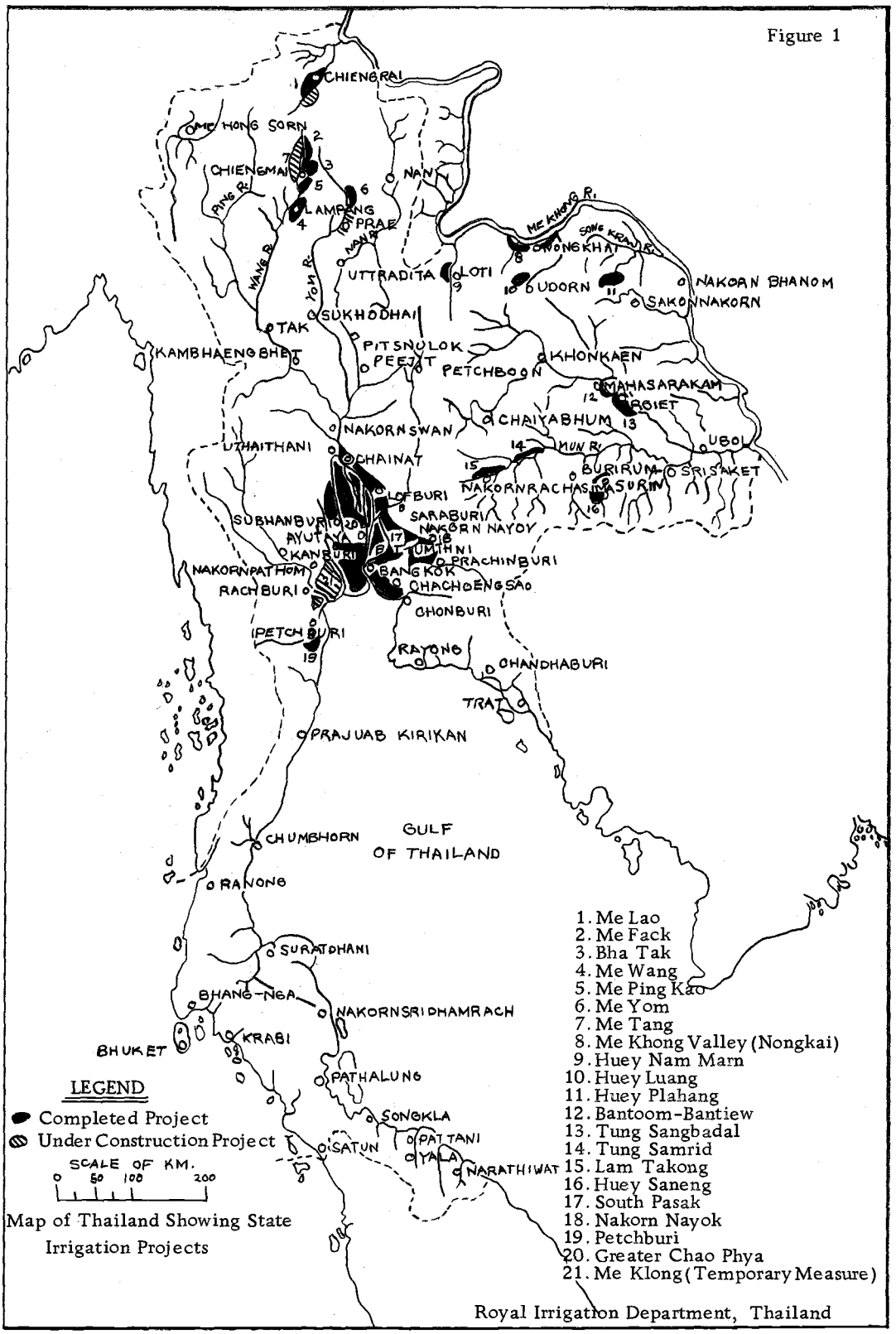
Project	Irrigable Area		Year of Construction	Year of Completion
	Rais	Acres		
Central Zone				
1 South Pasak	680,000	272,000	1915	1924
2 Chiengrak-Klong Darn	1,335,000	534,000	1921	1931
3 Subhan	674,700	269,880	1921	1955
4 Nakorn Nayok	574,000	229,600	1933	1954
5 West Bank	368,800	147,520	1939	1963
6 Tidal Tract	443,500	177,400	1939	1963
7 Me Klong	390,000	156,000	1941	1959
8 Petchburi	210,000	84,000	1942	1956
9 Greater Chao Phya				
North Subhan	700,000	280,000	1952	1962
Noi River	1,232,000	492,800	1952	1962
Chainat-Pasak	820,000	328,000	1952	1962
Maharaj	414,000	165,600	1952	1962
Nakorn Luang	228,000	91,200	1952	1962
Extension of Noi River and Maharaj	170,000	68,000	1952	1962
Subtotal	8,240,000	3,296,000	---	---

Table 1. Continued.

Project	Irrigable Area		Year of Construction	Year of Completion
	Rais	Acres		
Northern Zone				
1 Me Fack	70,000	28,000	1928	1936
2 Me Wang	77,000	30,800	1933	1949
3 Me Ping Kao	44,900	17,960	1937	1941
4 Bha Tak	56,000	22,400	1948	1954
5 Me Lao	166,400	66,560	1951	1961
6 Me Yom	230,000	92,000	1951	1963
7 Me Tang	153,000	61,200	1955	1964
Subtotal	797,300	318,920	---	---
Northeastern Zone				
1 Lam Takong	100,000	40,000	1939	1957
2 Tung Samrid	153,000	61,200	1939	1957
3 Huey Saneng	46,200	18,480	1939	1956
4 Tung Sangbadal	180,000	72,000	1939	1955
5 Bantoom-Bantiew	29,000	11,600	1939	1955
6 Huey Luang	40,000	16,000	1939	1956
7 Huey Nam Marn	5,500	2,200	1939	1954
8 Me Khong Valley	64,000	25,600	1939	1955
9 Huey Plahang	40,000	16,000	1957	1961
10 Tung Samrid (Extension Area)	23,000	9,200	1958	1963
Subtotal	680,700	272,280	---	---
Total	9,718,000	3,887,200	---	---

Source: Derived from. Thailand. Royal Irrigation Department. State Irrigation Projects. Completed and Under Construction. Bangkok. 1958. p. 1-3.

Figure 1



Map of Thailand Showing State Irrigation Projects

The Petchburi Irrigation Project lies on a vast agricultural land, called the Petchburi Plain, in the southern part of the central zone along the west coast of the Gulf of Thailand. The total area of the Petchburi Plain is about 332,000 rais (132,800 acres). Like other parts of the country, rainfall over this plain is not adequate for rice growing. The records indicate that the amount of rainfall during the rice growing season is only 800 mm. (31 in.) while the amount of water required for rice is approximately 1,800 mm. (71 in.). The Petchburi Irrigation Project was, therefore, constructed in 1942. The purpose of the project was to divert water from the Petchburi River, the main source of water supply, to irrigate an area of about 210,000 rais (84,000 acres) on both banks of the river.

According to hydrological records, the available flow in the Petchburi River during the rice growing season was only 25 m^3/sec. (882 ft^3./sec.) which would irrigate an area of only 136,000 rais (54,400 acres). This means that there was not a sufficient continuous flow in the river to irrigate the whole area of the project. After careful consideration, it was determined that an area of 136,000 rais (54,400 acres) on the right bank of the river had more suitable topography for irrigation. This area was divided into two parts:

1. From the river bank to the railroad.

Rice fields	2,000 rais (800 acres)
Farm crops	12,000 rais (4,800 acres)

Unclaimed lands	86,000 rais (34,400 acres)
Total	100,000 rais (40,000 acres)

2. From the railroad to the Gulf of Thailand.

Rice fields	36,000 rais (14,400 acres)
Grand Total	136,000 rais (54,400 acres)

The Government, therefore, decided to choose the area on the right bank as the Petchburi project area. The construction works involved a diversion dam with appurtenant structures across the Petchburi River in order to raise water up to the desired level, a distribution system of three main canals and sixteen laterals for carrying irrigation water to the fields, and different kinds and sizes of irrigation structures have been built since 1942.

A few years after the construction of the project was started, the unclaimed lands previously mentioned were gradually cleared for cultivation. As the new lands were opened up, it appeared that various kinds of farm crops were well adapted in this area because the soil is an alluvial soil deposited by the ten-year frequency flood of the Petchburi River. Instead of using these new lands for paddy fields, farmers preferred to grow farm crops such as peanuts, pumpkins, pineapples, bananas, sugar cane, coconuts, some water melons, and cantaloups which provided them with more income. Generally speaking, these crops require an amount of irrigation water of about one-third that required by rice. The amount

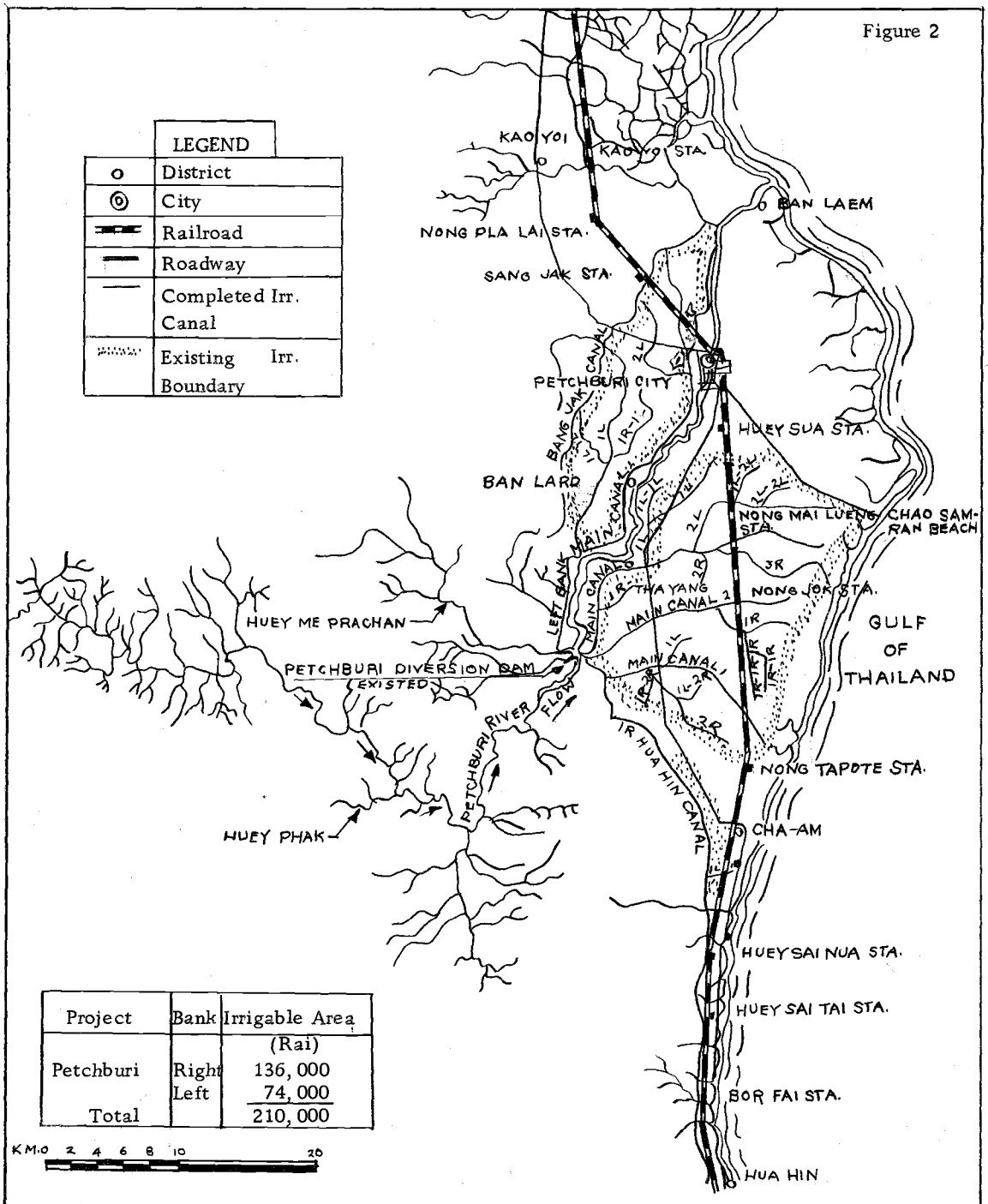
of water designated for irrigation of paddy fields in this area, therefore, exceeded the actual requirement of farm crops. It can be said that the change in crop pattern on these new lands brought about a good opportunity to extend the project area to include 74,000 rais (29,600 acres) on the left bank of the river. This area could be irrigated by surplus water of the right bank. In other words, 25 m^3/sec. (882 ft^3/sec.) of the continuous flow in the river could irrigate the whole project area of 210,000 rais (84,000 acres). The construction works including one main canal, four laterals and several canal structures were constructed on the left bank in 1949. At present, the construction works on both banks of this project have been completed, and the project is in full operation.

