STUDY ON GROUND WATER USE FOR FARMING AT BAN NAKAH VILLAGE AS A BASIC FACTOR OF RURAL AGRICULTURAL DEVELOPMENT IN THAILAND

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ABSTRACT

STUDY ON GROUND WATER USE FOR FARMING AT BAN NAKAH VILLAGE AS A BASIC FACTOR OF RURAL AGRICULTURAL DEVELOPMENT IN THAILAND

By

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Since 81 per cent of Thailand's population are farmers, and since 90 per cent of total foreign exchange earnings come from agricultural products, to develop agriculture in the rural areas is the basic factor in increasing Thailand's economy. Besides, the development of transportation and marketing for agricultural products, ground water use in the areas of nonsurface water availability is a basic factor of farming.

The report areas have an abundant ground water resource which is readily available throughout the country. Ground water for irrigation is obtained from bedrock aquifers. Shallow high capacity wells are possible utilizing recharge through permeable unconsolidated reservoir rocks and consolidated rocks. Water from alluvium can be classified as being of low sodium hazard. In general, water from aquifer is suitable for irrigation under most ordinary conditions. Water from shale and siltstone of the upper Khorat Group are not studied because the quality yielded by the majority of wells is not sufficient for most agricultural uses. Sandstone produces waters somewhat similar to that of alluvium so far as irrigation is concerned.

The water is satisfactory for most agricultural uses. Water from limestone can be grouped as low sodium hazard and low to high salinity. The concentrations of boron and chloride in the water are not reported as a problem for irrigation. Most of the brackish and salt water has not exceeded 250 mg/l of chloride content.

The study on ground water use for farming is based on cost and benefit analysis in consideration. Figures, tables of basic data of ground water available and expenditures of drilling ground water wells against the income from these investments are included for reference and analysis.

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This work is dedicated to the Thai farmers who have devoted themselves to my country for centuries, and to my parents to whom my debt is beyond thanks.

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GLOSSARY

Aquifer	Subsurface zone capable of producing water, as from a well.
Baht	The monetary unit used in Thailand.
Bedrock	Solid consolidated rock.
Brackish	Slightly salty water.
Capacity	Refers to the amount of water an aquifer will yield.
Cavern	Large cave with water in bedrock strata--such as a limestone cavern.
Conglomerate	The hard rock produced by cementation of gravel.
Consolidated	Earth materials which have been pressed or cemented into a compact mass.
Depreciation	A lessening value.
Discount rate	An annual basis and expressed as the ratio between the discount and the maturity value.
gpm	Gallons per minute
Ground Water	Subsurface water which is the zone of saturation (below the water table).
Limestone	A rock formation that consists of calcium carbonate.
ppm	Parts per million.
Permeability	Measurement of the resistance encountered by water in its attempt to move through a porous material.
Porosity	A measure of the percentage of a porous material which is open spaces.
Rai	A measure of land which is equal to 1,600 square meters.

Rate of return	The marginal efficiency of capital or the return on operating asset investment.
Recharge	Replenishing the ground water with natural precipitation or through artificially induced infiltration.
Mg/l	Milligrams per liter.
Sandstone	A cemented or otherwise compacted rock which is predominantly composed of sand-sized particles.
Shale	Clay which has been compacted to form a soft rock which breaks easily into thin layers.
Sinking fund	Defined as a segregation of funds to be applied to debt reduction.

CHAPTER I

INTRODUCTION

I. THE IMPORTANCE OF AGRICULTURE IN THAILAND'S ECONOMY

Agriculture occupies the place of pivotal importance in Thailand's economy, providing employment to 81 per cent[1] of the nation's population. About one-third[2] of the Gross Domestic Product originates in the agricultural sector, consisting of agricultural crops, livestock, fisheries and forestry, and substantially more income is earned in the marketing and processing of agricultural commodities. The major exports of Thailand still remain the primary products, rice, rubber, teak, maize, kenaf, cassava, oil seeds, and other upland crops which account for 90 per cent[3] of total foreign exchange earnings. Thailand's overall economic progress depends on first developing the agricultural sector in order to lay a sound basis for further development of the other sectors of the economy.

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[1]Somnuk Sriplung, Potentials in the Economic Development of Thailand Agriculture (Bangkok, Thailand: Ministry of Agriculture, 1968), p. 7.

[2]The National Economic Development Board, The Second National Economic and Social Development Plan (1967-1971) (Bangkok, Thailand: 1968), p. 83.

[3]Ibid.

> In the developing countries if the policy that agricultural and industrial development should be synchronized within the economy is correct, one would agree with the view that the future economy of Thailand will depend largely on how fast the traditional agriculture can be transformed into the modern and scientific agriculture and how fast for shifting population from the agricultural sector to the non-agricultural sector in the next decade.[4]

In the less advanced countries, skill and capital are limited and if we put too much emphasis on industry at first we would probably be draining away skill we need for the government or for agriculture or for the other parts of the economy. We may have to raise territory, get all sorts of control. For Thailand, we have 81 per cent of the population as farmers already in their fields, but they do not practice modern scientific agriculture. It would be better to develop them into modern and scientific agriculture in order to increase agricultural growth for the few each year then to increase industrial growth.

Many people consider agriculture merely as the improvement of enterprise or the formation of projects. The former refers to better production of individual crops or livestock. The latter refers to the expansion and extension of farm requisites such as seeds, fertilizers, irrigation, agricultural chemicals, implements, as well as credit. It is true that all these are essential, or accelerators, for agricultural development. But the

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[4]The Proceedings of the Sixth National Conference on Agricultural Sciences, Agricultural Economics (Bangkok: Kasetsart University Press, 1967), pp. 52-53.

fundamental elements of agriculture consist of the farmers, their farms, and their farm businesses. Agriculture in Thailand is an industry that involves the production process of 3.2 million small farms.[5] The strength of farm economy in Thailand should not be measured only by the number of agricultural development projects but should be judged by the actual production and living conditions in the rural village where the farmers work, shelter, and trade.

Traditional methods of farming refer to the cultivation practices inherited by farmers from the experiences of their ancestors and are still in use. Some of them may remain to be used for years because the biological nature of both plants and animals do not change much. Some of them have to be discarded should the farmers intend to increase production efficiency in order to be able to complete favorably the other. This will call for partial and gradual changes. So innovation in the production process is necessary if the farm level has become a function of agricultural metabolism.

II. OBJECTIVES AND POLICY

One of the primary policy objectives in the development of the agriculture sector is to accelerate and diversify production, to assure that the benefits of higher

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[5]Ministry of Agriculture, A Study on Agricultural Economic Conditions (Bangkok: Phakdi Pradit Press, 1965), p. 1.

productivity accrue to the farmers and to promote the security and dignity of agricultural occupations. The following specific objectives are designed to realize the general sector policy objective:[6]

A. To improve and expand the government infrastructure projects, such as irrigation and transportation, in the rural areas.

B. To develop the natural agricultural resources and to utilize them efficiently to obtain the maximum long term economic benefits.

C. To improve and strengthen agricultural research and experimentation so as to moderate farming techniques and increase productivity.

D. To improve the quality and grading of agricultural products to satisfy domestic and foreign demands.

E. To improve the land-tenure system in order to promote commercialization of agriculture while maintaining the requisites of the contracting parties.

F. To promote agricultural institutions such as farmers' associations, cooperatives, people's irrigation associations, and young farmers' association, so that these institutions can represent the farmers and express their interests.

G. To improve the marketing system of agricultural products and to strengthen the bargaining position of the

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[6]The National Economic Development Board, The Second National Economic and Social Development Plan (1967-1971) (Bangkok, Thailand: 1968), p. 83.

farmers so that they will receive an equitable share of the final retail price of the commodities they produce.

H. To extend increased government services to the farmers, especially in the field of agricultural credit, price support for the principal crops and various extension services.

III. THE IMPORTANT ROLE OF GROUND WATER IN FARMING

Thai people have known how to practice diversion irrigation which is one of the objectives of water resources development for hundreds of years, but nothing has been known definitely as regards the advent of irrigation.

> The reason of its inception has naturally arisen from the needs for a large amount of water to grow rice which is the staple food of the Thai people and which requires water at a maximum height of ten m.m. per day. Therefore, if the rice grown of a heavy strain requires approximately six months or 183 days to bring it to maturity, water at a height of 1,830 m.m. will be needed throughout the rice growing season. In the case of rice of a medium strain requiring approximately 135-150 days, it will require water at a height ranging from 1,350-1,500 m.m.[7]

But the average rainfall during six months in the wet season in the north is about 1,075 m.m.[8] and some regions in Thailand is less than 1,000 m.m.[9] Not only is the rainfall insufficient but also irregular. It is therefore essential

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[7]The Ministry of National Development Handbook, Royal Irrigation Department (Bangkok, Thailand: 1970), p. 27.

[8]*Ibid*.

[9]Division of Agricultural Economics, Agricultural Statistics of Thailand (Bangkok: 1967), pp. 155-58.

to supplement the deficient supply of water.

With population pressure (population growth rate 3.2)[10] and to accomplish these goals, the more income and the more production targets, at least, the increase should be enough to feed additional mouths in the family, Thai farmers have to earn more of their income by changing of operational efficiency, the diversification of production lines, and the adopting of technological innovations.

Water is unfortunately the limiting resource, to permit rapid and widespread diversification of farming through second cropping.

> Although we have constructed many storages of water with capacity of 31,408.59 million cubic meters in 1970 and can supply water to cover 3,181,294 hectares of irrigable area, due to the lack of dikes and ditches to irrigate water to farms, only 1,539,984 hectares have water available from dikes and ditches.[11]

Almost all of the rest, 9,520,016 out of 11.1 million hectares of cultivated area,[12] depend on rainfall. Some of them try to get water for farming by digging ponds. Some farmers who own land adjacent to river banks get water for farming by pumping water from the rivers. Due to lack of surface water, water from dug wells had been in use for a long time. In the rural area, well water is usually used for consumption by both mankind and animals and a little for

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[10] Thailand Official Year Book (Bangkok: Government House Printing Office, 1964), p. 1.

[11] The Ministry of National Development Handbook, Royal Irrigation Department (Bangkok: 1970), pp. 70-71.

[12] Division of Agricultural Economics, Agricultural Statistics of Thailand (Bangkok: 1967), pp. 88-102.

agricultural purposes, especially for kitchen vegetable growing. The drilling of ground water wells in the water shortage sector will strengthen, to a great extent, the public welfare, in addition, farmers will be able to raise livestock throughout the year with a broad expansion opportunity, as well as vegetable growing for home consumption which is always in shortage in the dry season. Moreover, vegetable growing and raising livestock on a commercial scale can be practiced, which is the main objective of this study. Moreover, ground water will assist, to a great extent, rice cultivation during the water shortage period. The expansion of water pump usage from the water source has always been encountered with its location for pumping; the water sources development through the use of groundwater would accordingly be of great assistance. To achieve this objective and policy of increasing agricultural production, the author has to evaluate costs and benefits of ground water use for farming in order to indicate that this measure is an appropriate factor of rural agricultural development in Thailand.

those needed for optimum growth. "For most crops, however, water that contains 1 to 2 ppm is satisfactory. Water up to 3 ppm may be used with tolerant crops. Water that contains more than 3 ppm is definitely unsuitable for irrigation purposes."[25]

Howard F. Haworth, Pongpan Na Chiangmai and Charoen Phiancharoen (1966)[26] reported the study of chemical analyses for 738 producing water wells. The study showed that (1) The water has an average sodium chloride (NaCl) content of 62.93 ppm; 82% have NaCl of less than 50 ppm; 20% have NaCl less than 100 ppm, and 10% have NaCl in excess of 100 ppm. If the 77 wells having average NaCl of over 100 ppm are subtracted from this group, of the remaining 661 wells, 90% have an average NaCl content of only 15.36 ppm. (2) The dissolved solids content of 738 production wells tabulated averages 774 ppm. If the 77 wells having average NaCl content above 100 ppm are deleted from this group, the remaining 661 wells contain 536 ppm total dissolved solids. Water quality for the area as a whole has been much better than the initial work in the area indicated. Success has been due in part to the fact that wells have been drilled in all parts of the area, better drilling practices, and

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[25] Ibid., p. 324.

[26] Howard F. Haworth, Pongpan Na Chiangmai and Charoen Phiancharoen, Ground Water Resources Development of Northeastern Thailand (Bangkok: Kurusapha Press, Bulletin No. 2, 1966), pp. 192-217.

CHAPTER II

REVIEW OF LITERATURE

I. GENERAL CHARACTERISTICS OF TOPOGRAPHY AND GEOLOGY

According to the Thailand Official Yearbook (1968)[13] the general characteristics of topography and geology are as follows:

A. Topography

The topography of Thailand is characterized by (1) folded mountains, which are in the southeastward continuation of the Himalayan System; (2) flat alluvial plains which are intersected by winding rivers and irrigation canals and are flooded during each rainy season; (3) certain amount of undulating country; and (4) maritime features such as sandy beaches, mangrove swamps, irregular coastlines, and numerous islands.

For convenience of description, Thailand may be divided into five physiographic provinces, namely, the Northern Folded Mountains, the Central Plain, the Khorat Plateau, the Southeast and the Peninsula.

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[13]Thailand Official Yearbook (Bangkok: Printed at Government House Printing Office, 1968), pp. 2-10.

The Northern Folded Mountains

This province consists of a series of parallel and longitudinal folded mountains in continuation of the Himalayan System, which runs down through the east of Assam in India, Yunnan Province of China and the Shan State of Burma. This great arc of ranges continues further south through the Peninsula of Thailand and Malaysia.

The strata of sedimentary rocks in the folded mountains were broken lengthwise in many places causing a great mass of magma to force up and fill the gaps. Thus Inthanon and Khun Tan are the two long granitic ranges formed in this way. Between the ridges of these mountains are relatively flat basins, where four major tributaries of Maenam Chao Phya are flowing. These rivers are Mae Ping, Mae Wang, Mae Yom and Mae Nan. The important changwats (provincial centers), such as Chiang Mai, Lampang, Phrae and Nan are situated on these river banks. The alluvial soils of these intermontane basins are fertile for rice cultivation and for growing vegetables, tobacco and various kinds of fruit trees such as lamyai, lichi and oranges.

The average height of the peaks in this region is about 1,600 meters above mean sea level. Doi Inthanon, towering up to 2,576 meters, is the highest peak in the Kingdom, and is about 50 kilometers southwest of Chiang Mai. The plain of Chiang Mai itself is about 300 meters above mean sea level. Doi Suthep, very well known as a touristic spot, and where the Royal Palace, Phu Phing Ratchanivet is situated rises to 1,676 meters high, overlooking the city of Chiang Mai from the west.

This northern folded mountain system extends down the western provinces of Tak and Kanchanaburi and ends there. The folding in this part gives rise to the valleys of rivers, such as Mae Moei in Amphoe (district or subdivision of a province) Mae Sot of the Province of Tak, Mae Khwae Noi and Mae Khwae Yai in the Province of Kanchanaburi.

It should be noted that the four rivers: Maenam Ping, Maenam Wang, Maenam Yom, and Maenam Nan, must pass through the narrow gorges before leaving the northern valleys for the central plain. The summer monsoon brings a great deal of moisture from the Indian Ocean. The orographic condition of the northern mountains causes much rainfall. Rapid runoff in the streams accumulates into a big current in those rivers, and if the current cannot be drained through the narrow gorges soon enough, this will result in flood.

The stream gradient of the tributaries of the four major rivers in the north is generally steep. The strong runoff during the wet season brings down a great amount of sediments and deposits them right at the mouths of the streams. This process has built up a string of alluvial fans at the foot of the mountains. These delta fans will increase in size and later join together forming a continuous piedmont plain. The piedmont plains are therefore commonly found on both sides of the alluvial flood plains of these four major rivers. The soils on the piedmont plains are fertile and are generally utilized for upland crops.

There are also many limestone hills in this region and they are easily identified by their precipitous features. Doi Chiang Dao, 2,182 meters high, one of the highest limestone mountains, is north of Chiang Mai. A famous cave in this mountain is visited by many tourists from all over the country each year.

Many of the remains of the prehistoric man have been found and excavated from the limestone caves of Changwat Kanchanaburi.

The Khorat Plateau

The Khorat Plateau, named after the second name of Changwat Nakhon Ratchasima, consists of two-sided fault and tilt rather than a uniform uplift of the strate of sedimentary rocks. The western tilt causes the ranges of Petchabun and Dong Phyayen to rise up longitudinally with their escarpments facing the central plain on the west. The elevation of the tilted rim of the plateau on this side varies from 130 to 200 meters above mean sea level, while the flat top mountains of Dong Phyayen are generally between 800 to 1,300 meters.

The southern tilt separates the plain of Cambodia from the plateau surface. Thus the two levels of land are traditionally called the Lower Cambodia and the Upper Thailand. The lifted portion forms latitudinal ranges of mountains known as San Kamphaeng and Dong Rak. The steep escarpments of these chains overlook the Cambodian plain in the south. The rim of the plateau on this side averages about 400 meters above mean sea level, while some of the peaks may rise to about 600 to 700 meters. When one stands on the edge of the escarpment or any high point on the chain of Dong Rak he will see a great expanse of the Cambodian plain, and it seems as he has seen the whole of Cambodia.

Close to the point, where the borders of Cambodia, Thailand and Laos meet at the southeast corner of the plateau, the rim of the escarpment turns northeastward to join with the junction between Mekong River and Maenam (River) Mun.

The land surface on the plateau slopes rather gently eastward towards the Mekong, while it does so fairly abruptly northward towards Maenam Mun. Maenam Chi flows southeast from the ranges of Petchabun to join with Maenam Mun which derives part of its water from Dong Phyayen mountains before uniting itself with Mekong River east of Changwat Ubon Ratchathani. The surface elevation of this Changwat is approximately 50 meters above mean sea level.

The general surface of the plateau is rolling with some studded flat top hills like Khao Yai and Phy Kadung. The tops are generally not horizontal, but are sloping in conformity with the tilt which has already been described.

Because of the rolling topography of the region, the drainage pattern is rather dendritic with the general direction of flow toward southeast. The heavy monsoon rain falling over the thin forest covers results in rapid run-off and causes flood almost yearly in Changwat Ubon Ratchathani, which is at the junction of Maenam Mun and Maenam Chi. These two major rivers and their tributaries on the plateau have built up scattered alluvial lands of various sizes. The largest among them is in Changwat Ubon Ratchathani where rice is the chief crop and its production is highest of the whole northeastern region.

Close to Mekong River the land surface is rather swampy with many lakes; the important one is Nong Han of Sakhon Nakhon. The presence of these lakes suggests the horizontality of the strata of sedimentary rocks as well as the shallow water table.

The great extent of the plateau consists of sandstone which is the parent material of the sandy soil found on the surface. The aridity of the region with its thirsty soil is traceable to this kind of rock. The underground water can be made available in many places by digging or boring of wells. But the water obtained is either salty or hard and therefore is not palatable or useful domestically. At present there are an increasing number of wells with fresh water, as a result of the government's drive to solve the water problems of the northeast.

Mekong River, which acts as the boundary between the

Kingdom of Laos and the Thai Kingdom meanders about in the north and east of the plateau. The section of this river along the frontier varies from 700 to 1,300 meters wide and is either studded with islands or broken up by many impassable rapids. The governments of the countries benefited by this river's system, including the Thai government, are determining to develop its water for agricultural and industrial purposes. Topographical surveys as well as scientific research are being taken for careful planning.

<u>The Southeast</u>

The Southeast, another part of Thailand's rolling country with many high hills in the center and along the eastern limit, extends from the foot of the San Kamphaeng range towards the south and includes Changwats Prachin Buri, Chon Buri, Rayong, Chanthaburi and Trat.

The area has been much dissected by numerous streams, all flowing in southerly direction; the important ones are Maenam Wen and Maenam Trat. One of the principal peaks in the Chanthaburi chain, Khao Khieo, rising 800 meters high up, is visible from the top of the Golden Mount in Bangkok. Another noted peak is Khao Soidao (literally means reaching for the stars), which towers 1,640 meters above mean sea level.

The southeast region is flanked on the east by a range of hills called Banthat (the ruler), because when looking at a distance far enough the top of the range appears as a straight line. This mountain range forms part of the frontier between Cambodia and Thailand.

Because the mountains in this region are close to the sea, the coastline is therefore much indented and fringed with rocky islands. Ko Chang, the largest island on this coast, and Ko Kut are very well known among tourists for their beautiful beaches and landscapes; the former contains a waterfall. Chon Buri and Rayong also have irregular coastlines with numerous islands not far from the shores; the important one is Ko Sichang which forms a good shelter for large ocean liners.

The short streams of this region have built up small alluvial basins and deltas along the coast. These are utilized for rice cultivation. The higher grounds and the well drained slopes are occupied by plantations, such as rubber, orchards, sugar cane, cassava and pineapple.