General Problem

In 1958, nine years after the second phase of the Petchburi Irrigation Project was started, the demand for water from the Petchburi River became considerably acute for both domestic and agricultural uses due to the fast growing population and the expansion of agricultural areas outside of the project.

The 1R lateral of the main canal No. 1, usually called the Hua Hin Canal as shown on the map, was originally designed to irrigate the project area along the first half of its length. For the second half, this canal was designed to carry only domestic water for the

Figure 2



Project	Bank	Irrigable Area (Rai)
Petchburi	Right	136,000
	Left	74,000
Total		210,000

Existing Petchburi Irrigation Project, Thailand

Districts of Cha-am, Bor Kaem, Maruktayawan, and Hua Hin which are outside of the project. The long narrow strip of land along the second half of the canal has already been used for cultivation, and at present the demand for domestic water is also increasing in direct proportion to population growth. Thus, the increment of water needed for the second half of the Hua Hin Canal is rapidly increasing.

As previously mentioned, the area of the Petchburi Plain is about 332,000 rais (132,800 acres), of which 210,000 rais (84,000 acres) is the area of the Petchburi Irrigation Project. The other 122,000 rais (48,800 acres), which are mostly paddy fields, are located outside of the project on the north and northeast in Muang Petchburi and Ban Laem Districts. These areas also have been seriously in need of water. In order to irrigate their paddy fields, farmers have had to build a temporary dam across the river and install pumping works. As the Petchburi River is torrential, the temporary dam is often washed away. This causes quite a loss to the farmers every year. Furthermore, the condition has been more severe in the dry season because the river flow recedes to only 0.50 $m.^3$/sec. (17.6 $ft.^3$/sec.). The farmers need help from the Government to improve and to stabilize the rice yield as well as aid in general economic development. It can be said that water shortage, both for domestic and agricultural uses for the areas outside of the existing project, is an important problem which must be solved by the Government.

The Government, through the Royal Irrigation Department, has realized the only solution to this problem is to construct a water conservation work to store the excess flow of the river in the wet season. Water released from the reservoir plus the additional side inflows from the tributaries would be available to irrigate the whole 332,000 rais (132,800 acres) of the Petchburi Plain and provide water for domestic use. To achieve this purpose, an impounding dam would have to be built at some place in the upper reach of the Petchburi River. Some existing irrigation canals and structures on both banks of the river must be enlarged in order to carry more water for these outside areas. As the Royal Irrigation Department already possessed a complete set of geological exploration, topographical, and hydrological data, Kang Krachan District has been selected as the damsite.

In 1958, an enlargement of the Petchburi Project was started under the name of Kang Krachan Project. It was designed as a multipurpose water development plan and was to tie in as a sub-phase of the larger Petchburi Project. Thus, the Kang Krachan Project, when completed, was to not only provide supplementary water for the now existing Petchburi Project and the extended areas, but also to provide for flood control, water for domestic use and hydro-electric power.

Research Problem

This study deals with the costs and benefits of the various purposes of the Kang Krachan Project, the allocation of costs, and the reimbursement of the project cost. Data for this analysis have been obtained from the Royal Irrigation Department, Thailand.

Objectives

1. To determine the general economic feasibility of the proposed project through an analysis of costs and benefits.
2. To recommend a possible method of cost allocation for reimbursement.
3. To allocate the costs to various purposes.

Hypothesis

1. Kang Krachan Project creates benefits to various purposes greater than annual costs.
2. The method of economic feasibility analysis in the U. S. can be applied to multi-purpose water resource development projects in Thailand.

Terms Used in This Thesis

It should be pointed out that some terms, which are officially

used in Thailand, are mentioned in this thesis. These terms are:

Rai is a unit area of land. Two and one'half rais are equal to an acre.

mm. or millimeter is a unit of length. 25.4 millimeters are equal to 1 inch.

m. or meter is a unit of length. 3.28 feet are equal to 1 meter.

km. or kilometer is a unit of length. 1.6 kilometers are equal to 1 mile.

$Km.^2$ or square kilometer is a unit area of land. 2.56 square kilometers are equal to 1 square mile or 640 acres.

$m.^3/sec.$ or cubic meter per second is a unit of measuring the volume of water discharged per second. 1 cubic meter is equal to 35.2875 cubic feet.

Baht is the basic monetary unit of Thailand. At present the rate of exchange is about 20.50 bahts to one U.S. dollar. In order to facilitate the comparison of these two units the writer, however, uses the rate of 20 bahts to $1 in this thesis.

CHAPTER 2

GENERAL DESCRIPTION OF PETCHBURI PROVINCE

1. Location

Petchburi, considered as one of the provinces in the central zone of Thailand, is located about 100 miles southwest of Bangkok. This province is bounded on the north by Rachburi Province, on the south by Prajuab Kirikan Province, on the east by the Gulf of Thailand, and on the west by Burma.

The total area of the province is 2,465 square miles which is divided into 6 districts as follows:

1. Muang Petchburi District (the site of Petchburi City)
2. Kao Yoi District
3. Ban Laem District
4. Ban Lard District
5. Tha Yang District
6. Cha-am District

The province is linked to Bangkok and other provinces by a highway and the southern railroad which pass through Petchburi City and the Petchburi Plain, providing facilities for transportation during the entire year.

2. Topography

Unlike other provinces in the central zone, the major part of the Petchburi Province is mountainous, covered by deep forests. Forests occupy about 1,740 square miles or 70 percent of the total land. This vast mountainous area lies along the west side of the province, mostly in the Districts of Tha Yang, Ban Lard, and Kao Yoi. It contains steep slopes running from the west to the east.

Between the foothills and the coast there exists a great plain on the east side of the province where the existing Petchburi Irrigation Project and its extension areas are located. The plain has, generally, gentle slopes running towards the seashore on the east and also from the north to the south. The topography of the total Petchburi Irrigation Project under the Kang Krachan Project will be described in more detail in Chapter 3.

3. Population

By the general census in 1960, the total population of the Petchburi Province is 237,853 (7, p. 1). The density of population is calculated as 96 per square mile.

Table 2 indicates the greater concentrations are in the Districts of Muang Petchburi, Tha Yang, Ban Laem, and Ban Lard where nearly the whole area of the Petchburi water development Project is

Table 2. Population in Various Districts of the Petchburi Province

District	Families		Population		Total Population
	Farm	Non-farm	Farm	Non-farm	
Muang Petchburi	6,886	6,341	36,534	34,957	71,491
Kao Yoi	3,966	1,074	22,230	4,979	27,209
Ban Laem	3,099	4,282	17,288	22,346	39,634
Ban Lard	5,629	710	29,945	3,415	33,360
Tha Yang	7,189	910	38,072	5,012	43,084
Cha-am	3,115	1,002	17,605	5,470	23,075
Total	29,884	14,319	161,674	76,179	237,853

Source: Derived from. Thailand. National Economic Development Board. Census in Thailand. Petchburi Province. Bangkok. 1960. p. 1.

located. The lesser concentrations are on the north and south portions of the province, in the Districts of Kao Yoi and Cha-am.

As compared to the whole province, the percentages of families and population in each district are shown in Table 3.

Table 3. Percent of Families in Petchburi Province on Farms and Percent of Province Population on Farms

District	Families		Population	
	Farm	Non-farm	Farm	Non-farm
Muang Petchburi	15.58	14.34	15.36	14.70
Kao Yoi	8.97	2.43	9.34	2.09
Ban Laem	7.01	9.69	7.27	9.39
Ban Lard	12.73	1.61	12.59	1.44
Tha Yang	16.26	2.06	16.01	2.11
Cha-am	7.05	2.27	7.40	2.30
Total	67.60	32.40	67.97	32.03

It is shown that approximately 68 percent of the total population are farmers. The percent of farmers is higher in Tha Yang, Muang Petchburi and Ban Lard Districts where lands are more suitable for cultivation. Ban Laem is the only district where the number of non-farm people exceeds the farmers. This condition is due to the fact that commercial fishing is an important industry in this district.

4. Agricultural Economy

Farming, as previously discussed, is the principal occupation of the people in the Petchburi Province. The vast plain, where the Petchburi and Kang Krachan Projects are located, is an important source of crop production.

Prior to the construction of the Petchburi Project, approximately 30 percent of land in this area was used for growing rice and some kind of upland crops. The average size of farm was 30 rais. The rice yield was as low as 0.300 metric ton per rai. Thus, only 23,400 metric tons of rice were produced annually. As compared to the 3,854,000 metric tons of rice produced in Thailand in 1942 (5, p. 36), rice production in the Petchburi Plain was less than one per-cent.

Since 1956, the year of completion of the Petchburi Project, rice yields in the project area have improved to 0.410 metric ton per rai. The result has been an increase in rice production to about 80,000

metric tons yearly. In addition, farmers have been able to produce crops other than rice on their lands. The farm incomes, therefore, have been more favorable.

Increasing and stabilizing crop yields will succeed more perfectly after the Kang Krachan Project has been constructed. It is estimated the rice yield in the whole Petchburi Plain will be 0.460 metric ton per rai. From the total harvested area of about 280,000 rais, 128,800 metric tons of rice are expected to be produced each year. Furthermore, several kinds of dry season crops grown in this area will provide a significant share of farm income to farmers.

A comparison of the current agricultural situation in the area of the Kang Krachan Project without irrigation with the situation after the completion of the project will represent the effect of the project on the area's agricultural economy. The results obtained will meas ure the benefits of the project. Total benefits from the Kang Krachan Project will be discussed later.

5. Water Resource

Petchburi River, the main source of water supply for the Petchburi Province, rises from mountains of the Tennesserim Ranges which is the western border between Thailand and Burma. As the river basin is formed up by the mountain ranges, this river drains the mountainous areas of the upper basin down to the sea. Along its

upper reach, several tributaries flow into the river. The two major tributaries are Huey Phak and Huey Me Prachan. The former drains the areas on the right bank and flows into the river at Tha Huey Phak Village, while the latter flows on the left and meets the river at a place just above the existing diversion dam of the Petchburi Irrigation Project.

Briefly speaking, the Petchburi River flows southeast across the country along its upper reach where exists a rugged terrain of densely forested rolling hills and valleys. After flowing for 74 miles from its source, the river arrives at the open country or the Petchburi Plain where the headworks of the Petchburi Irrigation Project are located. From this place the river changes its route by flowing northeast along its lower reach through the Plain and the City of Petchburi. Finally, the Petchburi River empties itself at the Gulf of Thailand. The total length of the river is about 100 miles. The total drainage area as measured on the map is 5,480 square kilometers (2,140 square miles).

Like other rivers possessing a small catchment area and steep slopes, the Petchburi River is torrential. It carries a flash flood for a short period of time following heavy rains in the mountains. In order to drain a large flood, usually caused by cyclonic rains of a Typhoon storm, the river banks in the upper reach have two top elevations to provide a floodway adjacent to the river's channel. As far

as the flood flows down to the Plain in the lower reach where the channel changes its shape, it will spill over the river banks and travel inland along the joining creeks and depressions of the Plain. Several districts and small villages of the Petchburi Province are located along these flowing routes. The normal overflow water, as an addition to local rainfall, naturally irrigates the paddy fields and a good yield for that season is expected. However, in some dry years which often occur, there is no overflow water from the river and the Plain is faced by a bad drought which results in a great loss in rice production. In contrast, approximately once in ten years, there might be great damage from a large flood caused by an unusual amount of Typhoon rain. These floods not only damage the growing crops, livestock, and farm property but also destroy the railroads, highways, bridges, and other personal and state property.

The Petchburi River is an important source of economic strength for the Petchburi Province. But without proper control, this river might cause great damage, affecting the national economic situation. Water conservation through dam construction and flood control is the only feasible way of improving the flow in the Petchburi River for irrigating the land on the Petchburi Plain.

6. Climate

a. Rainfall

As mentioned in the preceding chapter, Thailand is situated on the Southeast Asia Peninsula stretching out of the mainland into the seas; the Indian Ocean on the west, the Gulf of Thailand on the south, and the Pacific Ocean on the east. These vast sheets of water are important sources of rainfall brought into the country by different kinds and directions of wind.

The seasonal wind which blows from the Indian Ocean on the southwest to the northeast of the country is called the Southwest Monsoon. It begins to blow in the middle of May and lasts to the middle of October. This wind carries the Southwest Monsoon rain which is the most important natural source of water for rice cultivation in all zones of Thailand.

When the Southwest Monsoon disappears, the Northeast Trade Wind or the Northeast Monsoon begins to blow in the opposite direction from November to January. This wind, as it passes over the cold regions of Siberia and China, brings coldness to the country. It can be said that there is practically no rain in Thailand during these three months except in the southern zone.

Because the Indian and Pacific Oceans are two great sources of

water adjacent to Thailand on the west and east sides respectively, the differences in temperature and pressure of weather always occur and form high and low pressure areas leading to cyclonic centers on the oceans. By this way the cyclonic storms or the Pre-monsoon storm of the Indian Ocean and the Typhoon of the Pacific Ocean are formed up.

In April, the Pre-monsoon storm center starts near the west coast of Thailand and creates a strong wind blowing northeast. It occasionally brings heavy rain onto the watershed area of the Petchburi River and causes the increase of inflow in the river lasting for about one week. In May and June, if the center of the storm is formed, it will move up to the north and carry heavy rain which brings about the rise in water level in Me Klong and Uthai Rivers. After that the storm paths will pass outside of the country and Thailand will receive no rain from this storm.

The Gulf of Thailand is another source of rain for the central zone. In March and April, the differences in pressure of weather form a center of a strong wind. Because the gulf is so small as compared to the Indian and Pacific Oceans, the amount of rain brought into the Central Plain by this storm is not heavy.

Among all seasonal winds and cyclones blowing through Thailand, Typhoon of the Pacific, the last cyclonic storm mentioned here, has a large influence on the supply of water in the country. This cyclone

has an occurrence of the same manner and within the same period as that of the Pre-monsoon storm. It originates on the vast water surface south of the Philippines Islands. Like other cyclones, its occurrence and blowing route cannot be accurately predicted. The Typhoon, when occurring, will travel to the mainland by one of these three routes. First, it blows directly to the north and occasionally brings about great flood damages to the Philippines and Japan. Second, its route might pass along the seashore of China. The last route of the cyclone is the way that passes through the Southeast Asia Peninsula to Thailand. However, before it reaches the country, its strong influence is partially destroyed by the nature of the earth. In Thailand this cyclone is, thus, usually called the "tail of Typhoon".

The center of a Typhoon storm does not occur at a particular place due to the position of the earth. Its blowing routes which pass through Thailand in different months can be roughly stated as follows:

In May, the southern part of the Central Plain may get some rain from the Typhoon.

Heavy rains of the Typhoon will soak the land in the north, northeastern, and central zones of the country in June, causing the first sharp rise in the rivers.

The blowing route of the Typhoon will move northwards far beyond the territory of Thailand in July. This condition might cause a temporary period of drought all over the country for two or three weeks.

In August, the north and northeastern zones of Thailand will obtain some rain from the Typhoon again.

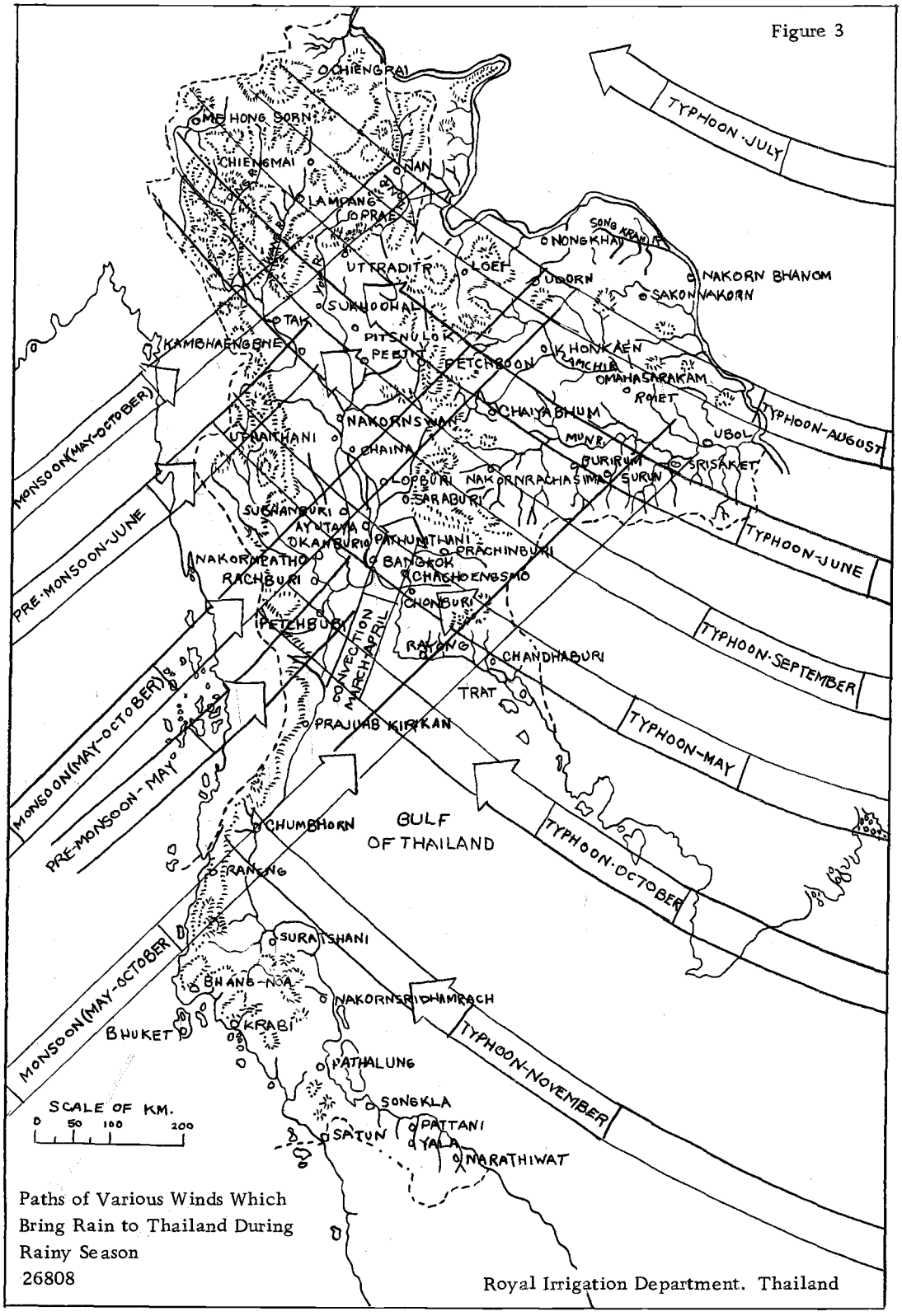
The combination of influences of Southwest Monsoon and Typhoon becomes greatest in September. All zones of the country obtain the heaviest rain from these storms. During this month the rivers usually drain large floods down to their plains.

In October, as the Typhoon continues to move its route further south, the Petchburi River Basin is, therefore, subjected to a heavy rain. Beyond this month the central zone of Thailand will obtain no more rain from this storm.

As previously mentioned, it is apparent that a large amount of water is brought into the Petchburi Plain on different occasions by three kinds of winds, the Pre-monsoon storm, the Southwest Monsoon, and the Typhoon, respectively.

The Pre-monsoon storm only creates a short period of sharp rise in the river. Because the upper reach of the Petchburi Basin, including the drainage areas above the proposed Kang Krachan damsite lies within the leeside of the Tennesserim Ranges, the distribution of the Southwest Monsoon rain is, thus, rather irregular. Fair intensity of rain generally occurs over the whole basin after the end of July. Moderate to heavy rains of the Typhoon is from October to November.

Generally speaking, the rainy season over the Petchburi River



Paths of Various Winds Which Bring Rain to Thailand During Rainy Season
26808

Royal Irrigation Department. Thailand

Basin lasts for six months beginning from the middle of May. After that the dry period begins.

Nine precipitation stations used in determining the mean annual rainfall over the basin are as follows:

1. Pak Tho
2. Kao Yoi
3. Ban Laem
4. Petchburi
5. Ban Lard
6. Tha Yang
7. Cha-am
8. Hua Hin
9. Pranburi

The period of rainfall records at the stations mentioned above is 37 years, from 1922-1959, except Petchburi City with a 53-year period, Tha Yang with a 34-year period, and Hua Hin with a 10-year period.