The big river mouths consist of tidal flats and mangrove swamps. Where there is no stream the coast is generally lined up with a beautiful beach and many coconut groves. Thus Chon Buri and Rayong are famous for their sea resorts with delightful weather most of the year.

The Central Plain

The Central Plain of Thailand may be divided into two distinct physiographic sub-provinces, the Northern Rolling Plain and the Chao Phya Delta.

The topography of the Northern Rolling Plain has been much dissected until its general surface has been levelled down much lower than the Northern Folded Mountains region; but it is still higher than the Chao Phya Delta. Only three major rivers flow through this rolling plain, namely, Maenam Ping with Maenam Wang already united, Maenam Yom and Maenam Nan. All of these rivers join together at Pak Nam Pho to form Maenam Chao Phya. The junction of these rivers is about the southern limit of the rolling plain. The north-south extent of this rolling topography is about Changwat Nakhon Sawan to Uttaradit, and the east-west extent is approximately from Changwat Kamphaeng Phet to the foot of the Phetchabun range.

The Chao Phya Delta commences south of Nakhon Sawan and extends down to the Gulf of Thailand. The triangular plain is traversed by two major rivers, Maenam Chao Phya and Maenam Tha Chin, the latter being known by different names as it flows through different changwats down to the gulf. The system of drainage in the Chao Phya Delta is the same as other deltas in many parts of the world, which are braided into many smaller channels, and are too numerous to be represented on the small scale maps. Another river, Maenam Pasak, flows down the valley of the Phetchabun ranges to join with Maenam Chao Phya at Changwat Ayutthaya. Maenam Maeklong on the west and Maenam Bangpakong on the east merely add the sediments to the lower part of the Chao Phya plain, and therefore form parts of this delta.

The flat land of the Chao Phya Delta is generally low and is usually flooded by rain water in the wet season, and this is very useful for rice growing. Bangkok, on the east bank of Maenam Chao Phya, stands only 1.80 meters above mean sea level. The higher grounds close to the east and west sides of the delta plain must be aided by irrigation. The Chao Phya Delta is the largest and most fertile plain of the country.

Much silt is transported from the four major tributaries of Maenam Chao Phya in the north down to the Gulf of Thailand. Silting in the gulf has been found to result in a land increase of about a meter and a half a year at the river mouth. Silting is therefore beneficial in one way but a great loss in the other, because a great mass of silt obstructs the navigational channels of the Chao Phya. The pilots have much difficulty in bringing the ships in and out of the Bangkok Harbor. The Government of Thailand spends a great deal on her annual budget in clearing the silt bar.

As a matter of fact the Chao Phya Delta does not consist of a flat land throughout, but is partly scattered with small isolated hills abruptly rising above the flat plain. These hills are the former islands in the old Gulf of Thailand when it was still as deep as Changwat Chai Nat or beyond. They are now buried by the sediment of clay up to their present bases. Khao Thapkhwai is one of such hills. It is rich with iron ore and is now being mined for the Thai Cement Company's smelting furnace.

<u>The Peninsula</u>

The Peninsula covers an area from Ratchaburi to the southern border between Thailand and Malaysia. The general topography is from rolling to mountainous, with a small amount of flat land.

The northern portion from Ratchaburi to Chumphon is flanked on the west by a high mountain range, the Tenasserim, which forms part of the frontier between Thailand and Burma. The east side consists of a long gentle sloping coastline, mostly sandy, touching the Gulf of Thailand. On this coast lies the famous beach, Hua Hin on Sea, which attracts tourists from all over the country and abroad. The streams and rivers here flow down for a short distance to the sea on the east. Maenam Phet is one of the big rivers of the region which has been dammed for irrigation. Numerous limestone hills standing precipitously over the rolling plain give much impression to the landscape of this region.

The massive mountain on the west side attains the height of 1,000 to 1,500 meters. Khao Luangprachuap, for instance, reaches the height of 1,247 meters. Some of the difficult passes leading from Thailand into Burma cross over these ranges; the important one is Jalinga Pass or Chong Singkhon, which connects Prachuap Khiri Khan with the town of Tenasserim.

The southern portion commences from the Isthmus of Kra and extends down to the Malaysian border. It faces the seas on both sides, the Andaman on the west and South China Sea on the east. This part of the country is marked by two almost parallel ranges in longitudinal direction, the Phuket and the Nakhon Si Thammarat, while the San Kalakhiri range commands the east-west trend along the border. The Phuket range extends from Chumphon down to Phang Nga, while the Nakhon Si Thammarat range stretches across the peninsula between Surat Thani and Satun.

The rolling country between the Phuket range and the Nakhon Si Thammarat range is studded with isolated peaks rising sheer out of the plain. One massive hill in this region is Khao Phanom Bencha, attaining the height of 1,401 meters, but others are mostly low limestone hills. The highest peak of the Nakhon Si Thammarat range is Khao Luang Nakhon Si Thammarat which rises 1,786 meters above mean sea level. The frontier range in the south varies in height from 400 meters at both ends to about 1,500 meters in the middle.

The streams and rivers in the southern portion of the Peninsula are generally short and flow down to the seas on both sides; the most important one is Maenam Kraburi, which forms part of the boundary between Thailand and Burma west of Ranong. The others are Ban Don, Tapi, Khirirat and Sungai Kolok; this last one acts as a portion of the eastern end of the Thai-Malaysian border. Many of the rivers in this region have built up delta lands suitable for rice cultivation. East of Patthalung and north of Songkhla lies a large lake, Thalesap Songkhla. This lake is bordered by a large plain which produces a large quantity of rice for the south.

The western coastline is much indented, because many hills come close to the shore, and physiographically it is a submerged shoreline. The evidence is clearly indicated by the V-shape Maenam Kraburi. Numerous islands are scattered along the western coast; the largest one is the tin rich island of Phuket. This island is also a changwat in the peninsula. The other islands of note are Tarutao, Lanta, Libong, Phrathong and Yaoyai. They are rich also in bird nests and fish. Contrary to the western coast, the eastern side of the peninsula has been uplifted and therefore the shoreline recedes much towards the east, giving rise to a generally smooth curvature along the shore. Some of the evidences indicating the uplift are the marine deposits found in many limestone caves high above the present sea level, and the rocks at the foot of the mountains now on dry land appear to be carved by the action of sea waves.

B. Geology and Mineral Resources

The principal rocks of the Kingdom include Paleozoic rocks, Mesozoic rocks, rocks of Tertiary age and some Quaternary deposits.

The Paleozoic rocks, found in extensive areas of the northern and the southern parts of Thailand, are chiefly sedimentary rocks of Ordovician limestone, early

Carboniferous sandstone, and Permian limestone. The thickness of these Paleozoic sediments is about 9,000 meters or more. The rock series are the important source of road and railroad ballast built in this country. Lime used in construction is also obtained from these rocks.

The Mesozoic rocks, found in almost the whole of Khorat Plateau, is sandstone. Other Mesozoic rocks are Triassic mafic and ultramafic intrusive rocks locally cropping out in the northern part of Thailand. The thickness of these sedimentary rocks attains a maximum of 2,000 meters. Those rocks in the contact zones between the intrusive and the sedimentary rocks were metamorphosed and mineralization occurred in these zones. Thus economic minerals, such as tin, wolfram, manganese, iron, lead, zinc and gold are found, and are clearly shown in the western part of Thailand where tin and wolfram are being mined.

Rocks of Tertiary age are basalt, andesite, rhyolite porphyry, diorite, quartz diorite, semiconsolidated fluvial and lacustrine deposits of clay, sand, gravel, marl, oil shale and lignite. In some places, the Tertiary sediments are about 400 meters thick. The important mineral found in these rock series is lignite in Lampang and Krabi. Lampang lignite was first mined for electric power production needed in the construction of the Bhumibol Dam project in Changwat Tak, and will in the near future be used for the production of synthetic fertilizer. A lignite mine at Krabi has also been opened up, and a lignite-fired power station erected on the mine site, now supplies power to several southern provinces.

Quaternary deposits include unconsolidated silt, clay, sand and gravel of stream channels, flood plains and terraces, beach and estuary deposits, and residual lateritic deposits. The thicknesses of Quaternary deposits are generally less than 50 meters, but the alluvial deposits in the Chao Phya Delta attain a thickness of more than 300 meters. The economic values of these deposits are to be found in many places, such as the tin placers in the Peninsula of Thailand, gold and gemstone placers located in the Southeast region, and the clay of the Chao Phya Delta which makes Bangbuathong popular in bricks used for construction.

C. Geologic Structure

There are three distinct geologic structural provinces in Thailand: the Khorat Plateau, the Chao Phya Depression, and the Region of Folded Mountains.

In the earliest orogenic movements the Ratchaburi limestone and the old rocks were compressed in longitudinal folds from the north down to the Peninsula of Thailand. This folding corresponds to the late Paleozoic Appalachian Orogeny of North America, and is followed by intrusion of elongated granite which appears in the north as Khuntan range. A late Mesozoic orogeny is suggested by the folding of the Khorat series of sedimentary rocks along the west side of the Khorat Plateau and followed by intrusions of tin and tungsten bearing granite.

The late Tertiary orogeny occurred by the elevation and gentle-down warping of the Khorat Plateau, by the depression of the Chao Phya region, and by high angle faulting, which is clearly shown by the Dong Rak range. In very recent time the Peninsular Thailand has been slightly tilted northwest, making the east coast appear as a broad coastal plain and a smooth emergent shoreline. The west coast is marked by drowned valleys, such as the V-shape Maenam Kraburi and the very irregular shoreline.

II. AVAILABILITY OF GROUNDWATER IN THAILAND FOR IRRIGATION

A. Knowledge of Groundwater

According to Piencharoen (1967)[14], in Thailand water from dug wells had been in use for a long time. In the rural area, well water is usually used for consumption by both mankind and animals. These wells usually contain a moderate quantity of water, so that excessive use will cause the wells to dry, and time must be allowed before the emergence of water, and only then can consumers resume its normal use. Moreover, some wells usually dry up in the hot season. In these wells soil water usually exists which may be apt to dry when no additional rainfall is available or upon evaporation by the bright sunshine. The water

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[14] Charoen Piencharoen, Ground-Water (Bangkok, Thailand: Department of Minerals and Resources, 1967), pp. 1-2.

remaining from the soil holding capacity will permeate deeper and rest in the voids of every kind and type of rock texture and horizons until these are saturated with water. The water impounded in such a rock is known as "ground water." However, the availability of water in other ground water sources will be more or less dependent largely upon thickness, width, and porousness of the water holding rock.

Ground water is only part of the subterranean water that occurs where all pores in the holding rock materials are saturated. The zone of saturation may extend up to the land surface in some places. At all other places, above the ground water zone, a zone of areation exists that may range in thickness from a few inches to hundreds of feet. All subterranean water occurs in open spaces within rock materials of the earth's crust. There are many kinds of rocks, and the number, size and shape of their open spaces differs greatly. Loose materials like sand, gravel, and rock fragments have pore spaces that are easily seen, but the spaces between particles of clay and other fine-textured materials may be extremely minute. Of the so-called solid rocks, some contain microscopic pores, others have large caverns, still others are extremely dense and compact--but even they are commonly fractured enough to form some opening that can admit water. All openings underground may be regarded as pores, for even the largest cavern is no more than a pore in comparison to the size of the earth. The ability of rock material to hold and yield water is determined largely by the characteristics of those pores.

Thomas (1955) showed that three types of ground water are distinguished as follows:[15]

1. Watercourses, consisting of channels occupied by a perennial stream, together with the enclosing and underlying alluvial material saturated with water that comes from the stream infiltration at the surface, or from adjacent water-bearing materials.

2. Loose water-bearing materials, chiefly gravel and sand, including the productive aquifiers.

3. Consolidated water-bearing rocks, of which limestone, basalt, and sandstone are the most important.

A subsurface zone which is below the water table and sufficient permeability is called an aquifer. A zone of low permeability, such as shale or clay, is called an aquatared if it will transmit only a small amount of water.

In the report area, there are five subsurface strata that may be aquifers depending upon local conditions. The bedrock may be separated into four of the units. These units will be described as Ground water in Ionia County, Michigan, studied by Swanson (1970) as shown below:[16]

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[15]Harold E. Thomas, "Underground Sources of Our Water," Water: The Yearbook of Agriculture, 1955 (Washington: The United States Government Printing Office, 1955), p. 73.

[16]David Eugene Swanson,"Ground Water in Ionia County, Michigan," Unpublished thesis, Michigan State University, 1970, p. 12.

Table 1. Subsurface Deposits and Their General Suitability as Aquifers

Gravel	excellent aquifers
Coarse sand	(high permeability)
Medium sand	
Fine sand	
Sandstone	
Limestone	
Clayey sand	very poor aquifers
Shale or clay	(low permeability)

Note: The details are shown in Table 2.

1. The capacity of ground water well yield.

According to the survey and study on geology and hydrology issued by the Department of Minerals and Resources (1965)[17] there were great amounts of ground water available in various regions; these amounts of ground water varied from region to region depending on the geological characteristics. Some regions, such as the Maeklong River area, had a very shallow water table and farmers could dig wells and pump water with small water pumps while the other regions could not. New techniques for drilling ground water wells were needed and some kind of turbine pump was used.

From the "Record of Wells" (1951-1971)[18] issued by

[17]Department of Minerals and Resources, Ground Water for Growing Rice (Bangkok, Thailand: Department of Minerals and Resources, survey report issue, 1968), p. 5.

[18]Division of Ground Water Development, Record of Wells, (Bangkok, Thailand: Department of Minerals and Resources, Volumes V, VI, VII, June 1958-September 1968; October 1968-September 1969 and October 1969-August 1971).

FIGURE 1. Map of Thailand

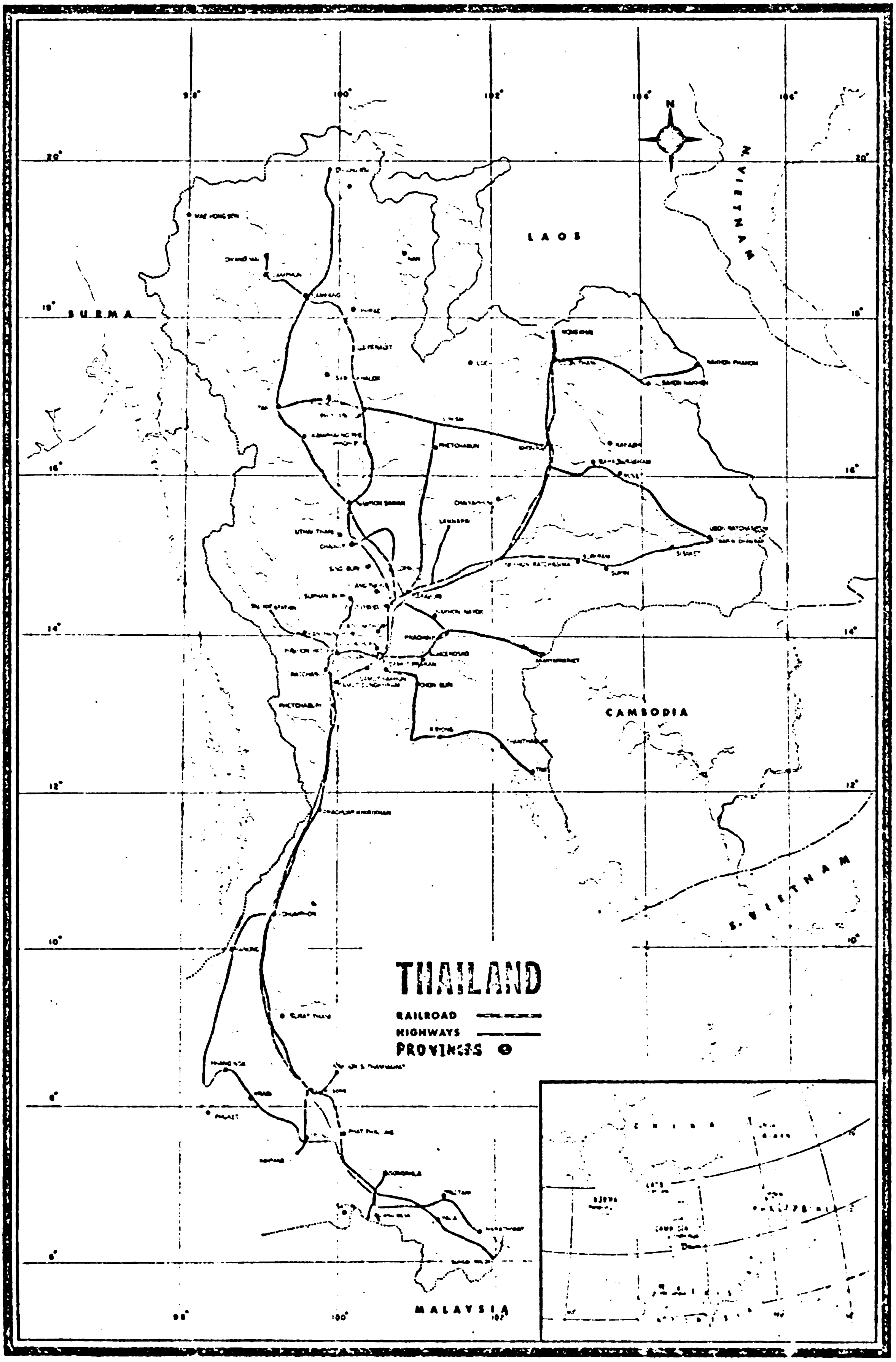

Table 2. General Characteristics of Bedrock Aquifers

Region	Water Quantity (gpm)	Depth (feet)	Water Quality	Districts	Aquifer
North Region	few				
Chiengmai	500-1,000	500-600	fresh	Maung	Hard rock mountains
				Sunkumpang	
			Fe	Doi-Saket	and
				Sarapi	
				Cheingdown	limestone caverns
Lamphoon	500-1,000	---	fresh	Pasung	---
	100-400	---	fresh	Ban-hong	---
	10-20	---	fresh	Ban-hong	---
Phrae	300	500	brackish	Song	sandstone, shale
	300	---	?	Maung	---
	300	---	?	Denchai	---
Nan	little	500	?	---	sedimentary & igneous rocks
Northeast Region					
Surin	5-10-100		brackish		80% shale
Buriram	"		Fe		20% sandstone
Sisaket	"				
Sakoluakoon		---		---	sandstone, siltstone, shale, conglomerate
	30-200		fresh		
Kalasin		600		Kuchinarai	shale
Roi-et	100	200	good	---	shale and unconsolidated rocks
Mahasarakam	100	600	saline	---	---
Chaiyaphoom	100	---	good	---	sandstone, shale

Table 2. General Characteristics of Bedrock Aquifers (Continued 1)

Region	Water Quantity (gpm)	Depth (feet)	Water Quality	Districts	Aquifer
Khonkaen	20	25	good	---	---
Udornthani	200	25	30%fresh	Nongbolumpu	sandstone, silt-stone, shale, con-glomerate
	---	---	20% brackish	Nonsoong	---
	---	400	50% salt*	Kumpavapi	---
	50-100	25	good	Pen	shale
	---	---	---	Ban Dung	---
	---	---	---	Nonghan	---
Nakornrajsima	100-300	---	---	Pimai	limestone, sand, metamorphic rocks
Loei	100-300	---	---	---	---
Ubolrajthani	75-100	75	good	Umnajalern	unconsolidated rocks
		75	---	Yosothorn	---
		75	---	Muang	---
		---	---	Kamraj	---
	200	---	brackish	Dejudom	---
Nongkai	30-100	---	80% fresh	Ponpisai	shale
	---		---	Srichiergmai	---
	---		---	Muang	---
	---		---	Kusumal	---
Nakompanom	300-500	---	---	Ta-Utane	unconsolidated rocks
				Tatpanom	unconsolidated rocks

Table 2. General Characteristics of Bedrock Aquifers (Continued 2)

Region	Water Quantity (gpm)	Depth (feet)	Water Quality	Districts	Aquifer
Central Region					
Sukhothai	500-1,000	---	good	---	Alluvial sand and gravel, 200 feet thickness
Pisanulok					
Chainart	1,000-2,000	500-600	good	---	Alluvial sand and gravel, 200-1,800 feet thickness
Singburi	---	---	fresh	Muang, In Prom	Alluvial sand and gravel, 200-1,800 feet thickness
Ayudhaya	---	---	fresh	---	Alluvial sand and gravel
Uthaithani	50-100	---	fresh	---	---
Suphanburi	50-100		fresh	---	---
Nakhornpathom	50-100		fresh	---	---
Nakhornayok	50-100		fresh	---	---
Saraburi	200-300	---	fresh	Vihandang	Hard rocks
Lopburi				Chaibadan	---
				Koksomlerng	---
Petchabun	20-30			Vichielburi	---
Nakhornsawan	little			Takli	sandstone, shale
				Bunpotpisai	
				Paisari	
West Region					
Karnchanaburi	150-200	---	fresh	Tamung Tamaka	

Table 2. General Characteristics of Bedrock Aquifers (Continued 3)

Region	Water Quantity (gpm)	Depth (feet)	Water Quality	Districts	Aquifer
Rajburi		---	brackish	Ban Pong	
				Jombung	
Phetchburi	little	---	---	---	
Phachuap-kirikhan	20	---	---	Hau Hin	metamorphic rocks
	100-200	---	good	---	limestone
East Region					
Cholburi	10	25-30	good	Sriraja	
Rayong	---	---	---	---	limestone
Chantaburi	30	---	---		
Prachinburi	50-100	---	---	Srimahapo	limestone
Trat	30-50	---	---	---	
Nakornnayok	200-500	---	---	---	
Chachoengsao	---	---	---	Panomsalakorm	
South Region					
Nakornsritham-maraj	500-1,000	---	---	Nabon	Alluvial sand and gravel, 700 feet thickness
Pattalung	1,000	---	---	---	
Songkhla	1,000	---	---	Hardyai	limestone
				Jana	sandstone
Pattani	500-1,000	---	---	---	Metamorphic rocks
Naratiwat	500	---	---	---	---

Table 2. General Characteristics of Bedrock Aquifers (Continued 4)

Region	Water Quantity (gpm)	Depth (feet)	Water Quality	Districts	Aquifer
Satul	20-30	---	---	---	Metamorphic rocks
Yala	20-50	---	---	---	Sandstone
Trang	1,000	---	---	---	limestone

Remarks: *Fewwells are not recommended for drinking.