From Table 4, the mean annual rainfall of 1,022.3 mm. (40 in.) is calculated. The maximum and minimum deviations from the means are also found as 79.6% and 69.1% respectively.

b. Temperature and Humidity

According to the location of the Petchburi Province, the climate

Table 4. Precipitation Data, Petchburi Province

Station	Record Period	No. of Yrs.	Monthly Mean Precipitation (mm.)												Annual Precipitation (mm.)			Deviation from Mean (%)	
			Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean	Max.	Min.	Max.	Min.
Pak Tho	1922-'59	37	12.3	29.9	26.1	68.2	122.6	107.1	121.1	125.5	206.2	192.3	78.9	14.3	1,104.5	1,983.2	341.0	+ 79.6	- 69.1
Kao Yoi	1922-'59	37	6.4	37.1	49.9	30.1	129.5	125.7	109.1	149.4	204.1	197.4	92.6	16.4	1,147.7	1,673.2	489.1	+ 45.8	- 57.4
Ban Laem	1922-'59	37	9.7	18.1	26.7	46.1	76.4	120.6	146.9	148.5	208.6	198.6	93.9	33.1	1,127.2	1,688.0	445.6	+ 49.8	- 60.5
Petchburi	1906-'59	53	15.4	20.8	47.9	68.0	131.1	124.5	136.3	141.2	213.8	267.6	118.2	35.1	1,319.9	1,828.7	628.7	+ 38.5	- 52.4
Ban Lard	1922-'59	37	12.7	24.3	37.2	28.3	94.3	82.6	103.9	109.2	152.2	214.5	96.5	30.9	986.6	1,567.9	488.4	+ 58.9	- 50.5
Tha Yang	1922-'56	34	9.7	13.6	19.9	44.6	82.2	83.6	81.3	82.4	133.7	159.5	77.9	17.7	806.1	1,158.4	460.3	+ 43.7	- 42.9
Cha-am	1922-'59	37	12.7	17.3	32.2	24.2	71.3	57.8	71.8	73.4	121.4	175.4	89.9	13.1	760.5	1,111.0	364.7	+ 46.1	- 52.0
Hua Hin	1949-'59	10	4.5	21.9	23.4	53.9	110.1	93.3	78.9	109.4	120.6	266.6	126.3	4.6	1,013.5	1,227.7	873.5	+ 21.1	- 13.8
Pranburi	1922-'59	37	12.6	36.8	24.4	51.0	104.6	79.6	79.9	83.4	110.5	184.9	138.9	27.7	934.3	1,672.0	348.3	+ 79.0	- 62.7
Total	319	96.0	219.8	287.7	414.4	922.1	874.8	929.2	1,022.4	1,471.1	1,856.8	913.1	192.9	9,200.3	13,910.1	4,439.6	+462.5	-461.3	
Average	35	10.7	24.4	32.0	46.0	102.5	97.2	103.2	113.6	163.5	206.3	101.5	21.4	1,022.3	1,545.6	493.3	+ 51.4	- 51.3	

Source: Thailand. Royal Irrigation Department. Report on Kang Krachan Project. Petchburi Province. Appendix 1, Hydrological Study of Petchburi River. Bangkok, February 1961. p. 7.

over the river basin is similar to that of various parts of the central zone of Thailand. Regarding temperature and relative humidity, the observed mean annual temperature on the coastal area is around 81°F with a mean monthly variation from 77°F in January to 84°F in June. The annual mean relative humidity is about 75 percent while the mean monthly variation in humidity ranges from 71 percent in January to 82 percent in October.

As compared to those in the northern zone of the country, both monthly temperature and relative humidity in the Petchburi River Basin vary a little all the year round.

CHAPTER 3

DESCRIPTION OF KANG KRACHAN PROJECT

1. Engineering Features

Dam and Reservoir

The reservoir which will conserve water during the rainy season will be the source of supply for the Kang Krachan Project. A topography map of the project area was made in 1942. In 1945, a survey and investigation to seek the most suitable damsite was undertaken.

After careful consideration, a damsite was chosen at Kao Chao, approximately 28 miles upstream along the river from the existing Petchburi Diversion Dam. This damsite is located at a place where a narrow gorge is formed up on the river. Beyond this point there exists an uphill valley land of moderate slopes which will serve as the storage area of the reservoir.

An earth dam is considered most suitable for construction on account of a large quantity of natural materials available in the vicinity. Clay and stones, for example, which will provide an impervious core of the dam and surface protection from destructive wave action are abundant. Transportation of these materials can be made economically. The foundation, however, may require grouting to assure that

the dam is placed on a stable foundation and free from harmful percolation.

The main structure as designed consists of a rolled earthfill dam of 54 m. (177 ft.) high at the maximum section and outlet works with intake tower, concrete diversion conduit, gate chamber, and stilling basin. Two dikes (smaller earth dams) to fill the saddles and a spillway to bypass 800 m^3/sec. (28,230 ft^3/sec.) of flood are also needed.

The Kang Krachan reservoir created by the impounding dam and dikes will occupy the surface area of approximately 45 square kilometers (11, 250 acres). The volume of water collected in the reservoir is enough to be released for irrigation of rice cultivation in the wet season and also for other crops in the dry season.

Other details of the main features are described as follows:

Dam crest elevation	+ 104 M. S. L.
Deepest stream bed elevation	+ 50 M. S. L.
Length of dam at crest	733 m.
Top width of dam	10 m.
Base width of dam	265 m.
Maximum water surface elevation	+ 102 M. S. L.
Minimum water surface elevation	+ 65 M. S. L.
Reservoir capacity	
maximum	860,000,000 m^3
at spillway crest	610,000,000 m^3

at outlet sill	15,000,000 m^3
Outlet capacity	
reservoir at elevation + 67 M. S. L.	45 m^3/sec.
Reservoir length along the river	15 km.
Crest elevation of uncontrolled spillway	+ 97 M. S. L.
Spillway length	230 m.
Base width of spillway	40 m.
Crest elevation of dike No. 1	+ 104 M. S. L.
Length of dike No. 1 at crest	296 m.
Top width of dike No. 1	10 m.
Crest elevation of dike No. 2	+ 102 M. S. L.
Length of dike No. 2 at crest	257 m.
Top width of dike No. 2	10 m.
Earth embankment	2,642,000 m^3
Rockfill and rip-rap	472,000 m^3
Sand and gravel filter	278,000 m^3

M. S. L. = Mean Sea Level

Source: Thailand. Royal Irrigation Department, Ministry of Agriculture. Petchburi Project, Tables and Maps. Bangkok, July 1962. p. 5, 41 and 79.

2. Agricultural Features

a. Existing Project Area

As stated in Chapter 1, the existing Petchburi Irrigation Project which lies approximately 28 miles downstream from the Kang Krachan reservoir has a total irrigated area of 210,000 rais (84,000 acres) of which 136,000 rais (54,400 acres) are on the right bank and the other 74,000 rais (29,600 acres) are on the left bank of the Petchburi River.

Table. 5. Rice Field and Dry Season Crop Area of the Existing Petchburi Irrigation Project

Item	Right Bank (rais)	Left Bank (rais)	Total (rais)
Rice field	84,000	74,000	158,000
Dry season crop area	52,000		52,000
Total	136,000	74,000	210,000

Source: Derived from, Thailand. Royal Irrigation Department. Report on Kang Krachan Project, Petchburi Province. Bangkok, February 1961. p. 11.

b. Extension of Project Area

It is shown in Table 5 that the total rice field of the existing project is 158,000 rais. This area requires irrigation water of about 25 $m.^3$/sec. which is the maximum available inflow of the river during the wet season. There is practically no crop growing during the dry

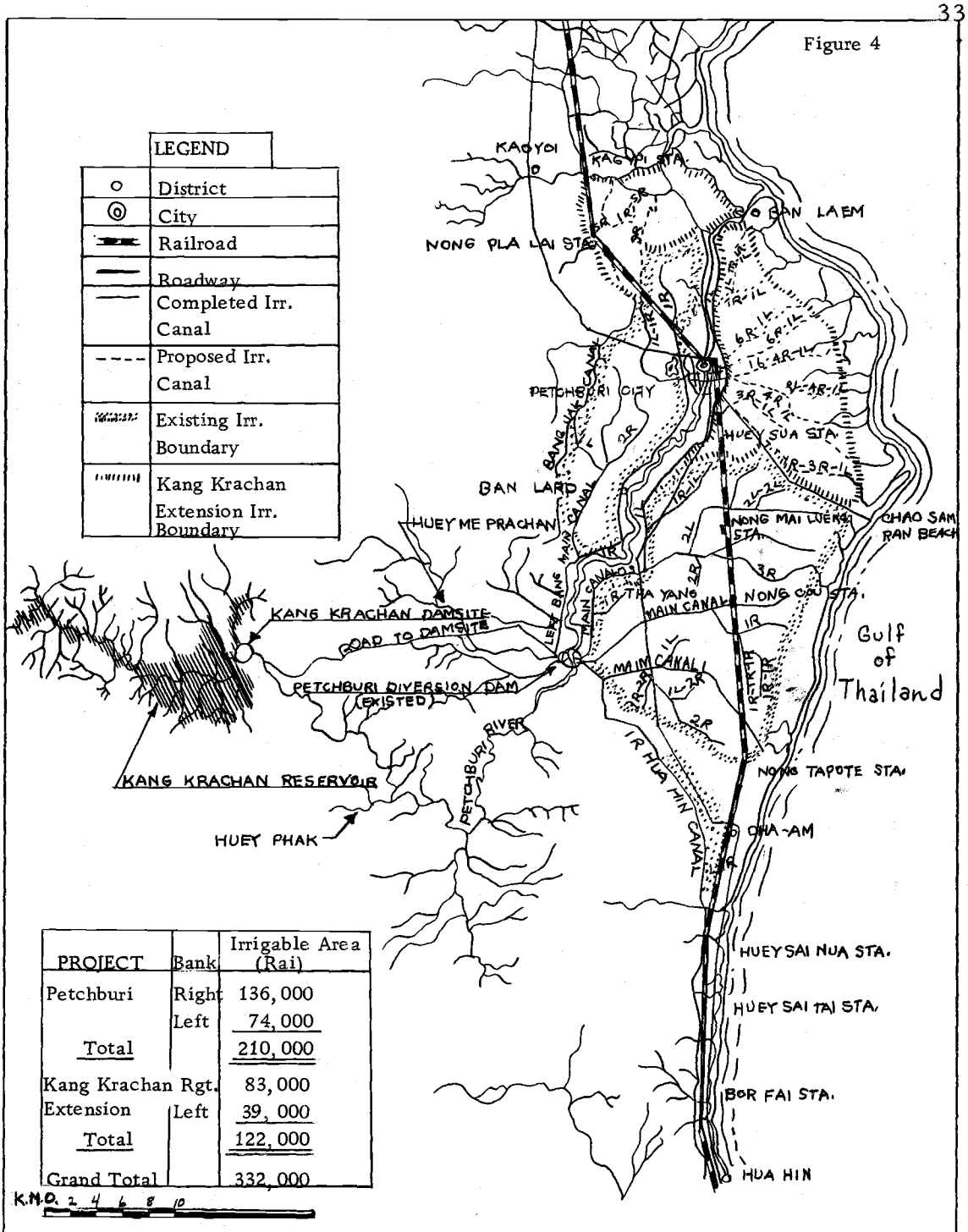
season because the river flow recedes to 0.50 m.^{3}/sec.

According to hydrological data, it is found, after the completion of the Kang Krachan Project, that the excess flow in the river can be conserved and regulated such that the constant flow of 22 m.^{3}/sec. can be released from the reservoir all the year round. This amount of water combined with another 18 m.^{3}/sec. side inflows from principal tributaries will be adequate for growing rice in the area of 280,000 rais (112,000 acres). In other words, the increase in the river flow to 40 m.^{3}/sec. provides the existing project with an extension of 122,000 rais (48,800 acres) of paddy areas. By including this area to the existing project, the total irrigable area of the Petchburi Irrigation Project under the Kang Krachan Project becomes 332,000 rais (132,800 acres).

Table 6. Rice Field and Dry Season Crop Area of the Whole Petchburi Irrigation Project at Completion of Kang Krachan Project

Item	Right Bank (rais)	Left Bank (rais)	Total (rais)
Rice field	167,000	113,000	280,000
Dry season crop area	52,000	---	52,000
Total	219,000	113,000	332,000

Figure 4



PROJECT	Bank	Irrigable Area (Rai)
Petchburi	Right	136,000
	Left	74,000
Total		210,000
Kang Krachan Extension	Rgt.	83,000
	Left	39,000
Total		122,000
Grand Total		332,000

Map of Petchburi and Kang Krachan Projects - Petchburi City

c. Project Topography

The topography of the Petchburi Irrigation Project as a whole is described separately as follows:

The project area on the right bank of the river is almost twice as big as that on the left bank. This area is bounded by the coast, Petchburi River, and high hills in Cha-am District, comprising gentle slopes running transversely from the river on the west towards the coast on the east. Soils generally are found to be very fertile and can be classified briefly into three types.

Sandy silt: found chiefly in the area along the river bank resulting from the silt deposited by the overflow of the river.

Sandy clay: as the area extends further away from the river, the soil gradually changes to sandy clay which is found generally in the area between the highway and the southern railroad.

Clay: The third type of soil is clay, the best soil for rice cultivation. Clay is found on a vast land between the southern railroad and the coast.

As compared with the area already mentioned, the project area on the left bank of the river is much smaller and less fertile due to its higher elevation. This area lies between the foothills which is the project western boundary and the Petchburi River, stretching northwards from the headworks of the project to the Gulf of Ban Laem in

Ban Laem District. It contains moderate slopes running from the foothills to the river. Along the central part of this area, however, there exists a large depression in which the land is used mostly for rice production.

d. Proposed Crop Pattern

As already shown in Table 6, 332,000 rais (132,800 acres) of land is the total irrigable area under the combined Petchburi and Kang Krachan Project, of which 280,000 rais (112,000 acres) are paddy fields. The other 52,000 rais (20,800 acres) will be used for growing dry season crops.

In selection of the crop pattern for dry season crop cultivation, twelve kinds of commercial upland and dry season crops have been found most profitable. These are sugar cane, bananas, coconuts, caster beans, cotton, corn, mung beans, soybeans, peanuts, sesame, chilli, and onions.

3. Irrigation Features

a. Water Requirement

Consumptive use records indicate that 1 cm. (0.39 in.) depth of water is consumed daily by rice. Because irrigation is required to supplement the seasonal rainfall, the water duty or the amount of

water required to irrigate a unit area of rice field per second can be computed as 0.000177 m^3/sec./rai for the existing project area on the right bank, and 0.000124 m^3/sec./rai for the existing project area on the left bank and also for the new extended area on both banks. The difference of figures is due to an unequal distribution of rain in these regions. The water requirement for rice growing in the whole project area can, therefore, be stated in the following table:

Table 7. Estimated Water Requirements for the Growing of Rice on the Whole Petchburi Irrigation Project Under the Kang Krachan Dam

Item	Paddy Area (rais)	Water Duty (m^3/sec./rai)	Irrigation Water required (m^3/sec.)
Right bank			
Existing project	84,000	0.000177	14.868
New extended area	83,000	0.000124	10.292
Total	167,000	---	25.160
Left bank			
Existing project	74,000	0.000124	9.176
New extended area	39,000	0.000124	4.836
Total	113,000	---	14.012
Grand Total	280,000	---	39.172 or 40 approx.

Source: Derived from, Thailand. Royal Irrigation Department. Report on Kang Krachan Project, Petchburi Province. Bangkok, February 1961. p. 11.

In the dry season 22 m^3/sec. of water will be released from the Kang Krachan reservoir, of which 1 m^3/sec. will be used for domestic water supply mainly for Hua Hin District, and the other 21 m^3/sec. for dry season crop growing. The average water requirement for these crops, as determined by the Royal Irrigation Department, is estimated to be 0.000062 m^3/sec./rai. After the transportation losses (percolation and evaporation) of about 35% are deducted from the original amount of water released, the dry season crops grown on 220,000 rais (88,000 acres) will obtain enough water. The cultivation of these crops can, therefore, be expanded in the new area of the Kang Krachan Project and on some parts of the existing Petchburi Irrigation Project where there is no rice grown during this period.

b. Irrigation Systems

Diversion Works

The diversion works of the existing Petchburi Irrigation Project is constructed at Tha Sig Village, approximately 28 miles downstream from the Kang Krachan Reservoir or 16 miles southwest of Petchburi City. The main feature is a diversion dam or barrage consisting of 4 openings of 6.00 m. wide, each with its appurtenant structures such as overflow weirs, boat and log way, and headgate structures of three main canals for the right bank area. The headgate structure of the

left bank main canal was built at the flood protection dike, about 500 m. upstream from the diversion dam.

These canal headgates were designed to discharge water for the existing project. By the Kang Krachan Project, the increase in water requirements for the extended area necessitates the expansions of canal headgates on both banks.

Canal Systems

Right Bank

Three main canals have been dug to convey water for the 136,000 rais (54,400 acres) irrigated on the existing project.

The main canal No. 1 which flows southeast carries water of 6.482 $m.^3$/sec. for the area in the southern part of the project. This main canal, itself, has a total length of about 17 km. (10.6 miles). Three laterals and two sublaterals have been built along its route.

The main canal No. 2 with its one lateral and two sublaterals serve the area of the central part of the project. This canal, carrying irrigation water amounting to 5.853 $m.^3$/sec., flows eastward to the coast.

The main canal No. 3 is the biggest of all canals in the project. It flows northwards for the first 10 km. and then changes its direction towards the coast on the east, constituting a total length of about 26

km. (16.25 miles). This canal originally was designed to convey 11.692 m^3/sec. of water for the northern part of the project. There are five laterals and three sublaterals taking off on both sides of the canal.

Under the Kang Krachan Project, the 1L lateral is to serve as a main canal for the new area to be irrigated and will have twelve new sublaterals. To achieve this purpose, the existing 1L lateral must be enlarged to carry 10.292 m^3/sec. additional water and be extended to the new area. As the existing 1L lateral was designed for a capacity of only 2.318 m^3/sec., the canal must be enlarged to a total capacity of 12.610 m^3/sec. The increased need for water to be carried by the 1L lateral will require enlarging the capacity of the main canal No. 3, which feeds the 1L lateral, to 21.984 m^3/sec. Consequently, the additional construction for extending irrigation on the right bank under the Kang Krachan Project will consist of the enlargement of the existing main canal No. 3, 1L lateral, canal structures, and the construction of the extension of 1L lateral and its sublaterals including all of the related structures.

Left Bank

The existing project area on the left bank obtains irrigation water from a main canal, two laterals, and two sublaterals. Under the Kang Krachan Project, the 1L lateral will be extended to serve as a main

canal for the new project area which requires more water in the amount of 4.836 $m.^3$/sec. The new capacities of the main canal and the 1L lateral have to be increased to 14.012 $m.^3$/sec. and 9.000 $m.^3$/sec. respectively. Therefore, the enlargement of the main canal and the 1L lateral with related structures and the additional construction for the new area are required.

The following Table indicates all irrigation canals and structures to be constructed under the Kang Krachan Project.

Table 8. Irrigation Canals and Structures Required for the Kang Krachan Project

Item	Quantity
Right bank	
Earth closure dike	6 units
Enlargement of main canal No. 3	10.200 km.
Enlargement of 1L lateral	6.900 km.
Enlargement of headgate of main canal No. 3	1 unit
Concrete lined canal	2.000 km.
Extension of 1L lateral	21.600 km.
New irrigation canal	12 canals
Head regulator	13 units
Canal turnout	1 unit
Culvert	4 units
Siphon	2 units
Concrete bridge	3 units
Timber bridge	47 units
Check drop	14 units
Inlet	19 units
Outlet	19 units
Tail regulator	13 units
Farm turnout	174 units
Left bank	
Earth closure dike	20 units
Enlargement of 1L lateral	14.800 km.
Enlargement of headgate of main canal	1 unit
Extension of 1L lateral	9.100 km.
New irrigation canal	5 canals
Head regulator	5 units
Timber bridge	18 units
Inlet	11 units
Outlet	5 units
Tail regulator	6 units
Farm turnout	32 units

Source: Derived from, Thailand. Royal Irrigation Department, Ministry of Agriculture. Petchburi Project, Tables and Maps. Bangkok, July 1962. p. 12-15 and 33.

CHAPTER 4

COSTS AND BENEFITS OF KANG KRACHAN MULTI-PURPOSE PROJECT

1. Costs

a. Irrigation

As the Kang Krachan Project is a multi-purpose project designed mainly for irrigation, the total project cost is, therefore, chiefly dependent upon the irrigation facility costs which consist of the costs of an impounding dam and the costs of an irrigation system adequate for the entire area.

The total cost of this project is obtained from computing detailed unit costs of various features of engineering works and materials in the construction of the project. All unit cost values involved in the computations are true figures obtained from actual construction works of many other projects which have been completed or are under construction at the present time. The proposed cost estimates are, therefore, considered reasonable with a fair degree of accuracy.

Dam

From details of computation, the cost of the main dam and its appurtenant structures is estimated at 127,836,000 bahts or

$ 6,391,800. The various items of cost are summarized and shown in Table 9. The detail of dam size and materials from which it is to be constructed was discussed on p. 29 - 30.

Table 9. Estimated Costs of Constructing Impounding Dam and Appurtenant Structures, Kang Krachan Project

Item		Cost in baht	Cost in $
Preparation works		9,296,000	464,800
Outlet works		13,832,000	691,600
Dam works		49,935,200	2,496,760
Spillway		7,550,000	377,500
Construction costs		80,613,200	4,030,660
Contingencies	10%	8,061,400	403,070
Engineering supervision and administration	10%	8,061,400	403,070
Foreign consultant services		8,000,000	400,000
Equipment		23,100,000	1,155,000
Total		127,836,000	6,391,800

Source: Derived from, Thailand. Royal Irrigation Department, Ministry of Agriculture. Petchburi Project, Tables and Maps. Bangkok, July 1962. p. 5.

Irrigation System

The Kang Krachan Project area which lies downstream from the original and existing Petchburi Irrigation Project, has been planned

on the basis of obtaining water from the reservoir to be created with the construction of an impounding dam on the Petchburi River. To achieve this objective, two main canals and a lateral of the Petchburi Irrigation Project must be enlarged to enable them to convey more water for the added area.

The basic costs incident to delivering water to the Kang Krachan Project, thus, consist of the costs of enlarging existing canals and structures of the Petchburi Irrigation Project and the costs of a new distribution system after the water reaches the new project area.

All costs associated with enlarging existing canals and creating a water distribution system over the new project area are estimated at 30,323,000 bahts or $1,516,150, Table 10.

Table 10. Estimated Cost of the Irrigation System for the Kang Krachan Project

Item		Cost in baht	Cost in $
Structures for irrigation system		12,879,000	643,950
Offices and houses		840,000	42,000
Telephone communication		500,000	25,000
Right of way		4,625,000	231,250
Construction costs		18,844,000	942,200
Contingencies	10%	1,884,400	94,220
Engineering supervision and administration	10%	1,884,400	94,220
Fuel		384,000	19,200
Spare parts		1,488,000	74,400
Equipment		4,686,000	234,300
All other (wages, transportation, etc.)		1,152,200	57,610
Total		30,323,000	1,516,150

Source: Derived from, Thailand. Royal Irrigation Department, Ministry of Agriculture. Petchburi Project, Tables and Maps. Bangkok, July 1962. p. 3 and 16.

It is seen that structures for the irrigation system constitute the largest single category of cost. A breakdown of these structures and their cost estimates is presented in Table 11.

Table 11. Estimated Cost of Structures of the Irrigation System for the Kang Krachan Project

Item	Quantity	Cost in baht	Cost in $
Earth closure dike	26 units	90,000	4,500
Concrete lined canal	2 km.	1,650,000	82,500
Head regulator	20 units	2,820,000	141,000
Canal turnout	1 unit	80,000	4,000
Culvert	4 units	308,000	15,400
Siphon	2 units	800,000	40,000
Concrete bridge	3 units	600,000	30,000
Timber bridge	65 units	1,229,000	61,450
Check drop	14 units	1,758,000	87,900
Inlet	30 units	872,000	43,600
Outlet	24 units	800,000	40,000
Tail regulator	19 units	578,000	28,900
Farm turnout	206 units	1,294,000	64,700
Total.	---	12,879,000	643,950

Source: Derived from, Thailand. Royal Irrigation Department, Ministry of Agriculture. Petchburi Project, Tables and Maps. Bangkok, July 1962. p. 12-15.

b. Drainage

Like distribution systems, drainage systems are essential works required for an irrigation project in order to remove excess water, usually caused by heavy rain, or to reduce a high ground water level. The cost of a drainage system for the Kang Krachan Project is estimated at 10,679,000 bahts or $533,950 which is shown in detail in

Table 12.