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--- No available information.

Source: Division of Agricultural Economics, "Ground Water Development," (by Division of Ground Water Development) Basic Data for Farm Management and Farm Planning, No. 12 (Bangkok: Ministry of Agriculture, 1971), pp. 36-41.

the Division of Ground Water Development, Department of Minerals and Resources, studying ground water wells, it is apparent that between June, 1958 and August, 1971, out of 3,656 ground water wells which had been drilled, 3,089 have proved successful in operation, accounting for 84.50 per cent of total drilled wells. Only 263 ground water wells or 7.19 per cent of total drilled wells were failures (not enough water) and 304 ground water wells or 8.31 per cent of total drilled wells were saline water. The minimum capacity of a ground water well is five gallons per minute and the maximum is 5,000 gallons per minute. The average capacity is approximately 35 gallons per minute which has proved satisfactory, thus enabling its operation to a broader extent, including the utilization of ground water for agricultural purposes (see Table 3).

During the period of the Six Year National Economic Development Plan (1961-1966)[19], various government agencies have tried to overcome the problem of water shortage in the rural areas. One thousand eight hundred and ten artesian wells were drilled and a number of village water supply units were established. During the Second Economic and Social Development Plan (1967-1971) a provision of potable water supply to the rural villages for consumption purposes was established in 30,000 villages out of a total of 50,000

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[19]The National Economic Development Board, The Second National Economic and Social Development Plan (1967-1971) (Bangkok, Thailand: 1968), p. 166.

Table 3. Distribution of Ground Water Wells from June, 1961 to August, 1971

Regions	Provinces	No. of Wells	Range in Depth (feet)	Size of Wells (inches)	Range of Water Yield (gpm)	Length of Slotted Perforation per Well in Feet
North Region	Chiengrai	21	270-855	6-8	10-200	40
	Chiengmai	50	55-505	6-8	10-1000	40
	Nan	23	120-472	6-8	5-30	40
	Phrae					
	Mae Hongsom					
	Lampang					
	Lamphoon	50	60-250	6-8	5-2000	40
	TOTAL	144				
North-east Region	Kalasin	97	45-1520	6-8	5-350	40
	Khoukaen	260	47-1289	6-8	5-2000	40
	Chaiyaphoom	143	70-1005	6-8	5-300	40
	Nakornpanom	211	50-1510	6-8	5-1000	40
	Nakornrajsima	354	22-1838	6-8	5-500	40
	Buriram	137	80-1056	6-8	5-80	40
	Mahasarakarm	135	60-2003	6-8	5-1000	40
	Roi-et	117	80-1274	6-8	5-200	40
	Loei	185	30-1029	6-8	5-1000	40
	Sisaket	176	50-1215	6-8	5-100	40
	Sakolnakorn	130	50-1508	6-8	5-400	40
	Surin	168	30-1031	6-8	5-150	40
	Nongkai	203	65-1550	6-8	5-800	40

Table 3. Distribution of Ground Water Wells from June, 1961 to August, 1971 (Continued 1)

Regions	Provinces	No. of Wells	Range in Depth (feet)	Size of Wells (inches)	Range of Water Yield (gpm)	Length of Slotted Perforation per Well in Feet
	Udornthani	298	70-1518	6-8	5-500	40
	Ubolrajthani	302	50-1148	6-8	5-700	40
	TOTAL	2,916				
Upper Central Plain Region	Tak					
	Sukhothai					
	Uttaradit	30	50-450	6-8	5-200	40
	Pisanulok					
	Kamphaengphet	3	105-250	6	5-40	40
	Phichit					
	Petchabun	49	106-1493	6-8	5-150	40
	Nakhornsanan	2	140-673	6-8	5-200	40
	TOTAL	84				
Central Plain Region	Karnchanaburi	25	70-430	6-8	5-1000	40
	Chainarl	8	125-245	6-8	10-2000	40
	Dhonburi					
	Nakhornpathom	1	680	8	4,000	40
	Nonthaburi	3	335-500	8	500-1000	40
	Pathumthani					
	Prachuap-Kirikhan	5	75-313	6-8	50	40
	Pranakhorn	5	505-615	6-8	50-400	40
	Ayudhya	4	330-500	6-8	20-1500	40

Table 3. Distribution of Ground Water Wells from June, 1961 to August, 1971 (Continued 2)

Regions	Provinces	No. of Wells	Range in Depth (feet)	Size of Wells (inches)	Range of Water Yield (gpm)	Length of Slotted Perforation per Well in Feet
	Phetchburi	12	170-850	6-8	10-20	40
	Rajburi	41	70-170	6-8	5-500	40
	Lopburi	55	54-538	6-8	5-150	40
	Samuthsongkharm					
	Samuthsakhorn					
	Saraburi	29	45-830	6-8	5-500	40
	Singburi	5	130-635	6-8	150-1000	40
	Suphanburi	5	410-550	6-8	10-800	40
	Ang-Thong	6	220-600	6-8	80-1000	40
	Uthaithani					
	TOTAL	204				
East Region	Chantaburi					
	Chachoengsao	1	430	6	10	40
	Cholburi	12	84-220	6-8	5-70	40
	Trat					
	Nakornnayok	7	60-320	6-8	5-50	40
	Prachinburi	82	80-275	6-8	5-500	40
	Rayong					
	Samutprakan	5	430-903	6-8	200-500	40
	TOTAL	107				

Table 3. Distribution of Ground Water Wells from June, 1961 to August, 1971 (Continued 3)

Regions	Provinces	No. of Wells	Range in Depth (feet)	Size of Wells (inches)	Range of Water Yield (gpm)	Length of Slotted Perfora-tion per Well in Feet
	Krabi					
	Chumporn					
	Trang	28	70-200	6-8	10-500	40
	Nakorn-Srithammaraj	6	450-500	6-8	10-500	40
	Naratiwat					
	Pattani	21	120-410	6-8	5-2500	40
	Phang-nga					
	Pattalung	11	130-465	6-8	5-1000	40
	Phuket					
	Yala	19	60-310	6-8	10-2000	40
	Ranong					
	Songkhla	89	55-750	6-8	5-5000	40
	Satul	27	60-270	6-8	5-120	40
	Surajthani					
	TOTAL	201				
	GRAND TOTAL	3,656				

Source: "Record of Wells," Department of Minerals and Resources, Volumes I-II-III (Bangkok: Division of Ground Water Development), 1961-1971.

in the entire country. Provision of water is in different forms, both deep and shallow ground water wells. This work has been undertaken by many government agencies, i.e., the Department of Public Health, the Department of Minerals and Resources, the Department of Public and Municipal Works and the different local government authorities.

2. Ground water recharge. Howard F. Harworth, Pongpan Na Chiangmai and Charoen Phiancharoen (1966)[20] studied Ground Water Resources Development of Northeastern Thailand and reported that ground water recharge in the plateau mainly results from infiltration of rainfall. The establishment of the automatic water level recorders was begun in 1958; between 1958 and 1963 eight recorders were installed on the following wells:

D1NR1	(alluvial aquifer)
D2NR2	(alluvial aquifer)
H_2-6	(alluvial aquifer)
C21KK1	(Khok Kruat aquifer)
A4S3	(Khok Kruat aquifer)
B77Ub28	(Unnamed Salt aquifer)
C26NP18	(Phy Kadung aquifer)
C30KK10	(Khok Kruat aquifer)

The rate of infiltration or recharge to the aquifer in the vicinity of these wells is so much different from that of the well D1NR1, shown in figure 2. In well D1NR1 the maximum peak of fluctuation of water level occurs almost

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[20] Howard F. Haworth, Pongpan Na Chiangmai and Charoen Phiancharoeu, Ground Water Resources Development of Northeastern Thailand (Bangkok: Kurusapha Press, Ground Water Bulletin No. 2, 1966), pp. 162-71.

in the same month as that of maximum rainfall in September or October. An explanation for this behavior is undoubtedly because the depth of well D1NR1 which is only 40 feet in alluvium is shallower than that of well D2NR2 and H_2-6 and the rate of infiltration tends to decrease with depth (figures 2 and 3). The fluctuation of water levels in observation wells C21KK1 (figure 3), A4S3 (figure 4) and C30KK10 (figure 5), all of which were drilled in Khok Kruat formation, also reach their peaks in rainy seasons although time lapses between the highest rainfall period and the peaks are irregular. This irregularity is probably the result of different nature of fissures in the rocks to which recharging water infiltrates at different rates. The decline of water levels following the dry months may support the idea that not only the unconsolidated resevoir rocks but also the consolidated rocks are recharged by rainfall. Records of fluctuation of water level in well Q26NP18 (figure 5), about 800 meters from the Mae Khong River, also indicate the decline of water level during the dry period of the year, and reach the highest peak during the rainy season. No recharge from the Mae Khong River to the ground water system in the vicinity of G26NP18 is indicated.

Although we do not study the recharge areas enough for the collection of data, the amount of annual rainfall is enough for recharging ground water for developing ground water wells for irrigation. With the long period of rainfall and heavy rain in the rainy season associated with

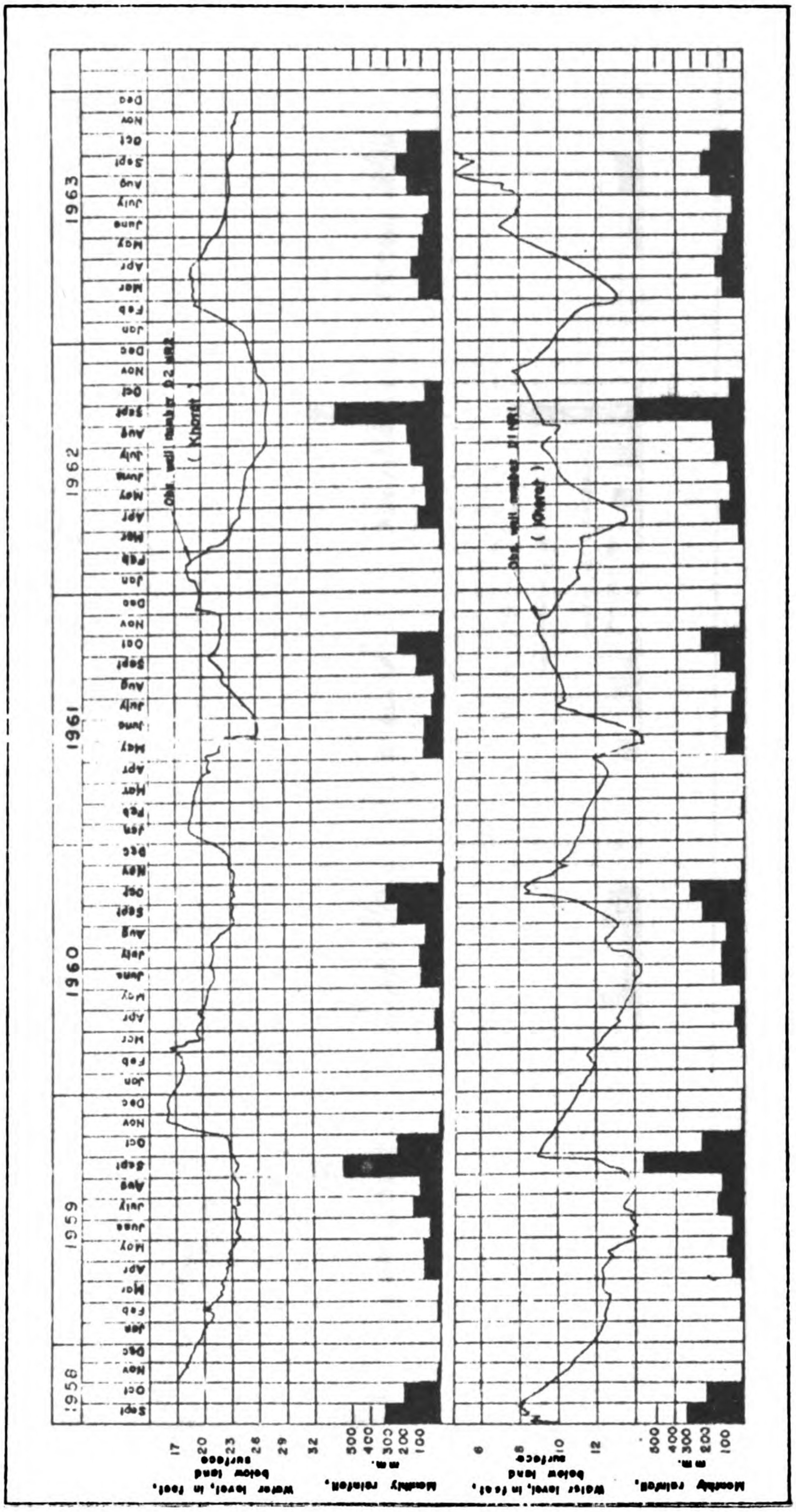

Figure 2. Graphs showing fluctuation of water levels in observation wells and fluctuation of monthly rainfalls in Nakhon Ratchasima

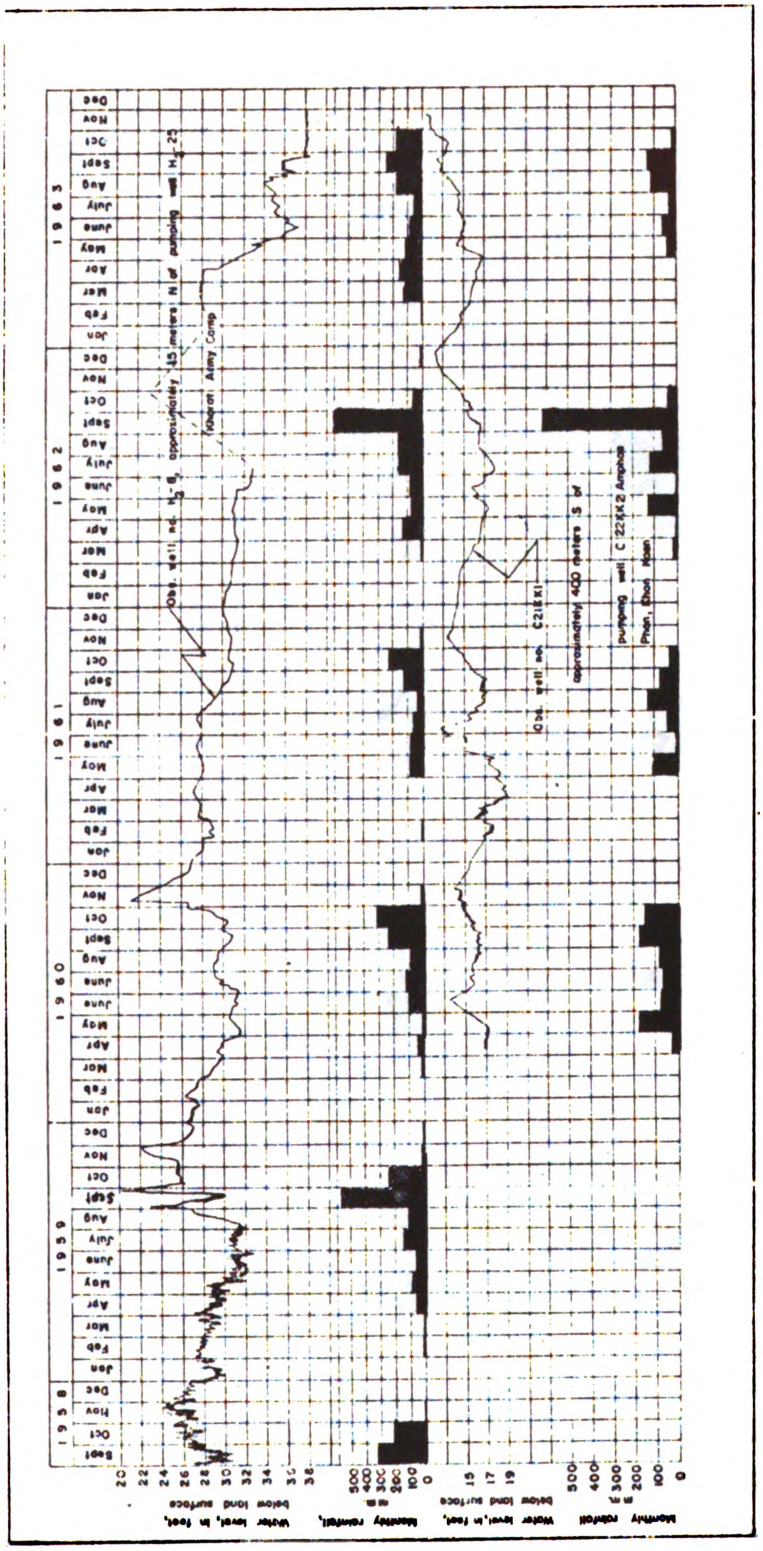

Figure 3 Graphs showing fluctuation of water levels in observation wells and fluctuation of monthly rainfalls in Nakhon Ratchasima and Khon Kaen

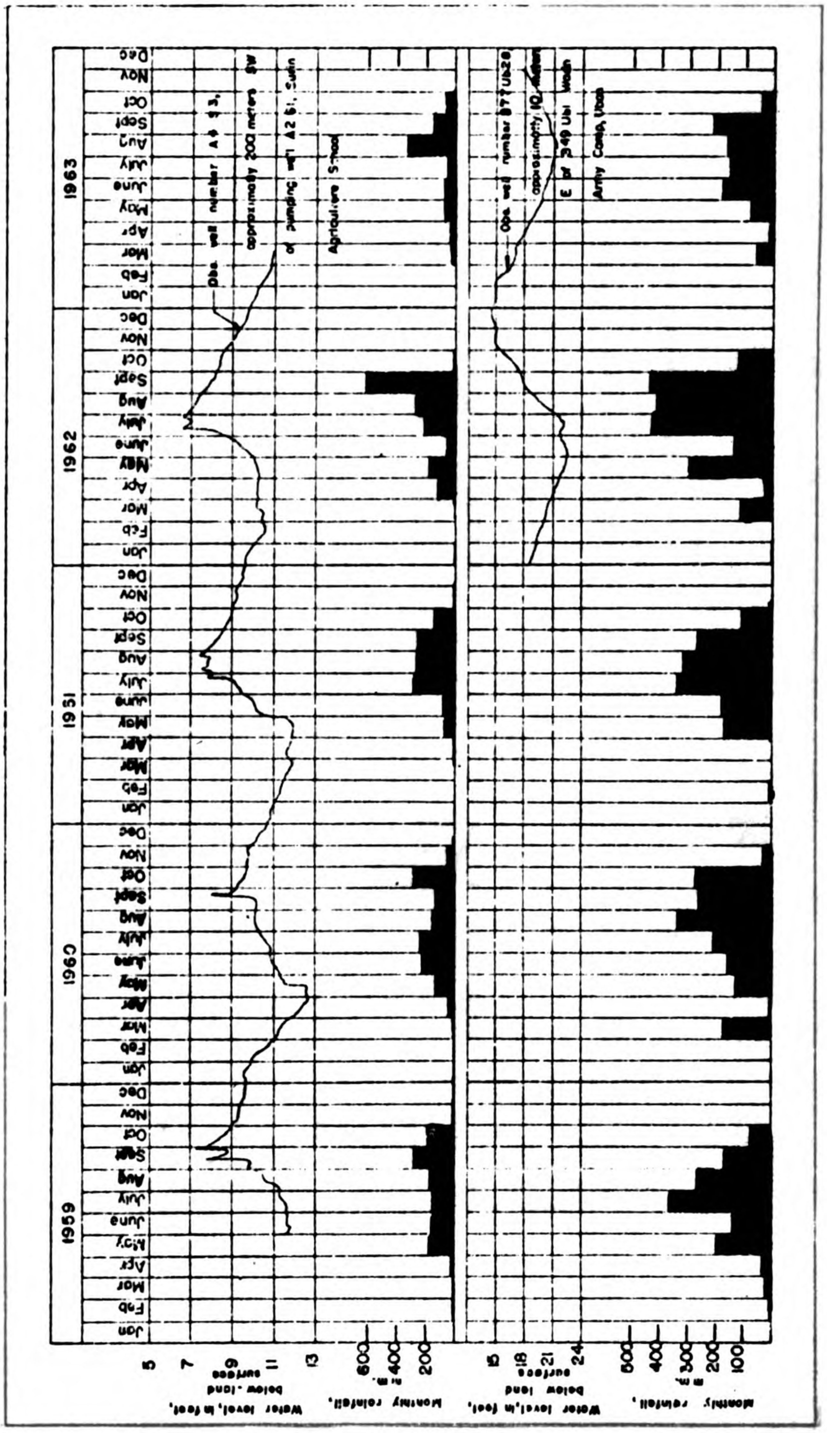

Figure 4 Graphs showing fluctuation of water levels in observation wells and fluctuation of monthly rainfalls in Surin and Ubon