Table 12. Estimated Cost of Constructing a Drainage System for the Kang Krachan Project

Item		Cost in baht	Cost in $
Structures for drainage system			
9 Culverts		350,000	17,500
2 Bridges		360,000	18,000
Right of way		5,600,000	280,000
Construction costs		6,310,000	315,500
Contingencies	10%	631,000	31,550
Engineering supervision and administration	10%	631,000	31,550
Fuel		725,000	36,250
Spare parts		1,347,000	67,350
All other (wages, repair, transportation, etc.)		1,035,000	51,750
Total.		10,679,000	533,950

Source: Derived from, Thailand. Royal Irrigation Department, Ministry of Agriculture. Petchburi Project, Tables and Maps. Bangkok, July 1962. p. 19-20.

c. Ditches and Dikes

Because water requirements for rice growing are high, to flood the land with water is the most important way of irrigating the rice crop. This type of irrigation is called flood irrigation. By this way, the main canals, laterals, and sublaterals must be located along the ridges to facilitate irrigation. Water released from farm turnouts on both banks of the irrigation canal automatically floods the fields.

An important problem usually arises in flood irrigating rice as lands to be irrigated usually do not lay perfectly level. Water released from the canal naturally will flow to the lowest levels.

To eliminate this problem ditches, which are long narrow channels for carrying water from an irrigation canal to any unit area of land, must be dug. When water reaches the rice fields it must be kept flooding. This requires dikes or small levees to retain water on the fields at a constant depth. Without ditches and dikes, the objective of flood irrigation of rice will not succeed.

Flood irrigation will be used for growing rice in the Kang Krachan Project. The project therefore, requires construction of ditches and dikes which will cost about 10,594,000 bahts or $529,700 as shown in Table 13.

Table 13. Estimated Cost of Constructing Ditches and Dikes for the Kang Krachan Project

Item	Cost in baht	Cost in $
Wages and Salaries	1,650,000	82,500
Fuel	660,000	33,000
Spare parts	990,000	49,500
Equipment	7,094,000	354,700
Small structures in ditches 141 drops and 9 flumes	200,000	10,000
Total	10,594,000	529,700

Source: Derived from, Thailand. Royal Irrigation Department, Ministry of Agriculture. Petchburi Project, Tables and Maps. Bangkok, July 1962. p. 3 and 27.

As a matter of fact, the Government should provide only an irrigation system for the farmers, leaving the construction of ditches and dikes, which is a minor piece of work, to individual farmer responsibility. At present, the Field Dikes and Ditches Act B.E. 2484 or 1941 A.D., which requires the owners of the paddy fields to construct ditches and dikes, is being enforced in some particular areas. In addition, the Government has requested all farmers who receive water from irrigation canals to build ditches and dikes on their farms. Because farmers lack engineering and water use knowledge, most of them do not cooperate with the Government in this task. They do not realize the cost of water because they have never been charged for irrigation water. The Government, therefore, decided to take the responsibility for construction of ditches and dikes on the project area. But the repayment of the construction costs, in the form of a land tax, must be repaid by the farmers.

d. Feeder Roads

A feeder road is usually built on one side of the embankment of a main canal or principal lateral. The advantage is to reduce the construction cost of the road's base because an embankment of a large canal can be well adapted as a roadway. Feeder roads in an irrigation project provide facilities for transportation of materials, equipment, and labor during the periods of construction and operation of

the project. They also provide for transportation of products produced from farms after the project has been constructed.

The construction cost of 8 feeder roads, about 52 miles in total length, for the Kang Krachan Project is estimated at 27,660,000 bahts or $1,383,000, Table 14.

Table 14. Estimated Cost of Feeder Roads for the Kang Krachan Project

Item	Cost in baht	Cost in $
Wages, Engineering supervision and administration, materials, and others	15,186,000	759,300
Fuel	1,950,000	97,500
Spare parts	3,114,000	155,700
Equipment	7,410,000	370,500
Total	27,660,000	1,383,000

Source: Derived from, Thailand. Royal Irrigation Department, Ministry of Agriculture. Petchburi Project, Tables and Maps. Bangkok, July 1962. p. 3 and 31.

e. Flood Control

Although the main purpose of the Kang Krachan Project is designed for irrigation, its impounding dam and resulting reservoir will conserve excess water in the rainy season and serve flood control purposes. However, the project does not require other or special flood control structures. Thus, the cost of flood control is not

considered as an added cost but as a resulting benefit.

f. Hydro-electric Power

The costs of power generating plant and transmission lines are not included as part of the total project cost at this time. The reason is that the Petchburi Province and nearby area are in the power network of the initial installation of generators at the Yanhee Project. Thus, the construction and installation of facilities and the production of power at the Kang Krachan Project damsite can be postponed until the time when electricity is needed. Provisions for future construction of power generating facilities will not materially increase the cost of the project as already outlined.

g. Operation and Maintenance

The O & M costs are estimated at 2 bahts per rai. This is based on experience on other long term state irrigation projects. For the irrigable area of 220,000 rais (88,000 acres) which is made up of 122,000 rais of land on the Kang Krachan Project receiving water for the first time and 98,000 rais on the existing Petchburi Project which will receive water during the dry season, the O & M costs would be 440,000 bahts or $22,000 annually.

h. Financing Charges

From all costs mentioned above, except the O & M charges, the total construction cost of the project is estimated to be 207,092,000 bahts or $10,354,600. A loan equal to the cost of the project will be needed to permit the construction of the project. Using the even payment amortization plan which calls for equal combined payments of principal and interest each year, with a 4 percent interest rate and a repayment period of 15 years, the total payment or the total project cost including interest becomes 279,391,230 bahts which is equivalent to $13,969,561.

In computation of the annual payment the formula

$$R = A \frac{i}{1 - (1 + i)^{-N}},$$

where

R = Annual payment

A = Principal

N = Repayment period

i = Rate of interest,

is used. Then,

$$R = 207,092,000 \frac{0.04}{1 - (1 + 0.04)^{-15}}$$

$$= 207,092,000 \; \frac{0.04}{1 - \frac{1}{(1.04)^{15}}}$$

$$= 207,092,000 \; (0.0899411)$$

$$= 18,626,082 \text{ bahts.}$$

For the repayment period of 15 years, the total amount which must be paid in the form of principal and interest is 18,626,082 bahts x 15 years which is 279,391,230 bahts. The interest charged on a 15 year payout would be 72,299,230 bahts.

2. Benefits

a. Irrigation

According to the main purpose of the Kang Krachan Project, irrigation benefits are considered the most important of all benefits created.

In order to evaluate the benefits from irrigation three kinds of benefits will be studied, these are direct benefits, indirect benefits, and public benefits respectively.

Direct Benefits

Direct benefits are the value of the immediate products and services for which the direct costs were incurred (1, p. 22).

There are two categories of direct benefits:

(1) The increase in "family living", including the home grown products consumed by the family, the higher level of other perquisites such as the farm dwelling, and the increase of the cash allowance for family living expenditures;

(2) The increase in cash income after the deduction of all production expenses, including a charge for depreciation and interest on the farm investment, and the deduction of the increase in the cash living allowance.

It has been mentioned that the irrigable area of the Kang Krachan Project is 122,000 rais (48,800 acres). Without irrigation, the cultivated area of this vast plain is only 45,075 rais (18,030 acres), of which 40,000 rais (16,000 acres) are rice fields while the other 5,075 rais (2,030 acres) are used for upland and dry season crop production. With sufficient irrigation water for the entire year from the Kang Krachan reservoir, the paddy area is expected to be 100,000 rais (40,000 acres). Besides, in the dry season, several kinds of crops can be grown in the project area and also in several parts of the Petchburi Irrigation Project.

In computation of direct benefits the principle of "with and without irrigation" will be employed.

The data used in calculation of the total production of the Kang Krachan Project are shown in the following Tables.

Table 15. Data for Calculation of Total Crop Production and Benefits of the Kang Krachan Project

Crop	Area-rais	Crop Yield metric ton/rai	Average Farm Price bahts/metric ton	Consumed	Cost of Fertilizer bahts/rai	Cost of Seed bahts/rai
Without Irrigation						
1. Rice	40,000	0.360	800	1.5 tons/family/year	---	8
2. Sugar cane	1,700	4.930	84	20 %	---	30
3. Bananas	1,000	1.200	650	20 %	---	128
4. Coconuts	775	1.400	800	20 %	---	75
5. Caster beans	1,600	0.160	2,000	---	---	10
With Irrigation						
1. Rice	100,000	0.460	800	1.5 tons/family/year	---	8
2. Sugar cane	20,000	4.930	84	20 %	---	30
3. Bananas	10,000	1.200	650	20 %	---	128
4. Coconuts	2,000	1.600	800	20 %	---	75
5. Caster beans	5,000	0.160	2,000	---	---	10
6. Cotton	20,000	0.090	3,500	---	---	3
7. Corn	80,000	0.200	900	20 %	---	3
8. Mung beans	13,000	0.150	3,200	20 %	---	5
9. Soybeans	10,000	0.130	3,000	20 %	---	6
10. Peanuts	42,000	0.105	2,000	20 %	---	40
11. Sesame	10,000	0.140	3,500	20 %	---	4.8
12. Chilli	3,000	0.185	4,000	20 %	---	70
13. Onions	5,000	1.500	2,500	20 %	---	75

Table 16. Total Production of the Kang Krachan Project With and Without Added Irrigation Water

Crop	Cultivated Area rais	Crop Yield metric ton/rai	Total Production in metric tons	Average Farm Price bahts/ metric tons	Value in bahts	Cost of Seed in bahts	Cost of Fertilizer in bahts	Net Farm Income in bahts
Without Irrigation								
1. Rice	40,000	0.360	14,400	800	11,520,000	320,000	---	11,200,000
2. Sugar cane	1,700	4.930	8,381	84	704,004	51,000	---	653,004
3. Bananas	1,000	1.200	1,200	650	780,000	128,000	---	652,000
4. Coconuts	775	1.400	1,085	800	868,000	58,125	---	809,875
5. Caster beans	1,600	0.160	256	2,000	512,000	16,000	---	496,000
Total . . .	45,075	---	25,322	---	14,384,004	573,125	---	13,810,879
With Irrigation								
1. Rice	100,000	0.460	46,000	800	36,800,000	800,000	---	36,000,000
2. Sugar cane	20,000	4.930	98,600	84	8,282,400	600,000	---	7,682,400
3. Bananas	10,000	1.200	12,000	650	7,800,000	1,280,000	---	6,520,000
4. Coconuts	2,000	1.600	3,200	800	2,560,000	150,000	---	2,410,000
5. Caster beans	5,000	0.160	800	2,000	1,600,000	50,000	---	1,550,000
6. Cotton	20,000	0.090	1,800	3,500	6,300,000	60,000	---	6,240,000
7. Corn	80,000	0.200	16,000	900	14,400,000	240,000	---	14,160,000
8. Mung beans	13,000	0.150	1,950	3,200	6,240,000	65,000	---	6,175,000
9. Soybeans	10,000	0.130	1,300	3,000	3,900,000	60,000	---	3,840,000
10. Peanuts	42,000	0.105	4,410	2,000	8,820,000	1,680,000	---	7,140,000
11. Sesame	10,000	0.140	1,400	3,500	4,900,000	48,000	---	4,852,000
12. Chilli	3,000	0.185	555	4,000	2,220,000	210,000	---	2,010,000
13. Onions	5,000	1.500	7,500	2,500	18,750,000	375,000	---	18,375,000
Total. . .	320,000	---	195,515	---	122,572,400	5,618,000	---	116,954,400

Table 17. Products Consumed in Farm Households, Kang Krachan Project, With and Without Added Irrigation Water

Crop	Total		Consumed	
	Metric Tons	Value in bahts	Metric tons	Value in bahts
Without Irrigation				
1. Rice	14,400	11,520,000	2,202.0	1,761,600
2. Sugar cane	8,381	704,004	1,676.2	140,801
3. Bananas	1,200	708,000	240.0	156,000
4. Coconuts	1,085	868,000	217.0	173,600
5. Caster beans	256	512,000	---	---
Total	25,322	14,384,004	4,335.2	2,232,001
With Irrigation				
1. Rice	46,000	36,800,000	4,885.5	3,908,400
2. Sugar cane	98,600	8,282,400	19,720.0	1,656,480
3. Bananas	12,000	7,800,000	2,400.0	1,560,000
4. Coconuts	3,200	2,560,000	640.0	512,000
5. Caster beans	800	1,600,000	---	---
6. Cotton	1,800	6,300,000	---	---
7. Corn	16,000	14,400,000	3,200.0	2,880,000
8. Mung beans	1,950	6,240,000	390.0	1,248,000
9. Soybeans	1,300	3,900,000	260.0	780,000
10. Peanuts	4,410	8,820,000	882.0	1,764,000
11. Sesame	1,400	4,900,000	280.0	980,000
12. Chilli	555	2,220,000	111.0	444,000
13. Onions	7,500	18,750,000	1,500.0	3,750,000
Total	195,515	122,572,400	34,268.5	19,482,880

The U. S. Bureau of Reclamation method is used for the derivation of direct benefits. Some adjustments, however, are needed to suit the conditions in Thailand. Pertinent information relative to the determination of irrigation benefits accruing through improvements in family living is shown below. The family living increases are at rates generally more conservative than recommended by the Bureau of Reclamation.

	Without Irrigation	With Irrigation
1. Cash expenditures for family living a year per family	3,495 bahts	3,845 bahts
2. Rental value of dwelling a year per family	30 bahts	30 bahts
3. Cash brought in by new settlers per new family	---	1,000 bahts
4. Investment on farm per family	35,253 bahts	37,015 bahts
5. Interest on farm investment	10 percent	10 percent
6. Depreciation on farm equipment per farm	283 bahts	283 bahts
7. Cash production expenses for rice per family	2,178 bahts	2,487 bahts

Table 18. Estimated Direct Irrigation Benefits From the Kang Krachan Project

Item	Without Irrigation	With Irrigation	Difference	Benefits
1. Type of farm	Dry farms	Irrigated farms		
2. Number of farms	1,468	7,166	5,698	
3. Rais per farm	30.7	30.7		
4. Area-rais	45,075	220,000	174,925	
	bahts	bahts	bahts	bahts
Increase in family living				
5. Products consumed	2,232,001	19,482,880	17,250,879	
6. Rental value of dwelling	44,040	214,980	170,940	
7. Cash expenditures for family living	5,130,660	27,553,270	22,422,610	
8. Total used for family living	7,406,701	47,251,130	39,844,429	
9. Less cash brought in by new settlers			5,698,000	
10. Net increase in family living			34,146,429	34,146,429
Increase in cash income				
11. Total products	14,384,004	122,572,400	108,188,396	
12. Less cash production expenses (including seeds and fertilizer)	3,770,429	23,439,842	19,669,413	
13. Less interest on investment	172,505	884,165	711,660	
14. Less depreciation	415,444	2,027,978	1,612,534	
	10,025,626	96,220,415	86,194,789	
15. Less total used for family living	7,406,701	47,251,130	39,844,429	
16. Payment capacity	2,618,925	48,969,285	46,350,360	46,350,360
17. Total direct irrigation benefits				80,496,789
18. Total direct irrigation benefits at 90%				72,447,110

Source: Table design follows Department of the Interior. Reclamation Manual 2.2.3.

Indirect Benefits

Indirect benefits which are also referred to as secondary benefits are the values added to the direct benefits as a result of business activities "stemming from or induced by" the project.

In the benefit-cost analysis many kinds of indirect benefits must be considered. These benefits, however, can be divided into two classes. The first class comprises those benefits which accrue in connection with the economic activity generated by the processing of the immediate products. The indirect benefits in this class are called "stemming benefits" because they accrue from increases in business opportunity. The second class consists of those benefits considered to accrue because expenditures for items needed in the production process by the producers of the immediate products stimulate other kinds of beneficial economic activities. These benefits are referred to as "induced benefits".

The indirect irrigation benefits of the Kang Krachan Project, thus, include the benefits stemming from the sales of added products for local and non-local processing, marketing, etc., and the induced benefits which represent the added profits of all enterprises from supplying goods and services for increased farm family purchases for family living and production requirements.

The indirect irrigation benefits of the Kang Krachan Project are

calculated from the U. S. Bureau of Reclamation method with some modification. The estimated indirect stemming benefit factors, as shown in Table 19, are used for approximating stemming benefits. These factors represent the best information that is available but are not based on empirical data.

Table 19. Estimated Indirect Stemming Benefit Factors for the Kang Krachan Project

Crop	Factor (percent)
1. Rice	13
2. Sugar cane	26
3. Bananas	24
4. Coconuts	24
5. Caster beans	30
6. Cotton	83
7. Corn	24
8. Mung beans	23
9. Soybeans	30
10. Peanuts	30
11. Sesame	24
12. Chilli	24
13. Onions	24

Source: These indirect stemming benefit factors are estimated. They are not based on empirical data.

Table 20. Estimated Indirect Irrigation Benefits from the Kang Krachan Project

Item	Without Irrigation	With Irrigation	Difference	Factor %	Benefits
1. Type of farm	Dryfarms	Irrigated farms			
2. Number of farms	1,468	7,166	5,698		
3. Rais per farm	30.7	30.7			
4. Area-rais	45,075	220,000	174,925		
A. Sales for local and non-local processing, marketing, etc.					
	bahts	bahts	bahts		bahts
5. Rice	11,520,000	36,800,000	25,280,000	13	3,286,400
6. Sugar cane	704,004	8,282,400	7,578,396	26	1,970,383
7. Bananas	780,000	7,800,000	7,020,000	24	1,684,800
8. Coconuts	868,000	2,560,000	1,692,000	24	406,080
9. Caster beans	512,000	1,600,000	1,088,000	30	326,400
10. Cotton	---	6,300,000	6,300,000	83	5,229,000
11. Corn	---	14,400,000	14,400,000	24	3,456,000
12. Mung beans	---	6,240,000	6,240,000	23	1,435,200
13. Soybeans	---	3,900,000	3,900,000	30	1,170,000
14. Peanuts	---	8,820,000	8,820,000	30	2,646,000
15. Sesame	---	4,900,000	4,900,000	24	1,176,000
16. Chilli	---	2,220,000	2,220,000	24	532,800
17. Onions	---	18,750,000	18,750,000	24	4,500,000
Subtotal benefit "A"	14,384,004	122,572,400	108,118,396	-	27,819,063
B. Purchases for family living and production expenses.					
18. Direct farm benefits			82,631,770		
19. Less increase in products consumed and rental value of dwelling			17,421,819		
20. Less increase in farm production expenses			19,669,431		
Subtotal benefit "B"			45,540,538	18	8,197,297
21. Total indirect irrigation benefits					36,016,360
22. Total indirect irrigation benefits at 90%					32,414,724

Source: Table design derived from Department of the Interior, Reclamation manual. 2.2.6.

Public Benefits

Public benefits, which also are considered as induced benefits, must be evaluated in monetary terms. According to the U. S. Bureau of Reclamation, public benefits consist of five categories. These are:

1. Settlement opportunities
2. Employment opportunities
3. Investment opportunities
4. Improving community facilities and services
5. Stabilization of economy

Settlement opportunities. The benefit from settlement opportunities per family is credited to a project for every opportunity to establish a family farm.

This benefit must be explained in terms of the intrinsic worth of the creation of opportunities for family farms, and must be valued in terms of the advantages of independent farm life (2, p. 215).

For the Kang Krachan Project, the benefit from settlement opportunities is estimated at 1,000 bahts per new farm. This amount is an arbitrary value of the opportunity cost.

Employment opportunities. The benefit from employment opportunities is the increase in income of laborers who might otherwise be seasonally unemployed, and to the wages paid to persons not

regularly in the labor force.

The benefit of this type, as Eckstein recommended, is the difference between the actual pay and the minimum pay which would induce them to give up their leisure (2, p. 216). Evaluation of this benefit, however, is possibly obtained when the data are available and correct. In Thailand, it is impossible to evaluate the benefit in this manner because the data, involving the minimum wages which cause laborers to accept employment, are not available. The benefit from employment opportunities for the Kang Krachan Project is, thus, estimated to be 1,000 man-days per year at the rate of 12 bahts per day. This provides an opportunity for workers to be employed more continuously throughout the project life.

Investment opportunities. The benefit of this type is claimed for the interest payments made on the farm investment if the area, without the water development project, is considered to offer no investment opportunities of investment of funds accumulated by the farmers.

The U. S. Bureau of Reclamation has suggested that a rate of not more than 1 1/2 percent should be used. Therefore, and because no estimate is available for Thailand, the 1 1/2 percent rate of interest on the increased farm investment is used in the computation of the benefit from investment opportunities for the Kang Krachan Project.

Improving community facilities and services. Improving community facilities and services can be seen from the extra

governmental services for which the extra taxes paid by the farms are spent.

The amount of this benefit is obtained, according to the U. S. Bureau of Reclamation, by estimating the increase in real and personal property taxes (2, p. 216).

As the situation in the U. S. differs from that in Thailand, this procedure is not applicable. For the Kang Krachan Project, this benefit is determined from the tax on the increased cultivated area at the rate of 5 bahts per rai. This tax can be spent to develop schools, public health, recreational facilities and religious activities.

Stabilization of economy. Without irrigation, the economic situation of the Kang Krachan Project area would be affected by unpredictable drought. Rice and dry season crop production depend upon rain water. When rainfall is below normal, great variation in yields from year to year occur. The elimination of the uncertainties of economic life by the availability of water for irrigation is, therefore, considered as a benefit through stabilization of the economy.

The benefits of this type are arbitrarily set at 5 percent of the direct benefits, except in areas where stabilization is desperately needed, then twice as much benefit is allowed (2, p. 217).

Because the Kang Krachan Project area has been subject to frequent and serious droughts, the benefit from stabilization of the local economy is set at 10 percent of the total annual direct benefits.

The estimate of public benefits of the Kang Krachan Project can be aggregated as follows:

1. Settlement opportunities	5,698,000 bahts
2. Employment opportunities	12,000 bahts
3. Investment opportunities	3,202,471 bahts
4. Improving community facilities and services	874,625 bahts
5. Stabilization of economy	8,049,679 bahts
Total public benefits.	17,836,775 bahts
Total public benefits at 90 percent	16,053,097 bahts

b. Benefits From Preventing Flood Damage

Some small scattered depression areas in Muang Petchburi and Ban Laem Districts, which lie outside of the Petchburi and Kang Krachan Projects, are sometimes damaged by a large flood of the Petchburi River. The Kang Krachan Project, when completed, will prevent flood damage on the paddy fields of about 4,000 rais (1,600 acres) in these areas. The benefits accruing to farmers will be in the form of the value of rice sold after deducting the value of seeds, rice consumed, and production expenses.