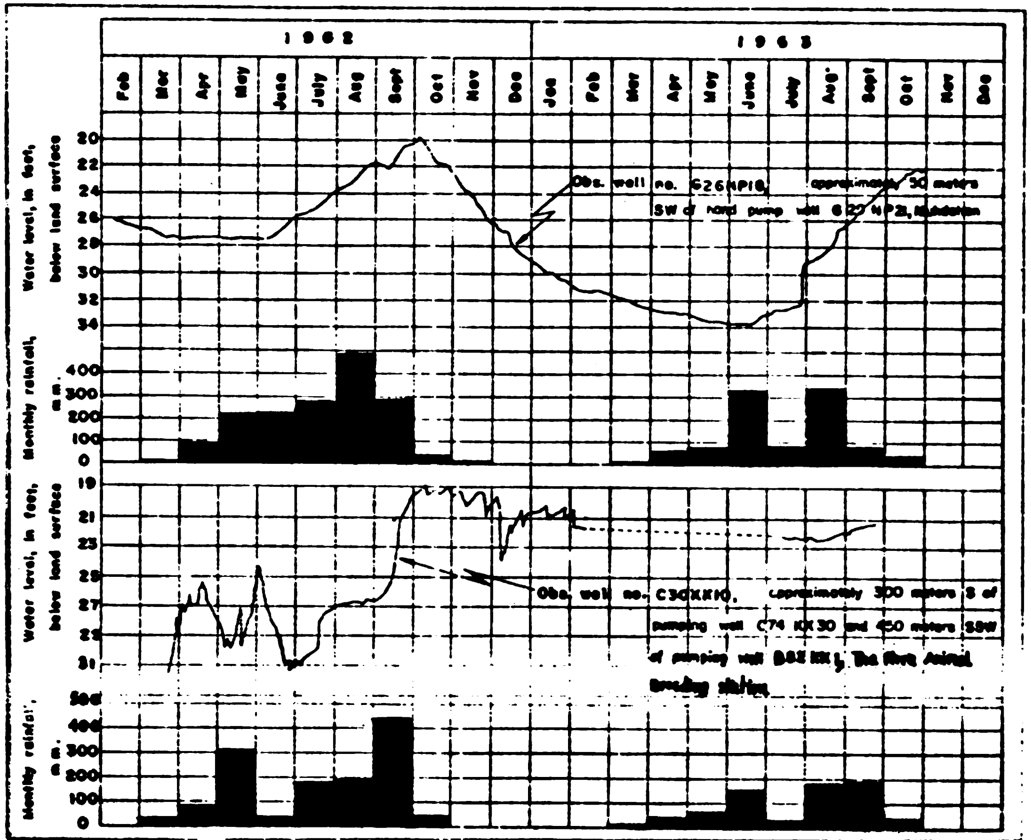

Figure 5 Graphs showing fluctuation of water levels in observation wells and fluctuation of monthly rainfalls in Nakhon Phanom and Khon Kaen.

sandy soils and loamy soil such as the Northeast region and the North region influence to a great degree the rate of precipitation infiltration. We can see the annual rainfall and the amount of rain which is distributed throughout the country in table 4.

3. The quality of groundwater. If irrigation water is of good quality, the soil to which it is applied may be improved because of the calcium in the water and the beneficial effect derived from leaching or washing any excess salts from the soils. But if the quality of ground water is unsatisfactory, the soil may deteriorate until it will no longer produce satisfactory crops.

Four major characteristics determine quality of water for irrigation:

"The total concentration of soluble salts; the concentration of sodium and the proportion of sodium to calcium plus magnesium; the concentration of bicarbonate; and the occurrence of the minor elements, such as boron, in amounts that are toxic."[21]

The total concentration of soluble salts is an essential consideration in waters that are used for irrigation. The range in salt concentration in ground waters pumped from wells may be varied in depths and locations.

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[21]Milton Fireman and H. E. Hayward, "Irrigation Water and Saline and Alkali Soils," Water: The Yearbook of Agriculture, 1955 (Washington: The United States Government Printing Office, 1955), p. 321.

Table 4. Annual Rainfall: Records of Selected Location by Geographical Regions, 1948-1967

A. Northern

Year	Chiang Rai		Chiang Mai		Nan		Uttaradit		Lampang	
	day	mm.	day	mm.	day	mm.	day	mm.	day	mm.
1948	117	1,535	119	1,544	108	1,256	125	1,287	100	1,113
1949	130	1,684	124	1,390	121	1,442	211	1,477	93	1,155
1950	127	1,554	132	1,618	103	1,059	135	1,813	72	1,012
1951	127	2,202	129	1,473	121	1,689	124	1,743	108	981
1952	112	1,682	116	1,364	113	1,461	121	1,248	117	886
1953	105	1,907	136	2,032	127	1,329	130	1,618	79	817
1954	96	1,663	114	981	103	1,078	106	1,375	94	1,012
1955	109	1,979	136	1,258	111	1,395	123	1,364	114	1,143
1956	117	2,020	128	1,324	119	1,289	123	1,568	113	1,073
1957	129	1,763	111 (r)	1,151	123 (r)	1,352 (r)	100	1,246	95 (r)	790
1958	126	1,669	112	1,130 (r)	114	962	120	1,335	110	906
1959	167	1,764	136	958	131	1,321	114	1,150	120	1,247
1960	151	1,692	122	1,339	125	1,286	112	1,382	114	1,181
1961	145	1,478	138	1,576	149	1,665	143	1,798	139	1,173
1962	124	1,248	117	1,129	119	1,145	117	1,486	117	938
1963	119	1,625	124	1,061	136	1,495	115	1,429	112	1,043
1964	147	1,334	124	1,115	142	1,329	121	1,292	112	1,004
1965	127	1,615	107	997	121	1,097	111	1,276	107	953
1966	136	1,834	115	865	137	1,303	113	1,266	120	1,110
1967	148	2,099	119	1,354	122	1,193	99	1,142	115	846

Table 4. Annual Rainfall: Records of Selected Location by Geographical Regions, 1948-1967 (Continued 1)

B. North Eastern

Year	Udon Thani		Roi Et		Ubon Ratchathani		Nakhon Ratchasima		Surin	
	day	mm.	day	mm.	day	mm.	day	mm.	day	mm.
1948	136	1,502	110	1,785	138	1,738	---	----	116	1,635
1949	134	1,581	61	1,688	137	1,778	116	1,363	98	1,335
1950	135	1,730	112	1,716	135	1,819	127	1,142	130	1,515
1951	141	1,790	121	1,498	129	1,700	121	1,304	124	1,484
1952	137	1,689	121	1,350	107	1,697	123	1,193	126	1,289
1953	133	1,597	123	1,244	130	1,346	139	1,333	146	1,342
1954	126	1,236	95	1,248	118	1,338	111	1,192	107	1,075
1955	118	1,144	90	1,116	113	993	116	1,312	117	1,347
1956	130	1,366	108	1,501	133	1,916	125	1,261	120	1,185
1957	121	1,313	100	1,194 (r)	130	1,491 (r)	122	1,099	136	1,204 (r)
1958	125	1,396	97	1,238	119 (r)	1,274 (r)	118	1,272	122	1,483
1959	117	1,523	97	1,376	114	1,307	119	1,400	126	1,236
1960	129	1,608 (r)	114	1,649	125	1,696	118	1,005	130	1,298
1961	132	1,555 (r)	92	1,539	139	1,810	116	950	142	1,316
1962	126	1,571	105	1,695	131	2,039	121	1,354	131	1,502
1963	131	1,513	113 (r)	1,253 (r)	131	1,515 (r)	130 (r)	1,359 (r)	131 (r)	1,301
1964	124	1,484	110	1,701	113	1,635	121	1,291	116	1,037
1965	123	1,572	89	1,213	120	1,298	125	1,078	114	1,275
1966	114	1,594	111	1,861	127	2,258	119	1,318	126	1,627
1967	94	1,470	91	1,339	105	1,297	104	920	111	1,172

Remark: --- No report.

Table 4. Annual Rainfall: Records of Selected Location by Geographical Regions, 1948-1967 (Continued 2)

C. Central Plain

Year	Nakhon Sawan		Lop Buri		Bangkok		Nakhon Patom	
	day	mm.	day	mm.	day	mm.	day	mm.
1948	122	1,158	118	1,515	130	1,614	40	1,150
1949	111	1,277	123	1,573	147	1,698	36	1,306
1950	99	1,139	113(r)	1,256	138(r)	1,636	43	1,158
1951	102	1,448	99	1,368	125	1,600	58	1,232
1952	100	1,347	105	1,246	143	1,516	33	1,367
1953	116	1,464	120	1,775	150	1,577	54	1,156
1954	95	954	96	1,201	132	1,501	65	1,307
1955	96	1,315	103	1,352	126	1,514	73	1,693
1956	113	1,359	110	1,436	137	1,338	54	1,333
1957	94	1,132	100	1,937	138	1,957	65	1,443
1958	79	891	102	1,246	125	1,298	66	1,173
1959	93	1,120	115	1,310	118	1,275	80	1,777
1960	85	888	101	908	123	1,646	76	1,428
1961	102	1,036(r)	136	1,281	135(r)	1,458(r)	63	1,095
1962	90	977	124	1,399	121	1,377	62	1,204
1963	101(r)	1,224(r)	118(r)	1,254(r)	131	1,540	31	681
1964	116	1,468	118	1,655	150	1,864	32	603
1965	113(r)	1,109(r)	128	1,385	143	1,703	--	-----
1966	111	1,439	123	1,595	141	1,668	100	1,412
1967	99	1,076	110	1,098	122	876	79	856

Table 4. Annual Rainfall: Records of Selected Location by Geographical Regions, 1948-1967 (Continued 3)

C. Central Plain (Continued)

Year	Phetchaburi		Aranya-prathet		Chanthaburi		Cha-choengsao	
	day	mm.	day	mm.	day	mm.	day	mm.
1948	49	1,200	156	1,512	164	3,554	64	1,332
1949	39	866	145	1,311	178	3,216	54	1,565
1950	74	1,022	156	1,849	195	3,160	51	1,287
1951	50	759 (1)	121	1,718	171	2,902	56	1,351
1952	76	1,282	143	1,884	174	3,396	72	1,613
1953	70	1,187	153	1,824	201	3,638	56	1,245
1954	69	1,092	119	1,207	172	3,546	55	1,481
1955	81	1,462	133	1,598	170	3,566	74	1,209
1956	75 (2)	1,369 (2)	136	1,825	189	2,990	83	1,510
1957	69	920	121	1,642	173 (r)	3,448	85	1,708
1958	51	1,101	130	1,784	157	2,784	87	1,198
1959	63	1,041	125	1,218	158	2,979	106	1,120
1960	56	915	138	1,712	143	3,792	97	1,628
1961	43 (r)	804 (r)	135	1,541	189	2,908 (r)	121	1,414
1962	46	754	132	1,350	162	3,087	113	1,619
1963	60 (r)	1,091	129 (r)	1,500 (r)	166	2,739 (r)	94	1,428
1964	50	1,112	126	1,358	185	3,402	85	1,291
1965	62	1,119	141	1,603	173	2,164	86	1,196
1966	64	1,637	147	1,793	192	3,500	95	1,755
1967	60	1,090	134	1,243	157	2,544	63	1,379

(1) Except in May and June.

(2) Except in March, June, July and December.

Table 4. Annual Rainfall: Records of Selected Location by Geographical Regions, 1948-1967 (Continued 4)

D. Southern

Year	Hua Hin		Chumphon		Songkhla		Phuket		Narathiwat		Surat Thani	
	day	mm.	day	mm.	day	mm.	day	mm.	day	mm.	day	mm.
1948	119	1,052	166	1,728	162	2,178	135	2,305	116	2,286	148	1,488
1949	117	831	190	1,789	171	2,079	173	2,334	156	2,500	154	1,450
1950	81	1,002	200	1,704	164	2,160	168	2,504	161	2,133	174	2,141
1951	125	869	186	1,938	170	2,289	176	2,590	159	1,971	169	2,181
1952	106	1,171	188	2,098	155	2,021	177	2,483	153	2,149	142	1,895
1953	124	1,492	183	2,329	158	2,383	177	2,538	160	2,938	176	2,063
1954	112	895	164	2,037	171	2,026	184	2,783	170	2,674	162	1,323
1955	120	1,229	163	2,388	167	2,244	180	1,981	154	2,587	158	1,817
1956	134	1,189	175	2,297	183	2,329	201	2,580	155	2,642	194	2,231
1957	129	932(r)	159	1,320	167	1,545	180	2,201	147(r)	2,104	166	923
1958	115(r)	892(r)	166	1,574(r)	153	1,603(r)	163	1,922(r)	158	2,419(r)	152	2,031
1959	109	954	183	2,110	168	2,217	161	2,347	162	3,311(r)	153	1,573
1960	107	8881	183	1,821	163(r)	1,831	193	2,479	170(r)	2,579	165	1,563
1961	140(r)	1,011(r)	202	2,758	176	2,127(r)	168	1,827	191	2,862(r)	178	1,399(r)
1962	125	684	174	2,420	144	1,886	172	2,127	181	2,449	159	1,651
1963	123	920	153	1,846	146	2,053	137(r)	1,927(r)	161	2,139(r)	146	1,772
1964	121	782	173	1,812	134	1,575	179	2,456	178	1,916	172	2,164
1965	123	992	184	2,062	159	2,496	176	2,273	176	3,723	177	1,639
1966	126	1,198	189	2,187	166	3,354	185	2,515	196	3,995	183	2,169
1967	115	850	178	1,883	153	2,128	157	2,279	173	2,716	---	-----

Source: Division of Agricultural Economics, Agricultural Statistics of Thailand (Bangkok: Ministry of Agriculture, 1967), pp. 155-58.

The salinization of soil affects the growth of crop plants in the following ways:[22]

The first is a reduction in the amount of water absorbed by the roots. This occurs because continued irrigation with saline water in the absence of a favorable salt balance results in a gradual but progressive increase in the osmotic pressure of the soil solution. Osmotic pressure is a measure of the soluble salts in solution and provides a method of expressing the concentration of the soil solution on an energy basis. Retardation of growth is virtually linear with increases in the osmotic pressure of the soil solution. Thus, one of the main effects of soil salinity is to limit the water supply of the plant.

The second is the major ions in irrigation water the cations calcium,magnesium, and sodium; and the following may be present: potassium, carbonate, nitrate, silica, iron and boron.

Sodium salts--if the proportion of sodium is high--may be absorbed on the soil particles and result in an unfavorable physical condition. The use of waters that are low in total salts but high in bicarbonate aggravates the sodium problem. If the amount of bicarbonate is considerably in excess of the calcium and magnesium present, it is referred to as residual sodium carbonate. Then sodium replaces calcium on the soil particles, the exchangeable

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[22] Ibid., p. 322.

sodium percentage of the soil increases, and the physical condition of the soil, especially the permeability, may be impaired.

The accumulation of the chloride ion in plant tissues frequently results in toxic symptoms. Among the crop plants that are sensitive to the chloride ion are peaches and other stone fruits, pecans, some citrus varieties, avocados, and some grapes and some plants such as tomato, flax, cotton and orchard grass are no more sensitive to chloride than to equal concentrations of sulfate salts.[23] Large amounts of sodium or potassium give a salty taste when combined with chloride.

> Moderate quantities have little effect on the usefulness of water for most purposes. A high sodium ratio may limit the use of water for irrigation. Chloride salts when combined with calcium and magnesium may increase the corrosive activity of water. It is recommended that chloride content should not exceed 250 mg/l.[24]

Iron is dissolved from practically all rocks and soils. It may also be derived from iron pipes, pumps, and other equipment. Larger quantities cause unpleasant taste, but this does not endanger health or use for irrigation.

Boron is essential to the growth of plants, but it may be toxic at concentrations only slightly in excess of

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[23]Ibid., p. 323.

[24]David Eugene Swanson,"Ground Water in Ionia County Michigan," Unpublished M.S. Thesis, Michigan State University, East Lansing, Michigan, 1970, p. 31.

those needed for optimum growth. "For most crops, however, water that contains 1 to 2 p.p.m. is satisfactory. Water up to 3 p.p.m. may be used with tolerant crops. Water that contains more than 3 p.p.m. is definitely unsuitable for irrigation purposes."[25]

Howard F. Haworth, Pongpan Na Chiangmai and Charoen Phiancharoen (1966)[26] reported the study of chemical analyses for 738 producing water wells. The study showed that (1) The water has an average sodium chloride (NaCl) content of 62.93 ppm; 82% have NaCl of less than 50 ppm; 20% have NaCl less than 100 ppm, and 10% have NaCl in excess of 100 ppm. If the 77 wells having average NaCl of over 100 ppm are subtracted from this group, of the remaining 661 wells, 90% have an average NaCl content of only 15.36 ppm. (2) The dissolved solids content of 738 production wells tabulated averages 774 ppm. If the 77 wells having average NaCl content above 100 ppm are deleted from this group, the remaining 661 wells contain 536 ppm total dissolved solids. Water quality for the area as a whole has been much better than the initial work in the area indicated. Success has been due in part to the fact that wells have been drilled in all parts of the area, better drilling practices, and

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[25] Ibid., p. 324.

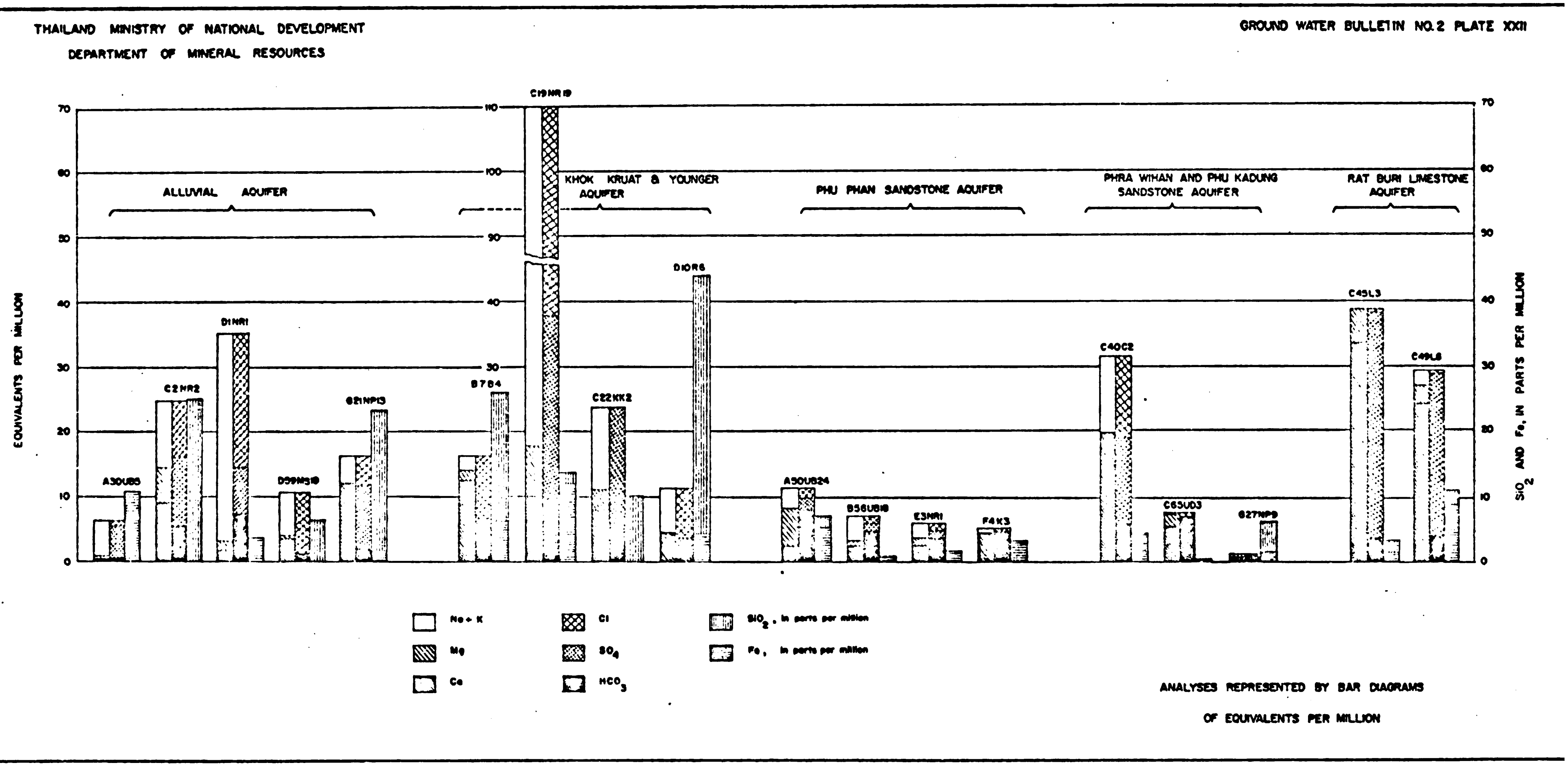
[26] Howard F. Haworth, Pongpan Na Chiangmai and Charoen Phiancharoen, Ground Water Resources Development of Northeastern Thailand (Bangkok: Kurusapha Press, Bulletin No. 2, 1966), pp. 192-217.

the sealing off of unsatisfactory water in some instances, and geologic-hydrologic studies.