Rice production = 4,000 x 0.460

= 1,840 metric tons

Seeds and consumed	=	(4,000 x 0.010) + (130 x 1.5)
	=	235 metric tons
Rice sold	=	1,840 - 235
	=	1,605 metric tons
Value of rice sold	=	1,605 x 800
	=	1,284,000 bahts
Production expenses	=	2,178 x 130
	=	283,140 bahts
Benefits from preventing flood damage	=	1,284,000 - 283,140
	=	1,000,860 bahts

c. Benefits From Domestic Water

This project, as previously stated, also will provide water for domestic use at Cha-am, Hua Hin, and other villages. Water divert ed from the Petchburi River at the headworks of the Petchburi Irrigation Project flows by the Hua Hin Canal which has been constructed for the purpose of conveying both irrigation and domestic water. The canal's route passes through these villages to the extreme end where the Hua Hin District is located, about 30 miles south of Petchburi City.

At present, a serious water shortage for domestic use in the dry season occurs in these areas. As the river flow recedes to only

0.50 m^3/sec., there is practically no water discharged into the canal from February to May. To satisfy the desperate need for water, several large storage ponds have been built along the Hua Hin Canal. Water released from the canal, in the wet season, has been stored in the ponds which has served as the source of domestic water in the dry season. This supplementary water, however, has not been sufficient to meet needs. The people still suffer from water shortage due to population growth and the expansion of some cash crop production in the dry season. The water shortage at the Hua Hin District becomes more serious in the period from February to May. During this period the number of water users increases rapidly because Hua Hin is one of the seaside resorts of the country.

By the Kang Krachan Project, 1 m^3/sec. of water from the reservoir can be delivered mainly to the Hua Hin District for domestic use during these four months. No special construction works are required for such an objective.

The benefits from domestic water are expressed in the form of a municipal tax expected to be imposed on the water users at the rate of 0.50 baht per cubic meter. Because actual expense data are not available all expenses associated with the processing and distributing of domestic water are estimated at 0.25 baht per cubic meter. The total annual benefits, aggregated in the four-month period of each year, are estimated to be 2,592,000 bahts.

3. Benefit-Cost Ratios

According to the proposed construction schedule, the Kang Krachan Project will require six years for completion of its construction works. As a conservative estimate, the direct irrigation benefits, indirect irrigation benefits, and public benefits are scaled to 90 percent of their corresponding totals. Under these conditions, the total annual benefits created by the Kang Krachan Project can be summarized as follows:

Direct irrigation benefits	72,447,110 bahts
Indirect irrigation benefits	32,414,724 bahts
Public benefits from irrigation	16,053,097 bahts
Total annual irrigation benefits. . . .	120,914,931 bahts
Benefits from preventing flood damage	1,000,860 bahts
Benefits from domestic water	2,592,000 bahts
Total annual project benefits.	124,507,791 bahts

In Current Concepts and Practices in Benefit-Cost Analysis of Natural Resource Developments, Regan and Timmons stated

> The period of analysis used by the various agencies is in process of change. All agencies use the economic life as the upper limit on project life. The Budget Bureau Circular prescribes the economic life, or 50 years, whichever is less. All costs are amortized during the period. Methods of handling replacements and salvage or remaining use

> values vary by agencies, and the problem is not specifically covered in the Budget Bureau Circular. (4, p. 8)

As the Petchburi River possesses a small watershed area and steep slopes, the reservoir, which will be formed up by an impounding dam, is rather small. Owing to a great quantity of silt usually carried by a large flood, it is expected that the storage capacity of the reservoir will be diminished by sedimentation and will become inadequate for requirements or worthless in a relatively short period of time. All irrigation canals and ditches of the Kang Krachan Project, which are small channels built in earth and generally called earth canals, are easily damaged. Roadways, embankments, and dikes are also nonpermanent structures. The economic life of the project is reasonably considered as 30 years which will be used as the basis for the benefit-cost analysis of this project.

The total project cost, as discussed on page 51, is estimated to be 207,092,000 bahts. This cost is amortized over a 30-year economic life period at a 4 percent interest rate. Thus,

$$\text{The annual investment cost becomes} = 207,092,000 \; \frac{0.04}{1 - \frac{1}{(1.04)^{30}}}$$

$$= 207,092,000 \; (0.05783010)$$

$$= 11,976,151 \text{ bahts}$$

The annual operation and maintenance costs are projected for the total project at 440,000 bahts which must be added as part of the total

annual project cost. This cost is based on an expenditure of 2 bahts per rai.

To be on the conservative side, no salvage value is considered to remain at the end of the analysis period. Salvage value, therefore is not involved in the determination of the total annual project costs. Thus, the replacement cost would be 6,903,067 bahts annually. This amount is derived by dividing the total project cost of 207,092,000 bahts by 30 years.

All annual costs associated with the Kang Krachan Project can be aggregated as follows:

Investment cost	11,976,151 bahts
Operation and Maintenance costs	440,000 bahts
Replacement cost	6,903,067 bahts
Total annual project cost.	19,319,218 bahts

The benefit-cost ratios with this annual cost structure become as follows:

1. Total project benefit-cost ratio $= \frac{124,507,791}{19,319,218}$

$= 6.4$

2. Total irrigation benefit-cost ratio $= \frac{120,914,931}{19,319,218}$

$= 6.3$

3. Direct irrigation benefit-cost ratio $= \frac{72,447,110}{19,319,218}$

$= 3.8$

These benefit-cost ratios are considered favorable and justify the development of the project.

4. Cost Allocation

Cost allocation is the process of apportioning project costs among the various purposes served by the project (13, p. 47). It is applicable to total project costs, including investment costs and costs of operation, maintenance, and replacement.

The objective of cost allocation is to distribute project costs equitably among the purposes served. Equitable distribution is achieved by preventing costs allocated to any purpose from exceeding corresponding benefits. As some purposes of the project may either be reimbursable or non-reimbursable, the method of cost allocation provides determination of how much the non-reimbursable part is to be carried by taxpayers and how much the direct beneficiaries should carry.

To allocate the project costs, the Subcommittee on Evaluation Standards recommended the separable costs-remaining benefits method. But where the separable costs cannot be readily estimated, the use of specific costs in accordance with the alternative justifiable

expenditure method is acceptable (13, p. 50).

The separable costs-remaining benefits method requires determination of separable costs and equitable distribution of costs incurred for several purposes in common. The procedure of cost allocation by this method is explained in the paragraphs that follow.

The separable cost for each project purpose is the difference between the cost of the multiple-purpose project and the cost of the project with the purpose omitted (13, p. 48).

The residual costs, which are distributed among several purposes, are defined as the difference between the cost of the multiple-purpose project as a whole and the total of the separable costs for all project purposes. Residual costs thus represent a remaining joint cost attributable to all or several purposes (13, p. 49).

In the cost allocation, the amount of project benefits used as a basis for allocation of the joint cost to any purposes is limited by the alternative cost which is the cost of providing equivalent services.

The differences of the benefits, limited by the alternative cost, for each purpose and their corresponding separable costs are called the remaining benefits from various purposes.

The residual or remaining joint cost, as mentioned above, must be allocated to all purposes in proportion to their remaining benefits.

Then, the total allocation to any purpose is the sum of the separable cost and the allocated joint cost for that purpose.

The recommended method of cost allocation is shown in Table 21.

Table 21. Hypothetical Example of Cost Allocation by Separable Costs-Remaining Benefits Method

Item	Irrigation	Flood Control	Industrial Water Supply	Total
	bahts	bahts	bahts	bahts
1. Benefits	60,000	40,000	20,000	120,000
2. Alternative cost	50,000	50,000	15,000	115,000
3. Benefits limited by alternative cost (lesser of items 1 and 2)	50,000	40,000	15,000	105,000
4. Separable costs	30,000	30,000	10,000	70,000
5. Remaining benefits (items 3-4)	20,000	10,000	5,000	35,000
6. Allocated residual cost	5,714	2,857	1,429	10,000
7. Total allocation (items 4+6)[1]	35,714	32,857	11,429	80,000

[1] In this example, the total multi-purpose project costs are assumed to be 80,000 bahts.

It is seen that the separable costs-remaining benefits method involves some complicated engineering calculations. This method, however, is applicable to cost allocation for the Kang Krachan Project. However, inasmuch as important data, such as single purpose alternative costs and separable costs for each phase of the multi-purpose project are not available, the allocation of costs for this project cannot be carried out.

It should also be stated that the purpose of discussion of cost allocation, as previously mentioned, is to recommend a possible repayment method which can be applied to multi-purpose water resource development projects in Thailand. The problem of repayment, at present, has never arisen because costs of all projects have been

repaid by the federal taxpayers. It is, thus, unnecessary to allocate the cost of the Kang Krachan Project for various purposes at the present stage of policy in my country.

CHAPTER 5

SUMMARY AND CONCLUSION

From the benefit-cost ratio analysis of the Kang Krachan Project in the preceding chapter, it is seen that the total project benefit-cost ratio is 6.4, the total irrigation benefit-cost ratio is 6.3 and the direct irrigation benefit-cost ratio is 3.8. The closeness of the total irrigation benefit-cost ratio to the total project benefit-cost ratio indicates that the principal benefits are created by irrigation. The benefit-cost ratios determined for this project are very favorable. It has not been determined whether other project alternatives would show more favorable ratios to establish priority of projects. Determination of whether other more profitable investment alternatives outside of irrigation development exist for the utilization of scarce capital resources has not been covered as an issue pertaining to this thesis problem.

Generally speaking, the Kang Krachan Project, as a sub-phase of the larger Petchburi Project, will be built to complete a full scheme of water resource development in the whole Petchburi Plain. The Kang Krachan Project combined with the Petchburi Project will provide a water conservation work for the purposes of irrigation, flood control, water for domestic use, and eventually hydro-electric

power. Therefore, no larger scale development than the Kang Krachan Project is needed. As a multi-purpose project, the Kang Krachan Project also will produce greater benefits than any combination of smaller projects.

It is realized the benefits from the Kang Krachan Project are in excess of the project costs, and each separable segment or purpose produces benefits sufficient to cover the costs of its inclusion. This project is, therefore, considered properly formulated and economically justified.

Development of water resources in Thailand has increased rapidly during the past 60 years. However, all modern irrigation projects which have been built are single-purpose projects. At present, water development projects should be multi-purpose projects to provide sufficient benefits for the fast growing population, for economic progress and to harness the full potential of the resource. Thus, the Kang Krachan Project is the first complete multi-purpose project scheduled to be built in Thailand.

The method of benefit-cost analysis, used for water development projects in the U. S., is applicable as a guide for multi-purpose projects in Thailand. However, some modification of computing the benefits are needed at the present stage of economic development of Thailand. This is due to the fact that situations in Thailand are not the same as those in the U. S., such as the standard of living of the

people, methods of farming, kinds of crops grown, taxation, government policy, and so forth. As a non-reimbursable policy is used in Thailand, the costs of all projects are repaid by the federal taxpayers. But, for the Kang Krachan Project, inasmuch as the government will provide ditches and dikes on farmlands for the farmers, a land tax for the project area must be paid by the farmers. A municipal water tax also will be paid by the users of domestic water. Thus, repayment of construction costs of the Kang Krachan Project is proposed from a land tax, municipal water tax, and revenues derived from the differential in the domestic and export price of rice.

The non-reimbursable policy eventually must be changed to a reimbursable policy. It is expected, in the future, that the allocation of project costs by the separable costs-remaining benefits method will play an important role in the repayment of the project costs. The reimbursable part of the project costs must be carried by farmers or direct beneficiaries while the non-reimbursable part will continue to be carried by the federal taxpayers.

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