The study for classification and suitability of water for agricultural uses is based on the sodium absorbtion ratio. The study reveals that nearly all waters from the alluvium can be classified as low sodium hazard, but range from low to high salinity hazard. In general, water from this aquifer is suitable for irrigation under most ordinary conditions, especially rice cultivation (Houk, 1951). Water from shale and siltstone of the Upper Khorat Group are not studied because the quantity yielded by the majority of wells is not sufficient for most agricultural uses. Sandstone produces waters somewhat similar to those of alluvium as far as irrigation is concerned. The water is satisfactory for most agricultural uses. Water from limestone can be grouped as low sodium hazard and low to high salinity.

In addition, many investigators concerned with irrigation water suggest other hazards caused by independent constituents or toxic elements, such as boron, sulfate, or chloride. The concentrations of boron in the water are not reported as a problem for irrigation. In only a very few locations excessive saline water for drinking has been found; most of the saline water has not exceeded 250 mg/l of chloride content. Thus it is shown that water quality is suitable for irrigation in Thailand (See table 2 and figure 6).

Figure 6. Chemical Analyses of Ground Water



B. Past Use of Ground Water for Irrigation

According to the Division of Ground Water Development, Department of Minerals and Resources (1968)[27] study and survey report, in 1960 the first ground water wells were used for irrigation (growing rice) at Ta Maka district, Kancharburi Province. Farmers themselves, using driven well and jetting well methods, have succeeded in drilling wells. They average 2-4 inches in diameter and 18-22 meters in depth; with a small pump they cost about 3,000-5,000 per well. The average water table is about 6-8 feet under the soil surface with little drawdown. During the 1960 to 1968 period, more than 10,000 rais of rice paddy have used ground water for irrigation. The farmers who do not own the wells must pay a fee of 10 tang (100 kilogram) of rice for irrigated water. It is better for them to pay this water cost because the rice paddy which receives enough water can yield 50-75 tang of rice, while those which lack water can yield only 25 tang of rice per rai.

The survey report issued by the Division of Agricultural Economics, Ministry of Agriculture (1969)[28] found

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[27]Department of Minerals and Resources, Ground Water for Growing Rice (Bangkok, Thailand: Department of Minerals and Resources, survey report issued, 1968), p. 7.

[28]Division of Agricultural Economics, Preliminary Report on the Economics of Ground Water Use for Farming in the Northeast (Bangkok, Thailand: Division of Agricultural Economics issue, 1969), p. 12.

that more than 2,000 farms in the villages of Sukothai and Pitsanulok provinces have been using ground water wells for irrigation. Some farmers do not grow rice as a single crop but change their farms into multiple crops by using ground water wells all year round. They realized that they can earn more money with multiple crops than with a single crop. In the same year, the survey report issued by the Division of Agricultural Economics found that at Srichiengmai district in Nougkai Province, the farmers who were members of the Farm Management Pilot Project under the Division of Agricultural Economics have tried to overcome the water shortage by drilling ground water wells for irrigation.

C. Potential Use of Ground Water for Irrigation

Water demand for irrigation tends to increase each year, both for surface water and ground water. But since there is usually conflict in the use of surface water, and because of unstable supply resources, Thai farmers prefer ground water as a supply, rather than surface water sources. It is apparent that ground water has generally been on the basis of one or more of the following advantages as Harold E. Thomas mentioned.

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[29] Harold E. Thomas, "Underground Sources of Our Water," Water: The Year Book of Agriculture 1955 (Washington, D. C.: The United States Government Printing Office, 1955), pp. 62-77.

1. Ground water may be reached within a few hundred feet of the place where it is to be used, and on the same property, whereas surface water may require pipelines and rights-of-way over stretches of several miles.

2. Ground water may be available for use in areas where the water in the streams and lakes has already been appropriated by other uses.

3. Yield from wells and springs generally fluctuates less than stream flow in alternating wet and dry periods.

4. Ground water is more uniform in temperature and soluble mineral load than surface water, and is generally free of turbidity and bacterial pollution.

5. Development of water from surface sources has been a necessity in many places where ground water can be obtained only at excessive depth below the surface or it can not be obtained in sufficient quantity at any depth, or a quality that makes it unsuitable for the use intended.

A major factor in the potential and the successful production of ground water for use for irrigation is the "know how"[30] of the technicians who are primarily responsible for the development and maintenance of production. The well industry can now obtain large quantities of water from fine textured materials for the successful development of pumps, casings, screens and new drilling techniques by

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[30] Harold E. Thomas, The Conservation of Ground Water (New York: McGraw-Hill Book Company, Inc., 1951), pp. 229-30.

the industry.

It is apparent that the potential use of ground water for irrigation has to be increased because the rate of population increase and technological advance in agriculture associated with the enlargement of areas planted in principal crops as shown in tables 5 and 6 respectively. An increase in population has a double-barreled effect on agricultural use of water and the rate of technological advance is also crucial.[31] This level of increase will undoubtedly cause problems in competing uses of water in selected areas and a need for further development of ground water resources.

Table 5. Mid-year Population Estimates: Thailand

A.D.	Thai Population (1000)	A.D.	Thai Population (1000)
1956	23,445	1962	27,995
1957	24,148	1963	28,835
1958	24,873	1964	29,700
1959	25,619	1965	30,591
1960	26,388	1966	31,508
1961	27,180	1967	32,680

Source: United Nations Monthly Bulletin of Statistics, January 1969.

[31]Roger C. Woodworth and LeRoy Rogers, "The Future Agricultural Use of Water: Southern Humid Region," Water Resources and Development in the South (Georgia: The Council of State Government Issue, API, Series 16, August, 1965), p. 19.

Table 6. Index Numbers: Area Planted of Principal Crops, 1950-1967

A. Food crops 1950-53 = 100

Year	Rice	Upland food crops				
		Maize	Mung beans	Cassava	Sugar-cane	Total
1950-53	100	100	100	100	100	100
1954	120	124	93	107	137	122
1955	100	130	102	98	148	129
1956	104	193	103	63	173	154
1957	88	228	112	274	183	188
1958	100	298	119	315	188	214
1959	105	470	137	447	211	285
1960	103	671	155	511	225	354
1961	107	720	108	710	177	353
1962	116	771	147	877	145	375
1963	115	982	298	994	213	503
1964	114	1,297	300	745	232	573
1965	112	1,355	357	724	202	586
1966	128	1,535	398	930	178	650
1967	111	1,748	393	1,006	213	727

Table 6. Index Numbers: Area Planted of Principal Crops, 1950-1967 (Continued 1)

B. Oil seeds

Year	Castor beans	Ground nuts	Sesame	Soy beans	Coconuts	Total
1950-53	100	100	100	100	100	100
1954	149	110	95	103	128	118
1955	144	112	102	98	132	120
1956	187	114	105	109	142	128
1957	262	135	132	120	146	144
1958	228	138	133	103	145	142
1959	278	139	129	101	144	143
1960	311	164	129	102	177	168
1961	362	116	85	109	199	161
1962	457	121	110	128	228	183
1963	448	116	117	154	241	190
1964	384	121	110	157	241	189(r)
1965	357	138	156	86	267(r)	201(r)
1966	430	218	180	210	266	245
1967	247	150	208	293	292	246

Table 6. Index Numbers: Area Planted of Principal Crops, 1950-1967 (Continued 2)

C. Fiber crops

Year	Cotton	Kapok and bombax	Jute	Kenaf	Ramie	Total(1)
1950-53	100		100	100	100	100
1954	89		55	60	136	84
1955	84		69	86	14	81
1956	103		110	177	36	114
1957	107	100	83	127	21	205(r)
1958	105	96	90	207	29	215(r)
1959	123	103	117	452	29	281(r)
1960	142	111	179	1,426	36	484(r)
1961	146	72	455	2,797	50	714(r)
1962	152	71	331	1,158	43	410(r)
1963	186	101	234(r)	1,556(r)	36	534(r)
1964	171	102	228(r)	2,220(r)	50	645(r)
1965	192	106(r)	338(r)	3,904(r)	64	980(r)
1966	213	100	441	5,389	21	1,265
1967	287	97	317	3,540	9	969

(1) Excluded kapok.

Table 6. Index Numbers: Area Planted of Principal Crops, 1950-1967 (Continued 3)

D. Garden crops, fruits, miscellaneous crops and total

Year	Garden crops	Fruits	Rubber	Tobacco	All crops except rice	All crops
1950-53			100	100	100	100
1954			111	128	114	99
1955			115	132	118	102
1956			119	133	129	108
1957	100	100	123	145	161	97
1958	112	97	127	143	167	108
1959	122	109	130	145	189	116
1960	157	154	134	137	228	119
1961	233	215	137	96	249	125
1962	305	207	139	96	243	132
1963	319	247	145	96	286	136
1964	301	245	147	120	306	138
1965	300	343	148	167	344(r)	142
1966	477	388	203	201	424	165
1967	483	389	204	146	418	150

Source: Division of Agricultural Economics, Agricultural Statistics of Thailand (Bangkok: Ministry of Agriculture, 1967), pp. 35-38.

CHAPTER III

THE CONCEPT OF GROUND WATER USE AND AGRICULTURAL DEVELOPMENT

Ground water is one of the natural resources which contains the largest storage of fresh water in the nation.[32] We can consider ground water as the storage of flow resources or some characteristics of fund resources. This concept of ground water can be applied to particular resources, such as our flow resources precipitation, the water in streams and lakes, sunlight, wind, tides and climate.[33] The flow of these resources comes in a continuous and predictable stream which continues regardless of whether the resources are used or not. Water can be retained in surface or underground reservoirs, while the energy from the sun can be stored both in plants and in certain chemicals. When flow resources are stored in this manner, they take on some characteristics of fund resources. These resources are renewable. But they must be used when they become available.

They have economic value when they become utilities.

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[32]Harold E. Thomas, "Underground Sources of Our Water," Water: The Yearbook of Agriculture (Washington: The United States Government Printing Office, 1955), p. 62.

[33]Raleigh Barlowe, Land Resource Economics (New Jersey: Prentice-Hall, Inc., 1958), p. 285.

The economist's concept of demand can be useful in this study. The needs and requirements concept does not permit, does not necessitate, critical evaluation of its relative relationship vis-a-vis other water services, and other competing or complementary lines of activity. Admittedly, the concept of demand will be used in very technical and less technical contexts, yet it carries with it a complex of functional relationships which give interpretative meaning to its use.[34] Generally speaking, both surface and ground water are free resources. They will not have economic value if they are not suitable for irrigation, for industrial or public use. We pay their costs in terms of the operation, maintenance, fuel, electricity, service, etc. The costs of ground water use vary from place to place depending on geographical characteristics, water quantities, the depth of ground water wells and equipment for irrigation.

The development of ground water wells for agricultural purposes is a kind of investment which can be classified as the capital intensive infrastructure, the capital investment of which is mainly concerned with public services; for instance, roads, bridges, irrigation, processing plants, warehouses and public utilities. In agricultural development, it is greatly imperative that

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[34]S. V. Ciriacy Wantrup, "Projections of Water Requirements in the Economics of Water Policy," Journal of Farm Economics, Vol. 43 (1961), pp. 197-214.

the level of infrastructure be developed in order to accelerate agriculture. Besides, even roads which are required to be developed for shipment of farm products from the producing area to the consumers' area, still exist numerous factors that call for the development within the agricultural structure on the farm level, at least in a state that would enable agriculture to move rapidly. This type of work is being chiefly undertaken by the government at present.[35]

The ground water resources development currently being undertaken in the Northeast by various agencies, although its capital investment is less than that for a dam or road construction, is relatively beyond the capability of an average individual farmer, due to the immeasurable amount of capital investment, and the main operation on which is the ground water use for consumption merely at a village level. This is different from the ground water wells within the area of Changwats Karnchanaburi, Singburi, and other Changwats which are undertaken by individuals since the capital investment is relatively low; currently about 2,000 wells are in existence.[36] The distinction is

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[35]The National Economic Development Board, The Second National Economic and Social Development Plan (1967-1971) (Bangkok, Thailand: 1968).

[36]M. C. Sithiphon, "Address given by M. C. Sithiphon who presided over the opening ceremony of Luang Suwanvajokasikit Statue," Agricultural Information Newsletter (1968), pp. 6-12.

obvious in terms of a well's pattern of water quantity, and topography. When justification is made on the pattern of drilling the ground water wells in the Northeast and the Central region, it is apparent that the infrastructure and technical externalities are in close relation in terms of technically exhibited indivisibility.[37] It means that once the ground water wells had been dug, the infrastructure in these areas will be in a better state and many homesteads can take advantage of the utilization as well, thus showing the increasing return to scale in the relevant range of output,[38] since the optimum use of any ground water well can be determined only by the joint use of several households. According to the economic records, it appears that the agricultural production of the large, through the very expensive irrigation system installed since World War II, in general, has been very poor. As a result, controversy has arisen on the water issue with rationalization to introduce other devices since the construction of each major irrigation dam entails huge sums of expenditure. In the meantime, the techniques of ground water wells and water pumps are progressively being made, thus reflecting low cost of investment, short range

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[37]John Friedmann, The Regional Development Policy: A Case Study of Venezuela (Massachusetts: The MIT Press, 1966), pp. 61-62.

[38]F. M. Bator,"The Anatomy of Market Failure," Quarterly Journal of Economics, 78 (1958), pp. 351-79.

construction, and quick return. Consequently, the undertaking along this line has come into existence on a nation-wide scale in other countries, for instance, India and Pakistan.[39]

In considering the drawing up of economic policy and plan, it is imperative to make justification on conditions of each locality due to its influence on the functional economic area, the pattern of which inclines of self-sustenance. This means a large-scale economic enterprise undertaken by the people in that locality,[40] who are concerned with their production for local consumption. Other enterprises consist of various products exported to localities which are the internal relations among localities inside the country. Consequently, in establishing a model for economy and policy, if a locality is included, such a model will gain better shape than that of others.[41] Let the Northeastern Region be taken into consideration. It is apparent that the majority of its people still remain farmers; these farmers grow rice for home consumption, leaving some surplus, if any, for sale. This includes

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[39] T. N. Schultz, "Production Opportunities in Asian Agriculture," Economist's Agenda, Michigan State University, June 20, 1968.

[40] Ibid.

[41] K. A. Fox, J. K. Sengupta, and E. Thorbecke, The Theory of Quantitative Economic Policy (Amsterdam: North-Holland Publishing Company, 1966).

field crops and livestock raising which also can earn a major income for these families. While the economic conditions are being expanded, the towns are enlarged accordingly, especially in Khon Kean, Udon Thani, Ubon Rachatani, and other provinces. The population in these provinces is increasing, thus reflecting urgent requirements for cereal food, animal meat, fish, chicken, eggs and vegetables. The locally produced foods which slowly expand are eggs and vegetables. But animal meat is sufficient since the Northeast has already been the source of production for its export.[42] Fish is imported from the Central Region. Likewise, chicken, which is usually obtained from indigenous breeds, is now starting to be in short supply and its price has a tendency toward soaring. Regarding upland crops, kenaf is being extremely expanded, as witness are the increased number of balling plants. Cotton has also earned its rapid expansion accompanied by the cotton-gin factory. All these crops are exported to other regions.[43] The improvements in the Northeast have resulted in more economic viability as well as a somewhat rapid growth in upland crop farming since the existing structure inclines to be convertible toward that trend.

But certain infrastructures, especially water

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[42]Division of Agricultural Economics, <u>Agricultural Statistics of Thailand</u> (Bangkok, Thailand: 1967), pp. 104-37.

[43]<u>Ibid</u>., pp. 76, 85.

shortage, is unable to make farmers change their farming to crop growing that requires much water, such as vegetables sufficient to meet the demand in that sector. The price of lettuce is Baht 1.50 per kilogram in Bangkok, in the Central Region, while in Udon Thani Province it is Baht 4-5 per kilogram.[44] Chicken eggs are also shipped from Bangkok for sale in Udon Thani, Ubon Rachatani and Nougkhai provinces despite the fact that the production cost of poultry raising for broilers and eggs in the Northeast is lower than that in Bangkok and its vicinities[45] on account of the availability of field crops grown in the area as poultry feed.[46] But farmers lack knowledge and techniques in poultry raising through the capital extensive infrastructure as well as confronting competition from the Central Region, the volume of business of which is greater than the poultry business enterprise in the Northeast; accordingly this hinders the attainment of rapid expansion. For this reason, justification for each crop in each locality would be of great benefit in setting up the agricultural development plan.[47]

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[44]Ministry of Agriculture, <u>A Study on Agricultural Economic Conditions</u> (Bangkok: Phakdi Pradit Press, 1965), pp. 32-41.

[45]<u>Ibid.</u>, p. 49.

[46]Division of Agricultural Economics, <u>Agricultural Statistics of Thailand</u> (Bangkok, Thailand: 1967), p. 55.

[47]Melvin M. Wagner, "Regional Specialization in Thai Agriculture," <u>Agricultural Economics</u> (Bangkok: Kasetsart University Press, 1967), pp. 41-51.

CHAPTER IV

OPERATION AND ACCOMPLISHMENT

I. GROUND WATER USE FOR VEGETABLE PRODUCTION

The village of Naka is situated in Amphur Muang District, Udon Thani Province, 14 kilometers north of the city of Udon Thani, adjacent to the Udon-Nongkhai highway. The Farm Management Pilot Project Unit had started its operation in the village in late 1965,[48] the work of which stresses the farm account and farm management for the purpose of finding out what types of main agricultural enterprises are engaged in by farmers in this village and how much are their earnings and expenditures incurred from and in each particular type of their enterprises through the farm accounts which are to be kept by the farmers themselves. From the farm accounts, it is learned that the main crop grown by farmers in this village is rice, through the transplanting method, for home consumption, with a small surplus for sale. Other types of enterprises are swine-raising through the purchase of piglets which are fattened for sale; this is one method of raising swine.

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[48]Division of Agricultural Economics, The Farm Management Pilot Project in the North-eastern Part of Thailand (Bangkok, Thailand: Ministry of Agriculture Issue, 1966), pp. 20-31.

The other way is to purchase swine of various sizes and rear them sporadically through the use of rice bran as a concentrated feed prior to further sale. Poultry-raising is mainly of the native breeds for sale of their meats. There exists some kenaf growing, but not on a large scale, due to the lack of water sources for kenaf retting. Since poultry raising has clearly been in existence in this village, the Farm Management Team had then advised farmer members to rear laying-hens for the purpose of selling their eggs. But feeds have become a problem because poultry feeds have to be bought from the city at prohibitive prices.

The Farm Management Team then emphasized the work of growing feed grain crops, i.e., corn and sorghum. But this activity was slow to expand due to the lack of farmers' experience in growing corn and sorghum which are mostly patterned on kenaf cultivation, i.e., a haphazard way of planting. An effort has been made by the team in giving advice to members on planting in orderly rows and spaces and in the use of the buffalo plow to cultivate between rows.

Due to the fact that farming has to depend largely on rainfall, which is inadequate to meet crop requirements throughout the year, water has, therefore, become one of the most vital problems in increasing the farmers' income. But if good water sources are available, it will help develop rice farming to its fullest extent. Likewise, it would also help develop livestock raising to have water for animal consumption throughout the year, including vegetable growing that might become another occupation potential, the net profit of which can be gained by increasing farmers' income on account of the proximity of the Udon market. There is a great demand for vegetables by the people of Udon Thani, thus resulting in their high prices.

Regarding livestock raising, besides the obstacles stated, it cannot be expanded to a great extent. The area planted in field crops is moderate. Consequently, only intensive farming can be implemented by growing field crops as a second crop in the paddy field. In so doing, there must be sufficient water prior to the rainfall or through the drilling of a ground water well. Accordingly, a contact has been made with the Department of Mineral Resources requesting its assistance in drilling the ground water well; in response the best cooperation was given which contributed toward the drilling of two ground water wells.

The first ground water well is located south of the Naka Village, about one-half kilometer in distance, while the second well is about two kilometers north. The first well was drilled in 1969 on the land connected to the bush and bamboo forests, a part of which was once cleared for kenaf cultivation within the area of 17.2 rai currently uncultivated but owned by four farmers with the land connected consecutively, leaving the balance area surrounded by paddy field. The second well was drilled in early 1970 on a small area of rolling land, approximately 3 rai, surrounded by paddy field. The operation has started from the first well, since there exists a large area of rolling land and its location is near the village. The existing 34 members were called for a meeting for the purpose of explaining the work plan; a water-pump would be installed in the well which had been drilled, thereafter water would be released to farmers for vegetable growing so that they might sell these vegetables in the Udon markets where the price is high. But farmers are in favor of having water released into their paddy field rather than for vegetable growing purposes since they are not convinced that they will be able to earn more if they grow vegetables, and they think that vegetable growing may be confined merely for home consumption. Despite the fact that farmers have been convinced by the officers that water can also be released into their rice fields, they still do not conceive the profit from growing vegetables. Another reason why farmers are not in favor of growing vegetables is that there exists brushwood and stumps on this land which will call for joint work among members in clearing brushwood and digging out stumps that might take much time to complete, prior to growing vegetables.

When such a problem arises, the Farm Management Team is of the opinion that the water-pumping machine used for pumping water from the well, obtained from the Department of Mineral Resources, of turbine design which produces high pressure quality capable of being used for a sprinkler system; as such, if the pump, main line and lateral line are installed with sprinkler nozzles, then the work can be quickly done. And farmers will see that the use of the sprinkler system is somewhat similar to rainfall. The only tasks they have to do are soil preparation and vegetable bedding without watering them; thus they can gain the farmers' confidence rapidly. Consequently, the Farm Management Team has made the decision to install the sprinkler equipment immediately irrespective of the existence of brushwood. In the meantime, only 4-5 members had contributed their labor in brush clearing and digging out the stumps. Upon completion of the sprinkler installation, 34 members decided to cooperate in land clearing and preparation of vegetable plots; these were completed in February 1970. They started to grow vegetables in March 1970 in an area of 3.975 rai* with the sprinkler irrigation and 7.443 rai* with furrow irrigation.

A. Investment

The investment in drilling a ground water well is mainly in the cost of drilling and of the water pump, totalling Baht*120,000 for both items (see Table 7). The subsidiary capital investments are sprinkler equipment

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*1 acre = 2.5 rai
1 dollar ≃ 20 baht.

and furrow equipment, i.e., pipe lines and nozzles. For furrow irrigation, the investment in which is cheaper than that of sprinkler irrigation, more labor use is required from farmers such as stump digging. Furrow making and plot and furrow leveling are required for conveyance of water into furrows. Apparently the investment cost is almost three times cheaper and more area can be covered. Considered as its fullest capacity for the sprinkler irrigation system, the original area of 3.975 rai can currently be expanded to 5 rai*, and for the furrow irrigation system, the original area of 7.443 rai can currently be expanded to 12 rai in the next year. Furrow irrigation requires the laying of the main lines with regulators at 12 meter intervals. The terminal of the main line is laid in the highest elevation from which water can be distributed into the paddy field, approximately 200 rai, since the level of the paddy field is lower than that of the farm turnout.

However, water distributed into the paddy field can be provided only when there is a shortage of rainfall. But it is expected that contribution can be given to the fullest extent, for seed bedding in times of seasonal requirement. Regarding water distribution for transplanting purposes, this will depend largely upon the kinds of crops cultivated in this area, i.e., if such crops are not

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*1 acre = 2.5 rai.

vegetables alone but other crops such as peppers, egg-plant, pumpkin and cucumbers are included, the water use for these crops in the stated area can be minimized. For this reason, water distribution for rice farming will be more effective, the detailed study of which will be made further on in this area, but the former study on ground water use for rice paddy fields is shown in Part II of this chapter.

The total cost of capital investment stood at Baht* 161,587. The lifetime for a water pump is estimated at 5 years, and 10 years for the ground water well and its water supply equipment. (Hydrologists are inclined to believe that the ground water well would have a lifetime of more than 10 years.) The annual depreciation is computed basically through the Sinking Fund Method**[50] at the rate of time deposits at the Government Savings Bank, i.e.,

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*1 dollar $\simeq$ 20 baht.

**The annual depreciation is computed basically through the Sinking Fund Method. This method is derived from the accumulated value of an immediate annuity:

$$s_{\overline{n|}i} = \frac{(1 + i)^n - 1}{i}$$

and the annual depreciation $d = \dfrac{C}{s_{\overline{n|}i}}$

where d is annual depreciation and C is the capital investment.

[49]J. W. Bennett, J. McB. Grant, and R. H. Parker, <u>Topics in Business Finance and Accounting</u> (Sydney: Halstead Press, 1964), pp. 3-22.

5 per cent per annum. The annual depreciation is computed at Baht 18,935.16. Through this Sinking Fund Method, when the annual depreciation is deposited in the time deposit account of the Government Savings Bank, the interest is payable. Thereafter, the amount of interest shall be compounded to a principal sum for the ensuing year. Upon completion of a period of time as computed, the sum will be accrued sufficiently to purchase new equipment for replacement of the old (Table 7).

Table 7. Total Investment and Depreciation of Ground Water Well Use for Vegetable Production

Items	Capital Investment (Baht)	Lifetime (years)	Annual Depreciation (Baht)
Ground water well	60,000	10	4,770.28
Water-pump	60,000	5	10,858.49
Sprinkler Irrigation Equipment	30,169	10	2,398.57
Furrow Irrigation Equipment	11,418	10	907.82
Total	161,587	--	18,935.16

Note: 1 dollar $\simeq$ 20 baht

The depreciation cost is computed the Sinking Fund Method,

i.e., $d = \frac{C}{S_{\overline{n|}i}}$

by $S_{\overline{n|}i} = \frac{(1 + i)^n - 1}{i}$

when d = annual depreciation
c = capital investment
i = loan interest, 5% per annum
n = time.

B. Income

The total income derived from the sale of vegetables through the use of the ground water well for the plots operated by sprinkler irrigation from March 1970 to February 1971 stood at Baht 75,042.50, with expenditures of Bhat 9,950. Hence the income over expenditure is Baht 65,092.05. For plots operated by furrow irrigation, the income derived from the sale of vegetables stood at Baht 95,414.30, with expenditures of Baht 18,068.50. Hence, the income over expenditures is Baht 77,345.80; thus, the total gross profit from the dual irrigation system, i.e., sprinkler and furrow, is Baht 142,437.85. The income is figured from the total sale of vegetables as against the expenditure incurred for seeds, fertilizer, pesticides, and cost of materials, especially hoes, handspades, and others including transportation cost of trucks and fuel cost for the water pump (See tables 8, 9, 10, 11 and 12).

Incidentally, it is observed that the computation for expenditure does not include the labor cost of vegetable growing. This is regarded as the opportunity cost in growing vegetables is equal to zero which should be true if it is considered that the income derived from this was nil originally. If the computation includes a deduction of the labor cost, it is apparent that the estimated return for this purpose is still higher than the interest rate (see table 9).

Another significant gain from the job implementation of farmers is high income from vegetables which they had never before obtained; but competition will arise between the use of labor for vegetable growing and rice farming during the months of May, June and July. In these months, farmers will neglect vegetable growing for rice farming, because rice is a major crop and is valuable to them in terms of human food over any other crop. This causes a drop in income during August, September and October. But when the transplanting season is over, these farmers will hurry home to resume their work on vegetable gardening. In addition, the farmer's enthusiasm is also involved--the aspiration of getting additional money and their industriousness which varied greatly in the initial stage of operation. The average income per month per family is figured at Baht 442.29 with a net income* of Baht 391.26. The most industrious farmer can earn a net income of Baht 964.81 per month. On the contrary, the idle farmer had a net income of only Baht 58.75 per month. But it is believed that low-income farmers will start to follow those farmers whose incomes are higher on future occasions.

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*Net income is derived from the total income over the total expenditures, but does not include the annual depreciation cost.

Table 8. The Expenditure in Baht of Vegetable Production of 12 Members by Using the Sprinkler Irrigation Method from A Ground Water Well

Month	Seed	Ferti- lizer	Fungi- cide and In- secti- cide	Tools	Fuel and Oil	Hired Labor	Main- ten- ance	Land Tax	Misc.	Total
Mar. 70	697.00	158.00	73.00	357.00	198.00	---	3.00	---	---	1,486.00
April 70	630.00	285.50	238.00	1,225.00	229.00	---	158.00	28.00	---	2,793.50
May 70	804.50	282.50	228.00	22.00	194.00	---	---	---	---	1,531.00
June 70	625.00	143.25	78.00	50.00	134.00	---	---	---	---	1,030.25
July 70	99.00	35.50	36.00	---	---	---	---	---	---	170.00
Aug. 70	230.00	11.00	49.00	---	---	---	---	---	---	290.00
Sept. 70	236.00	83.50	9.00	---	179.00	---	---	---	---	507.50
Oct. 70	220.00	152.50	64.00	---	70.00	---	---	---	---	506.50
Nov. 70	214.50	114.00	65.00	---	106.00	---	---	---	---	499.50
Dec. 70	52.00	51.50	36.00	---	117.00	---	---	---	---	256.50
Jan. 71	223.50	149.50	70.00	43.00	102.25	---	---	---	---	588.25
Feb. 71	120.50	115.00	40.00	---	15.00	---	---	---	---	290.50
Total	4,152.00	1,581.75	986.00	1,679.00	1,344.25	---	161.00	28.00	---	9,950.00
Av. per Month	346.00	131.81	82.17	141.42	112.02	---	13.42	2.33	---	829.17
Av. per Month per Household	28.83	10.98	6.85	11.79	9.34	---	1.12	0.19	---	69.10

Note: 1 dollar $\simeq$ 20 baht.

Table 9. The Expenditure in Baht of Vegetable Production of 22 Members by Using the Furrow Irrigation Method from A Ground Water Well

Month	Seed	Fertilizer	Fungicide and Insecticide	Tools	Fuel and Oil	Hired Labor	Maintenance	Land Tax	Misc.	Total
Mar. 70	1,140.50	319.50	227.00	50.00	399.00	34.50	---	---	---	2,170.50
April 70	1,355.00	357.25	235.00	1,029.00	341.00	34.50	251.00	---	5.00	3,607.75
May 70	1,553.50	648.50	338.00	122.00	316.00	2.00	---	---	---	2,980.00
June 70	956.50	234.50	229.00	45.00	182.00	---	---	---	---	1,647.00
July 70	318.50	103.00	80.00	---	22.00	---	---	---	---	523.50
Aug. 70	391.50	98.00	52.50	---	---	---	---	---	---	542.00
Sept. 70	491.00	125.50	99.00	196.00	191.00	6.00	---	---	---	1,108.50
Oct. 70	452.50	447.00	154.00	3.00	151.00	---	6.75	---	---	1,214.25
Nov. 70	219.50	346.00	180.00	9.00	154.00	---	18.00	---	---	926.50
Dec. 70	254.75	390.50	127.00	40.00	168.00	10.00	31.00	---	---	1,021.25
Jan. 71	408.00	353.50	88.00	71.00	292.75	133.50	---	---	---	1,346.75
Feb. 71	452.50	326.00	123.00	---	41.50	37.50	---	---	---	980.50
Total	7,993.75	3,749.25	1,932.50	1,565.00	2,258.25	258.00	306.75	---	5.00	18,068.50
Av. per Month	666.15	312.44	161.04	130.42	188.19	21.50	25.56	---	0.42	1,505.71
Av. per Month per Household	30.28	14.20	7.32	5.93	8.55	0.98	1.16	---	0.02	68.44

Note: 1 dollar ≃ 20 baht.

Table 10. The Income in Baht of Vegetable Production of 12 Members by Using The Sprinkler Irrigation Method from A Ground Water Well

Month	Income	Expenditure	Return
March 70	5,563.00	1,486.00	4,077.00
April 70	11,601.25	2,793.50	8,807.75
May 70	13,846.75	1,531.00	12,315.75
June 70	8,424.50	1,030.20	7,394.30
July 70	3,287.50	170.00	3,117.50
August 70	2,098.50	290.00	1,808.50
September 70	1,474.00	507.50	966.50
October 70	4,819.00	506.50	4,312.50
November 70	5,834.50	499.50	5,335.00
December 70	6,837.25	256.50	6,580.75
January 71	6,199.00	588.25	5,610.75
February 71	5,057.25	290.50	4,766.75
Total	75,042.50	9,950.45	65,092.05
Av. per Month	6,243.54	829.17	5,424.421
Av. Per Month Per Household	521.13	69.10	452.04

Note; 1 dollar $\simeq$ 20 baht.

Table 11. The Income in Baht of Vegetable Production of 22 Members by Using the Furrow Irrigation Method from A Ground Water Well

Month	Income	Expenditure	Return
March 70	6,171.00	2,170.50	4,000.50
April 70	13,643.00	3,607.75	10,035.25
May 70	16,446.00	2,980.00	13,466.00
June 70	9,242.00	1,647.00	7,595.00
July 70	4,422.00	523.50	3,898.50
August 70	3,433.00	542.00	2,891.00
September 70	2,345.75	1,108.50	1,237.25
October 70	7,841.25	1,214.25	6,627.00
November 70	7,775.05	926.50	6,848.55
December 70	10,999.00	1,021.25	9,977.75
January 71	6,296.50	1,346.75	4,949.75
February 71	6,799.75	950.50	5,819.25
Total	95,414.30	18,068.50	77,354.80
Av. per Month	7,951.19	1,505.71	6,445.48
Av. per Month per Household	316.42	68.44	292.98

Note: 1 dollar $\simeq$ 20 baht.

Table 12. The Income in Baht of Vegetable Production of 34 Members of the Udon Thani Farm Management Project by Using the Sprinkler and Furrow Irrigation Methods from A Ground Water Well

Month	Income	
	Sprinkler	Furrow
March 70	5,563.00	6,171.00
April 70	11,601.25	13,643.00
May 70	13,846.75	16,446.00
June 70	8,424.50	9,242.00
July 70	3,287.50	4,422.00
August 70	2,098.50	3,433.00
September 70	1,474.00	2,345.75
October 70	4,819.00	7,841.25
November 70	5,834.50	7,775.05
December 70	6,837.25	10,999.00
January 71	6,199.00	6,296.50
February 71	5,057.25	6,799.75
Total	75,042.50	95,414.30
Av. Per Month	6,243.54	7,951.19
Av. Per Month Per Household	521.13	316.42

C. Evaluation

When justification has been made on the income and expenditure as mentioned above, the capital investment for this project can therefore be estimated, thus:

1. Payout Period

The estimate of the payout period will be a rough figure to show how many years the total income can cover the investment by deducting the expenditure on operation and maintenance from total income; thereafter, it can be comparable to the capital investment. For this project, the gross net income derived from its operation has obviously stood at Baht 142,437.85 per year and the total investment of Baht 161,587.00. Consequently, the number of years that can meet the recovery of investment will be 1.13 years or 1 year and 2 months.

2. The Marginal Productivity of Capital

The return on capital will emerge in the future which depends upon the time or age limit of the assets invested as to how long they would last. The return on capital in cash from the investment of equipment and materials in the use of the ground water well is a margin after deducting the operating costs for vegetable growing including the depreciation cost of the assets. Normally, the primary income is brought up for computation wherein the depreciation cost is not included. However, the interest shall not be included since comparison is required to figure out the rate of return on capital as against the interest rate.

The principle applied for computation is based on the profit maximizing operator, i.e., money receivable in the future will be deducted by the discount to be the current value. Then the present value of the capital asset will be, assuming continuous compounding:

$$P(t) = \int_{0}^{t} R(t)e^{-it} dt \quad . \ . \ . \ . \ . \ . \ . \ (1)$$[50]

when $P(t)$ = value of the total capital assets or present value of the project

$R(t)$ = annual return or the fund inflow function

e^{-it} = the present value factor under continuous discounting over time t at rate of return i.

Suppose $R(t) = (t) = R$ is a constant which implies that the annual return remains equal in every year, then $P(t)$ becomes

$$P(t) = \frac{R}{i} (1 - e^{-it}) \quad . \ . \ . \ . \ . \ . \ . (2)$$

which is the equation that requires to find out the value of i in a duration. However, if $t \rightarrow \infty$, then $P(t)$ becomes

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[50]Adolph E. Grunewald and Erwin Esser Nemmers, Basic Managerial Finance (Chicago: Holt, Rinehart and Winston, Inc., 1970), p. 213.

$$P(t) = \frac{R}{I} \quad \ldots\ldots\ldots (3)$$

a) When justification is given to the project of a five-year duration, the time that a water pump has to be changed but the depreciation cost is not deducted, the rate of return computed from equation (2) will be 87 per cent per annum (see table 13).

b) When justification is given to the project of a ten-year duration--the time that the entire equipment has to be changed but the depreciation cost is not deducted, the rate of return will be 88 per cent per annum.

c) When justification is given to the project of similar duration to (b) above, but the depreciation cost is deducted, the rate of return will be 76.50 per cent per annum.

d) When justification is given to the return irrespective of duration (equation 3) by deducting the operation and maintenance and depreciation cost from the total income, the rate of return on capital will be 76 per cent per annum.

From the consequences of computing the rate of return through the various methods aforementioned, it is apparent that when the rate of return is compared with the rate of interest, the minimum rate of return of the above four methods is higher than the interest rate. This can be regarded as a measure that the investment in the ground water well development for agricultural purposes is the

Table 13. The Estimated Return Without Deducting the Labor Cost (Vegetables)

Discount Rate %	Integrate of the return in 5 yrs. duration without deducting the depreciation	Integrate of the return in 10 yrs. duration without deducting the depreciation	Integrate of the return in 10 yrs. duration by deducting the depreciation	Integrate of the return irrespective of duration by deducting the depreciation
76.00				161,587.00
76.50			161,365.16	
87	161,609.05			
88		161,837.31		
	The Estimated Return by Deducting the Labor Cost			
41.50			161,114.01	
42.00				161,587.00
49.50	160,721.81			
53.50		161,599.88		
Total Cost	161,587.00	161,587.00	161,587.00	161,587.00

most appropriate one. If the welfare of farmers in the rural area is taken into consideration, such a measure as mentioned above will be further strengthened.

II. GROUND WATER USE FOR RICE PRODUCTION

This part of operation and accomplishment on ground water use for rice production is based on the data study by the Division of Ground Water Development, Department of Mineral Resources. This study emphasizes ground water use for growing rice as the supplement irrigation of upper rice paddy fields or application to growing rice out of season without depending on annual rainfall or surface water irrigation. The data of water requirement, expenditures and yield of rice cultivation is based on the previous study in the FAO report issued in Thailand.[51] It is apparent that the water requirement for rice cultivation is about 1800 cubic meters per rai. The average costs* of rice production* is about Baht** 200 per rai.** The maximum yield of rice production is about Baht 200 per rai. The maximum yield of rice production in the condition of lack

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[52]Department of Rice, Survey Report on Rice Cultivation in Thailand (Bangkok, Thailand: FAO report issue, 1960), pp. 15-30.

*Average cost = seed, insecticide and fungicide and hired labor for rice cultivation; does not include family labor.
Rice production = the production of rice without using chemical fertilizer.

**1 acre = 2.5 rai
1 dollar ≃ 20 baht.

of water requirement is 250 kilogram while the minimum yield of rice production in the condition of optimum water requirement is 500 kilogram per rai (see table 14).

Table 14. Comparison of the Average Rice Yield Between Lack of Water and Optimum Water Requirement

Items	Rice Yield Kilogram/rai
Lack of Water Requirement	Maximum 250
Optimum Water Requirement	Minimum 500
Gain	250

Source: FAO report issued on rice cultivation in Thailand.

The objective of the study is interested in how much it costs for drilling a ground water well to use for rice cultivation and how much is its return for this process. What capacity of well yield is appropriate to the number of paddy fields?

A. Investment

The investment in drilling the ground water wells varies by size and water pumps. Total cost for drilling a ground water well with a capacity of 400 m^3/hr, size 12", 0-120' with appropriate water pump is about Baht 180,000. This well capacity can supply water for rice cultivation of approximately 800 rai. Total cost for drilling a ground water well with capacity of 200 m^3/hr, size 10", 0-120' with appropriate water pump is about Baht 150,000. This well capacity can supply water for rice cultivation of approximately 400 rai. Total cost for drilling a ground water well with capacity of 100 m^3/hr, size 8", 0-120' with appropriate water pump is about Baht 120,000. This well capacity can supply water for rice cultivation approximately 200 rai. Total cost for drilling a ground water well with capacity of 50 m^3/hr, size 6", 0-120' with appropriate water pump is about Baht 90,000. This well capacity can supply water for rice cultivation of approximately 100 rai*(see table 15).

The depreciation is computed through the Sinking Fund Method as in part I. The total investment and depreciation of ground water wells in different sizes, depths and water capacity use for paddy fields is shown in Table 15.

B. <u>Income</u>

The total income derived from the value of rice production through the use of ground water wells for rice

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*1 acre = 2.5 rai
1 dollar ≈ 20 baht.

i.e., 400 m^3/hr = well capacity yields water 400 cubic meters in one hour.
12", 0-120' = size of well in diameter in inches and depth in feet.

Source: From the estimated investment in drilling ground water wells by the Division of Ground Water Development.

Table 15. Total Investment and Depreciation of Ground Water Wells in Different Sizes, Depths, and Water Capacity, Use for Paddy Field

Items	Ground Water Well Capacity, 400 m^3/hr			Ground Water Well Capacity, 200 m^3/hr			Ground Water Well Capacity, 100 m^3/hr			Ground Water Well Capacity, 50 m^3/hr		
	Diameter & Depth 12", 0-120'			Diameter & Depth 10", 0-120'			Diameter & Depth 8", 0-120'			Diameter & Depth 6", 0-120'		
	Capital Invest. Baht	Life time Year	Annual Deprec. Baht	Capital Invest. Baht	Life time Year	Annual Deprec. Baht	Capital Invest. Baht	Life time Year	Annual Deprec. Baht	Capital Invest. Baht	Life time Year	Annual Deprec. Baht
Ground Water Wells	100,000	10	7,350.46	80,000	10	6,360.37	60,000	10	4,770.27	50,000	10	3,975.23
Water Pumps	80,000	5	14,477.98	70,000	5	12,668.23	60,000	5	10,858.49	40,000	5	7,238.99
Total	180,000		22,428.44	150,000		19,028.60	120,000		15,628.76	90,000		11,214.22

Note: 1 dollar ≃ 20 baht.

cultivation per annum. It is apparent that total income derived from ground water wells with a capacity of 400 m^3/hr stood at Baht 520,000--with an expenditure of Baht 61,000.00. Hence, the income over expenditure is 519,000. For total income derived from a ground water well with capacity of 200 m^3/hr it was Baht 260,000 with expenditures of Baht 36,700. Hence the income over expenditure is Baht 223,300. Total income derived from a ground water well with a capacity of 100 m^3/hr stood at Baht 130,000 with expenditure of Baht 12,800. Hence, the income over expenditure is Baht 117,200. For total income derived from a ground water well with a capacity of 50 m^3/hr stood at Baht 65,000 with an expenditure of Baht 13,400. Hence, the income over expenditure is Baht 51,600 (See tables 16 and 17).

Incidentally, it is observed that the computation for expenditure does not include the family labor cost in rice cultivation. This is regarded as the opportunity cost in rice cultivation equal to zero, which should be true if it is considered that the income derived from this was nil originally. If the computation includes the deduction of the labor cost, it does not appropriate for digging deep ground water for growing rice, but it is still appropriate to this investment if we compare to the original time.

Table 16. Annual Expenditure of Ground Water Wells Used for Growing Rice

	Depreciation	Maintenance	Fuel & Oil	Depreciation	Maintenance	Fuel & Oil
	Paddy Field 800 rai			Paddy Field 400 rai		
	Ground Water Well No. I			Ground Water Well No. II		
	Baht	Baht	Baht	Baht	Baht	Baht
	22,428.44	9,000	52,000	19,028.60	7,500	29,200
Total		83,428.44			55,728.60	
Average Per Rai		104.28			139.32	
	Paddy Field 200 rai			Paddy Field 100 rai		
	Ground Water Well No. III			Ground Water Well No. IV		
	15,628.76	5,000	15,800	11,214.22	4,000	9,400
Total		36,428.76			24,614.22	
Average Per Rai		182.14			246.14	

Note: 1 dollar ≃ 20 baht
1 acre = 2.5 rai

Table 17. Annual Income, Expenditure and Return of Rice Production

Items	Income	Expenditure	Return	Income	Expenditure	Return
	Paddy Field 800 rai			Paddy Field 400 rai		
	Ground Water Well No. I			Ground Water Well No. II		
	Baht	Baht	Baht	Baht	Baht	Baht
Total	520,000	83,428.44	436,571.56	260,000	55,728.60	204,271.40
Average Per Rai	650--	104.28	545.72	650--	139.32	510.68
	Paddy Field 200 rai			Paddy Field 100 rai		
	Ground Water Well No. III			Ground Water Well No. IV		
Total	130,000	36,428.76	93,571.24	65,000	24,614.22	40,385.78
Average Per Rai	650--	182.14	467.86	650--	246.14	403.86

Note: 1 dollar $\approx$ 20 baht
1 acre = 2.5 rai.

C. Evaluation

1. Payout Period

The estimate of the payout period will be a rough figure to show how many years the total income can cover the investment by deducting the expenditure on operation and maintenance from the total income as follows:

(a) Gross net income derived from a ground water well with capacity 400 m^3/hr stood at Baht 519,000. The number of years that can meet the recovery of investment will be 6 months.*

(b) Gross net income derived from a ground water well with capacity 200 m^3/hr stood at Baht 223,300. The number of years that can meet the recovery of investment will be one year.

(c) Gross net income derived from a ground water well with capacity 100 m^3/hr stood at Baht 117,200. The number of years that can meet the recovery of investment will be 1-1/2 years.

(d) Gross net income derived from a ground water well with capacity 50 m^3/hr stood at Baht 51,600. The number of years that can meet the recovery of investment will be 2 years.

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*One season of rice cultivation is about 5-6 months.

2. The Marginal Productivity of Capital

The return on capital will emerge in the future which depends upon the time or age limit of the assets invested as to how long they would last. The return on capital in cash from the investment of equipment and materials in the use of ground water wells is a margin after deducting the operating costs for rice growing including the deduction cost of the assets. The income is computed from the production of the paddy at minimum farm prices. The principle applied for computation is based on the profit maximizing operator as the source of previous vegetable growing. The results of the estimated return are shown as follows:

(a) When justification is given to the project on a five year duration, the time that a water pump has to be changed, but the depreciation cost is not deducted--the rate of return computed from equation 2 will be 166, 94.5, 53.5 and 25 per cent per annum respectively (see table 18).

(b) When justification is given to the project on a ten year duration, the time that the entire equipment has to be changed, but the depreciation cost is not deducted, the rate of return will be 166, 95.5, 57.5 and 34 per cent per annum respectively.

(c) When justification is given to the project of similar duration as in (b) above, but the depreciation cost is not deducted, the rate of return will be 154, 83, 44, and 19.5 per cent per annum respectively.

(d) When justification is given to the return irrespective of duration (equation 3) by deducting the operating, maintenance and depreciation cost from total income, the rate of return on capital will be 153.65, 82.91, 44.64 and 22.65 per cent per annum respectively.

From the consequences of computing the rate of return through the various methods and categories aforementioned, it is apparent that when the rate of return is compared with the rate of interest, the minimum rate of return of the above four methods is higher than that of the interest rate. The results of the estimated return are shown in Table 18.

Table 18. The Estimated Return Without Deducting the Labor Cost (Rice)

Items	Total Cost	Discount Rate %	Integrate of the return in 5 years duration without deducting depreciation	Integrate of the return in 10 years duration without deducting depreciation	Integrate of the return in 10 years duration by deducting depreciation	Integrate of the return irrespective of duration by deducting depreciation
Ground Water Well No. I	180,000.00	153.65				180,000.00
		154			179,591.885	
		166	180,075.72	180,120.47		
Ground Water Well No. II	150,000.00	82.91				150,000.00
		83			149,807.82	
		94.5	150,399.94			
		95.5		150,146.38		
Ground Water Well No. III	120,000.00	44			120,258.01	
		44.64				120,000.00
		53.5	120,432.98			
		57.5		119,964.78		
Ground Water Well No. IV	90,000.00	19.5			89,668.78	
		22.65				90,000.00
		25	90,185.79			
		34		89,839.43		

CHAPTER V

CHANGE IN COMPOSITION OF INCOME AND LABOR USE

I. INCOME OF MEMBERS UNDER THE UDON THAINI FARM MANAGEMENT PROJECTS

Of the total vegetable growers at present, thirty-four are already members of the Farm Management Project. Accordingly, through these 34 members whose farm accounts have been recorded, the comparative study can be made for the change of income and labor use from their original sources. However, when the duration from March-February 1969-1970 is compared with the duration from March-February 1970-1971, when the ground water well existed, it is obvious that the changing structure has been manifested to a certain extent, even not as much as per the details shown hereunder.

The change in income--when justifying the income derived from the two crops relatively--shows that in the period from March-February 1969-1970, crop income is mainly from the sale of rice, accounting for approximately 64% of the total income. Other crops which are emphasized in the income are Kenaf, vegetables and various plants accounting for 17.56%, 5.00%,and 13.41% respectively. Various plants include watermelon and peanuts which are moderately cultivated. But after the use of the ground water well for irrigation, the composition of income is tremendously different, i.e., income derived from vegetables rose to 81.57%, while income from rice has fallen to 14.56%, despite the fact that the income derived from the sale of rice in these two years are similar, i.e., the average sale of rice from 34 families was Baht 802.11 in the period March-February 1969-1970 and Baht 895.03 in the period March-February 1970-1971. For Kenaf, no cultivation was available in 1970-1971 (See details in table 19).

Incidentally, when a monthly income is shown in contrast between the two years, it is apparent that the monthly income of the previous year was mainly from the regular sale of paddy to the small rice mill by a small quantity in the village almost every month, while the sale of paddy in bulk was conducted in the period of October, November, December, January and February when the new harvest comes, or in other words, the rice will be sold out immediately after harvest in order to obtain money for buying daily necessities. Consequently, the income derived from the sale of rice reached a maximum in March-February 1969-1970. In March-February 1970-1971, the year that the ground water well was introduced for irrigation in vegetable growing, although the existence of the monthly sale of paddy was evident, the sale in bulk had been made after witnessing the new rice. This is due to the fact that the monthly income derived from the sale of vegetables,

Table 19. The Average Income in Baht of Crop Production of 34 Members in Comparison, Prior To or After the Existence of the Ground Water Well

Description		Income from Crop Production Per Household				
		Rice	Vegetables	Kenaf	Other Crops	Total
Prior to the existence of the ground water well--March 12-February 13	Amount of income	802.11	62.66	219.99	167.89	1,252.65
	Percentage	64.03	5.00	17.56	13.41	100.00
After the existence of the ground water well--March 13-February 14	Amount of income	895.03	5,013.43	---	238.02	6,146.48
	Percentage	14.56	81.57	---	3.87	100.00

which is rather high and had never before existed, has helped in living subsistence as well as in agricultural and family expenses. Moreover, it is obvious that the monthly income is higher than that of the previous year in almost every month (See figures 7 and 8).

II. THE ESTIMATED INCOME OF RICE PRODUCTION

For rice growing, it is apparent that the benefit of rice production without ground water use is only Baht 125. The estimated benefit of rice production with ground water use is computed from various categories of wells. The benefit of rice production with ground water well No. I which covered 800 rai of paddy fields is Baht 345.72. The benefit of rice production with ground water well No. II which covered 400 rai of paddy fields is Baht 310.68, and with ground water wells No. III and No. IV that covered 200 and 100 rai of paddy fields are Baht 267.86 and 203.86 respectively. The results are shown in Table 20.

III. LABOR USE ON CROPS OF MEMBERS UNDER THE UDON FARM MANAGEMENT PROJECT

Formerly rice farming took up about farming depends upon 81.74 per cent of the entire labor force. But when computing the labor use during the time of using ground water for irrigating vegetables, the percentage of labor use in rice cultivation has decreased to only 41.04 per cent. Labor use for vegetable growing has increased from 9.18

per cent to 57.95 per cent. Labor use for rice cultivation is based on the number of working days (10 hours is equal to one man-day). From tables 21 and 22 it is apparent that labor use in the year that ground water was used for vegetable growing, as well as for rice farming, was less than that of the previous year--the year that no ground water was in existence. This is due to the lack of labor use for harvesting and threshing. It is obvious that the total labor use in the year of the ground water well's existence was more than the previous year. The seasonal distribution of labor has improved since labor can be used for vegetable growing in the idle months (See figures 9 and 10). The labor use for rice remains at the status quo, despite the fact that there may be a competition for labor use between vegetables and rice during the transplanting season. But the working hours can be staggered for vegetable growing anyway.

From the bottleneck in labor use shown in the income table, it is obvious that income from vegetables will gradually decrease during the transplanting and harvesting season. This is due to the fact that farmers will spend their time mostly on rice cultivation for the reasons mentioned above. However, it should be noted that labor use for vegetable growing should be less than it was, since minor labor will be used in water distribution through both irrigation systems. Labor used in vegetable growing are seed bed preparation, cultivation, fertilizer application,

Figure 7. The Average Income on Crops by Month of 34 Members of the Udon Thani Farm Management Project from March 1969 to February 1970

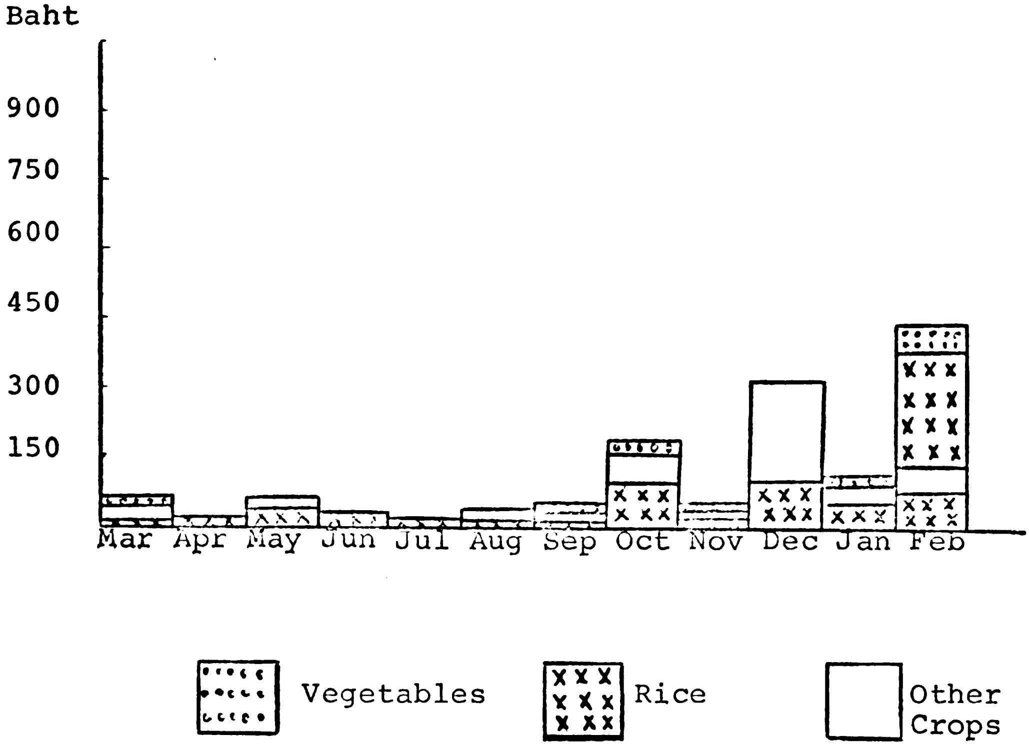

Figure 8. The Average Income on Crops by Month of 34 Members of the Udon Thani Farm Management Project from March 1970 to February 1971

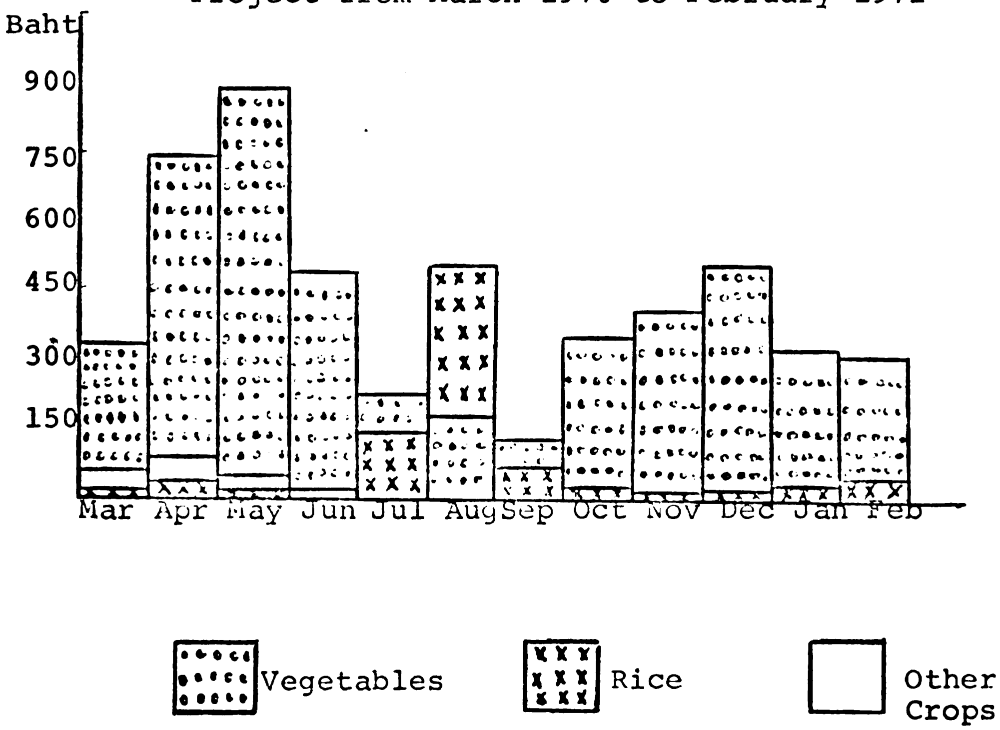

Figure 9. The Average Labor by Month of 34 Members of the Udon Thani Farm Management Project from March 1969 to February 1970

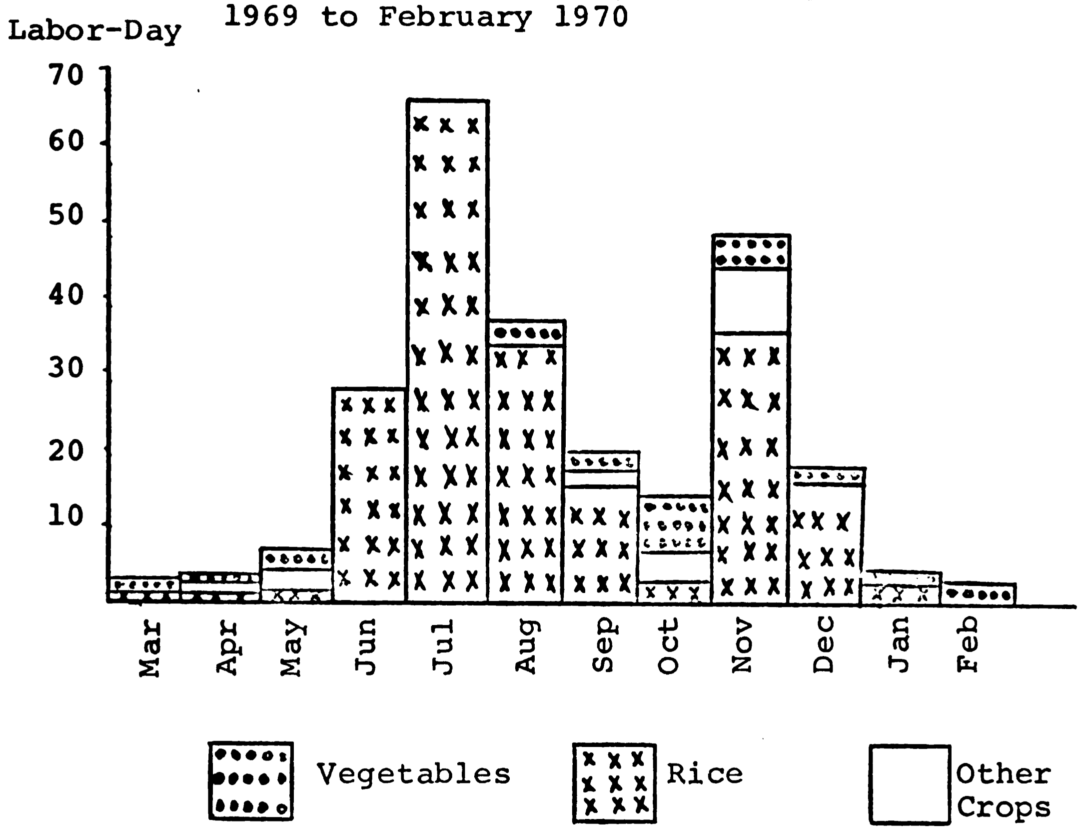

Figure 10. The Average Labor by Month of 34 Members of the Udon Thani Farm Management Project from March 1970 to February 1971

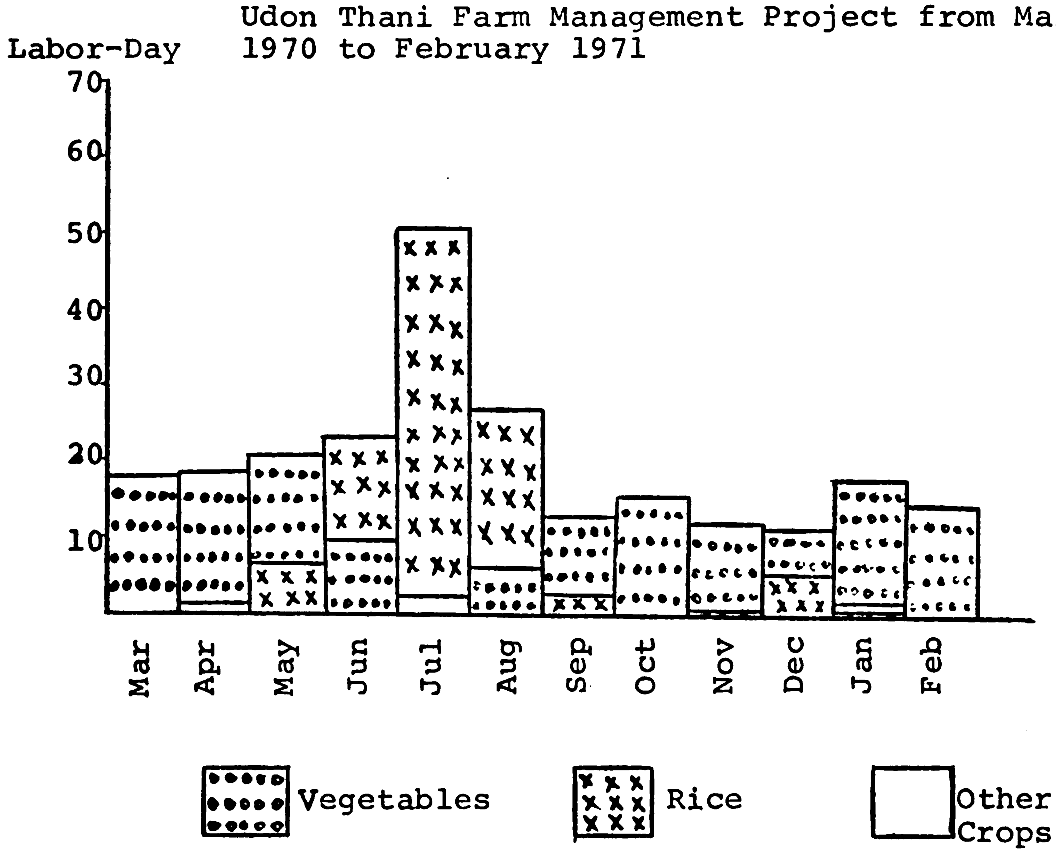

Table 20. Annual Comparison of Cost and Benefit Between Lack of Ground Water Well Use and Ground Water Well Use for Rice Production Per Rai

Items	Rice Production Value	Rice Production Cost*	Expenditure of Ground Water Wells	Rice Production Benefit
	Baht	Baht	Baht	Baht
Without Ground Water Use	325	200	---	125
With Ground Water Well Use				
Ground Water Well No. I	650	200	104.28	345.72
Ground Water Well No. II	650	200	139.32	310.68
Ground Water Well No. III	650	200	182.14	267.86
Ground Water Well No. IV	650	200	246.14	203.86

Note: 1 dollar $\simeq$ 20 baht.

*Rice production cost = seed, insecticide and fungicide, hired labor cost; does not include family labor or cost of chemical fertilizer.

Table 21. The Average Family Labor (Man-days) in Crop Cultivation by 34 Members of the Udon Thani Management Project 1970-71

Description		Labor Used			
		Vege-tables	Rice	Other Crops	Total
Prior to the existence of ground water well	Man-days	22.51	200.48	22.27	245.26
March 69 Feb. 70	Percen-tage	9.18	81.74	9.08	100
Existence of Ground Water well	Man-days	163.86	116.04	2.88	282.78
March 70 Feb. 71	Percen-tage	57.95	41.04	1.01	100

Note: 1 man-day = 10 hours.

Table 22. Labor Use (Man-days) of 34 Members of the Udon Thani Farm Management Project, 1970-71

Month	Vegetables Cultivated Areas 3.975 rai Household Labor man (Sprinkler)	ani-mal (Sprinkler)	Vegetables Cultivated Areas 7.443 rai Household Labor man (Furrow)	ani-mal (Furrow)	Rice Cultivated Areas 200 rai Household Labor man	Rice Household Labor ani-mal	Rice Hired Labor man	Other Crops Cultivated Areas ani-mal	Other Crops Household Labor man	Other Crops Household Labor ani-mal	Other Crops Hired Labor man
March 70	254.72	---	382.7	---	---	---	---	---	---	---	---
April 70	243.6	---	396.35	---	---	---	---	---	49.00	---	---
May 70	277.5	---	408.4	---	235.63	216.13	146.00	---	---	---	---
June 70	126.9	---	187.6	---	786.23	542.23	159.5	---	---	---	---
July 70	42.7	---	54.6	---	1725.5	598.4	206.1	---	---	---	---
Aug. 70	48.4	---	144.85	---	889.81	---	---	274.81	---	---	---
Sept. 70	152.9	---	314.25	---	99.40	---	4.1	---	---	---	55.00
Oct. 70	193.6	---	355.25	---	---	---	212.63	4.00	---	---	72.30
Nov. 70	147.05	---	303.85	---	9.60	14.0	1599.03	---	---	---	---
Dec. 70	132.87	---	281.5	---	186.60	---	215.3	---	---	---	72.00
Jan. 71	200.65	---	410.2	---	14.10	---	---	---	---	---	13.30
Feb. 71	155.5	---	355.35	---	---	---	---	---	47.30	---	---
Total	1982.39		3574.60		3946.87	1370.76	2578.66	278.81	96.30		212.60
Av. Per Month	165.20		297.88		328.91	114.23	214.89	23.23	8.03		17.72
Av. Per Month Per Household	13.77		13.54		9.67	3.36	6.32	0.68	0.24		0.52

Note: 1 Man-day = 10 hours.

watering vegetables newly cultivated (watering is not necessarily done all the time from the planting date until harvesting time for sale) and cutting vegetables for marketing.

In the initial stage of using sprinkler irrigation, although it is challenging to members in vegetable growing, irrigation is not quite practical on account of the farmers' primitive conviction. They did believe that watering had to be done both morning and evening, or at least once a day. The sprinkler system provides watering every 5 days and every vegetable plot will be given water for two hours each time. Water is pumped into the relief tank for watering the newly cultivated vegetables and for washing the harvested vegetables for marketing or for diluting fertilizer for spraying vegetables. But farmers used water stored in the relief tank for watering vegetables every day, both morning and evening. They refused to obey the officer's instructions because of their fear that the vegetables might die. Later, some vegetable plots rotted which was apparently true as warned by the officers, thus easing the situation. Obedience was mediocre, since some farmers still conducted watering upon seeing the surface soil dry.

The furrow irrigation that started in the same time was about as effective as that of the sprinkler. This furrow irrigation provided water every 5 days, but thereafter the surface soil dries more quickly than that watered by the sprinkler; only the subsoil can hold a great deal of moisture. Some farmers stole water for watering vegetables at night because watering was strictly prohibited by the officer. It appeared that the vegetables rotted and died as a result. This issue has been solved through the effective use of water distribution which farmers had witnessed with their own eyes. Consequently, the change from the primitive attitudes of the farmers toward modern technology, previously unknown to them, calls for experiences and takes an appropriate time to achieve.

CHAPTER VI

PROBLEMS AND FURTHER PROCEDURES

As already stated above, the average farmer in the Northeast and throughout the country cannot afford to invest in construction of a ground water well from his own funds. Consequently, it is the task of the government to provide capital for investment in the initial stage in order to develop, to a better extent, the agricultural structure. This type of investment must be, as much as possible, beneficial to all the people in a village, rather than to drill a well in one place wherein the owner of that piece of land only is allowed to operate the well. The consequences will be that water use can not be provided to its fullest extent because of the lack of labor. Only one man can take advantage of it. Another problem may arise in regard to the same piece of land; for instance, in the vegetable cultivating area of Naka village, the land belongs to four owners. Prior to the operation, the officer called the villagers to a meeting and explained the objectives of having them participate in a joint project of vegetable growing on the piece of land which was left idle. The agreement had been made between the land owners and the farmers who volunteered to grow vegetables on the basis of mutual understanding among farmers who made negotiations and agreement on the operation by themselves. Finally, a conclusion was reached that the vegetable growers who had to clear the brushwood, dig out stumps and improve the soils would be free from rent for two years, but would share the local administration tax with the owners. For the subsequent period, the growers would be allowed to continue their vegetable gardening, but the rent must be paid by them. Currently, the agreement on a period of time and rent fee has not yet been definitely fixed. But it is expected that upon completion of the rent, the period of the first agreement will be extended to 10 years. Such an expectation is due to the negotiation made in the meeting of the farmer group members including land owners who are also the vegetable growers, and this agreement is expected to be completed during 1971.

From the experience mentioned above, it is apparent that the joint meeting was helped by farmers themselves; the officer only pointed out principles and problems, but the solutions to problems on the joint work were settled by the farmers themselves. This has proven effective. Because of the farmers' close relations and because this work contributed benefits to many farmers who were glad to pay compensation to the land owners whose profits were waived as well, the agreement could be made without any difficulty.

Consequently, the task to be done in a subsequent stage is water fee collection. This will be determined on the principle of depreciation of the capital assets, repair cost of equipment and accessories, fuel cost, cost of water pumps, and land rent as a total cost to be collected from vegetable growers. This money collection procedure should be imposed on farmers who will make arrangement for collection among those who gained the profits by electing a president, vice-president and treasurer from among the farmers themselves. The treasurer shall collect money and deposit it in the Government Savings Bank every month. The criteria for water fee collection will be determined on the depreciation cost and others as aforementioned. Upon the expiration of the usage limit of any asset, the deposit accrued in the bank shall be withdrawn to purchase new equipment immediately for replacement. In addition, the monthly and annual expenditure for repair cost, land rent, fuel for the engine, will be told to all group members in order to keep them informed on the monthly financial status by holding a joint meeting regularly once a month. Water fee collection will commence in March 1972.

These problems of ground water use for vegetable cultivation at Naka village can apply to rice cultivation and other agricultural production as well throughout the country.

CHAPTER VII

COMMENTS

The consequences gained from the operation of the ground water irrigation for agricultural purposes at Naka Village, Udon Thani Province, in spite of a short period of operation, have shown accomplishment both from the economic point of view and the welfare and security of farmers. For this reason, if the Ministry of Agriculture has approved this task to be included in the major project for national agricultural development, it would help accelerate agriculture since the task requires some innovators to change into steps as follows:

1. Thailand needs a sufficient supply of low-interest credit. The agricultural credit available at present does not help very much in farm production and marketing. Most of the loans are spent for other purposes, especially for consumption and ceremonies. This opens the way for the middlemen or landlords to give integrated services by lending money, selling commodities, and buying farm products immediately after harvest. Merchants make loans to farmers at a high rate of interest. Later they collect principle and interest in kind from farm products.

As a result, farmers have hardly any product left to sell. In the case of a rice farmer, for instance, he may have no rice to sell to obtain cash for better living and for the improvement of production and marketing during the following year.

> The 52% of the commercial corn growers, for instance, reported that they had to borrow to finance cultivation, and 60% of these loans were used for farming expenses, 17% for living expenses, and 9% for farm implements, for clearing land, buying land ceremonies, 4% for each item, and only 1% for paying off old debts and 1% for buying draft animals. The studies show that 38% of the farmers got loans from corn dealers, 24% from relatives, 12% from grocers, 9% from local money lenders, 6% each from cooperatives and neighbors, 4% from banks, 1% from self help land settlements. Rates of interest vary from 7% to 89% per annum.[53]

This is a serious obstacle to the development of agricultural production and marketing.

If the country desires to see the farmers have more products for sale in the market, improvements must be made based on three principles: (1) the availability of adequate credit, (2) low interest rates, and (3) long-term repayment whereby the farmers will have no difficulty in repaying their loans.

2. Thailand needs area land use planning. According to the 1963 Census of Agriculture, there are 3.2 million farms in Thailand with production activities in

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[53] Chaiyong Chuchart, "The Role of Agricultural Marketing in the Economic Development of Thailand," The Agricultural Economics Society of Thailand (Bangkok: Phrae Pitaya Press, 1962), pp. 222-23.

an area of 11.1 million hectares of cultivated land. The average physical size of farms is 3.5 hectares which is more than three times larger than those of Japan and the Republic of China (Taiwan). Although the physical size of the farm is larger, the volume of farm business in terms of production value is much smaller than that of the other two countries. Compared with the average farm sizes in Canada and the United States (115-130 hectares),[54] the average Thai farm (3.5 hectares) is more than 30 times smaller. It should not go unnoticed that, of these 3.2 million farms, almost 20 per cent are under the size of one hectare.[55] Due to comparatively favorable man-land ratio, Thailand is fortunate in having 83 per cent of her farmers as owners. This high percentage of land owners, where land reform programs have been actively carried out, is significant. Since the fields are scattered in different places, consolidation of fields within a farm involves many difficulties. We also have been warned of the facts that the possibility of enlarging the physical size of farms appears to be limited because:

(a) Most of the cultivable lands have been used, particularly land good for paddy production,

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[54]The Proceedings of the Sixth National Conference on Agricultural Sciences, Agricultural Economics (Bangkok: Kasetsart University Press, 1967), p. 53.

[55]*Ibid.*

(b) marginal lands suitable for reclamation require costly investment,

(c) the population in Thailand is increasing very rapidly at an annual rate of 3.2 per cent, and

(d) the speed for shifting population from the agricultural sector to the non-agricultural sector is very slow.

With limited success of the first two remedies, the last and probably the best alternative will be area land use planning which has been tried with considerable success in certain parts of South Korea, Japan, and Taiwan. This approach together with some cooperative operations can greatly increase the efficiency of field work without impairing the private ownership of farm resources.[56]

The procedure of area land planning is briefly described below.

A detailed survey of soil contours and land ownership is carried out in advance by aerial or field survey techniques. This information is super-imposed on separate maps for record. Each farmer is able to set up bench-marks to identify the location and size of his fields. Next, all fields are consolidated and rearranged into larger ones by abolishing the field boundaries.[57]

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[56] R. P. Dore, Land Reform in Japan (London: Oxford University Press, 1959), pp. 277-97.

[57] Government of India, "Consolidation of Holdings," Progress of Land Reform (New Delhi: The Manager Government of India Press, 1963), p. 272.

Levelling is done when necessary. Farm operations including land preparation, crop planting, fertilization; weed, pest, and disease control measures; irrigation and drainage; crop harvesting; and crop transportation from the fields to the village can be done by individual or group action. If conditions permit, the farmer carries out all farm operations on the consolidated field without participating in any group action or he participates in one or two operations by group. For each group operation, the participants work together by themselves or engage a private firm under contract to work for them. If the work is done by themselves, the participants contribute labor and materials proportionally according to the amount of their land in an area. If the work is done by a private firm, the costs are allocated the same way.

Changes in field layout (1) increase the efficiency in the use of labor and capital, (2) save land by abolishing field boundaries, (3) make it easier to adopt certain technological innovations, and (4) preserve the family operated unit. Thailand may consider the programs of area land use planning in the very near future.

Suggested measures to maximize the net returns of small farms are the increasing of operational efficiency, the diversification of production lines, and the adoption of technological innovations. These measures require capital investment, infrastructural improvement, and farmers' organizations. An individual small farmer would have great difficulty implementing these measures unless he participates in some kind of group activity. The contribution of Farmer's Associations and Irrigation Associations will further agricultural development. It is only through group actions that the bargaining power of small farmers can be strengthened.

3. Thailand needs more subsidies and technical assistance for private practices. Government payments or subsidies to individuals would be used both directly and indirectly as a measure of farm securities. Two leading examples of the use of government payments are provided by the agricultural conservation payments program and by the soil bank and conservation reserve programs. The ACP program in the United States, for instance, was started during the middle 1930's as a cost-sharing improved farming practice demonstration program.[58] Arrangements were made to pay farmers part of the cost of liming their fields, building terraces, strip cropping, sodding waterways, and accepting and carrying on other approved practices. If the agricultural products were surpluses in some areas, the government payments would compensate farmers for taking crop land out of productive use and encouraged owners to

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[58] Raleigh Barlowe, "Federal Programs for the Direction of Land Use," Reprinted from the Iowa Law Review (Winter, 1965), Vol. 50, No. 2 (Iowa: Iowa University Press, 1965), p. 360.

change land use to another product such as raising livestock.

Another important aid for private practices is provided in the form of technical assistance and advice. Several government agencies, including sections of the Departments of Agriculture, Commerce, and Interior provide service affecting farmers. These services range from the distribution of leaflets and publications to personal counseling and advice. Farm management assistance and guidance for cooperating farmers is provided by the governmental agencies. Technical assistance and advice on small and large business problems is supplied by the Department of Commerce. Self-Help Settlement is provided by the Department of Interior.

4. Thailand needs price guarantees and supports. Price supports geared to some specified percentage of the parity prices for various farm commodities have been a standard feature of farm policy. Support arrangements have varied from year to year but have often been tied to acreage allotments, marketing quotas, acreage reduction programs, and programs for the retirement of crop land from use. Payments were made to farmers to plow under given acreages of already planted crops thereby reducing total production. Since then acreage controls, penalties for overplanting, and rewards for program compliance have been used extensively to limit production while price

supports have been used to guarantee minimum prices for authorized production.

5. Thailand needs ground water management and new regulation. There is water, more or less of it, more or less accessible, almost everywhere under the earth. As uses of water increase, this ground water resource is becoming very important. Due to the population growth rapidity, the increased uses of groundwater by industry, for irrigation and for domestic consumption, ground water sources of supply are being exploited. The use of ground water has created new water problems. Under natural conditions the hydrologic cycle tends to be in balance, but man's use of the water usually upsets this balance. Use of water without knowledge of the effects of use or in disregard of them might be called exploitation and might be a problem in the future. Thus the term exploitation, as it implies development without knowledge of consequences, no longer applies, if we concern ourselves to use the term water management and set regulations to control man's use.

Good management of ground water resources depends upon knowledge of basic water facts. We need more detailed studies of ground water in local areas, and more basic research on replenishment and movement of ground water. We need to know more about ground water chemistry also. We must continue to improve our methods of storing surplus water in underground reservoirs.

However, even the hydrologic facts on ground water are not enough. We must know also what the demand is for water in a given area, what the economic trends are, what the future demand may be. What will be the effects of withdrawal and use of water upon the ground water reservoirs?

In the Santa Cruz Valley of the Gila River Basin,[59] Arizona, for instance, heavy pumping for irrigation started in 1914 in some places and has been more or less continuous since, but the rate for development has been accelerated since 1942. Pumpage has increased from about 275,000 acre-feet in 1945 to about 500,000 in 1949, when it was estimated to have been about 20 times the recharge. The Eloy area was declared a critical area by the state land commissioner in 1948, shortly after Arizona's ground water law was passed. Since then increased withdrawals have not been permitted, whether from existing wells or new wells. As an outstanding example, water levels in the Eloy area have dropped 50 feet on the average in the period 1940 to 1949.

Another good example of what can be accomplished through water management techniques is afforded by the City of Kalamazoo, Michigan. In the past, farmers were facing ground water well depletion and the competition between the municipal water supply and irrigation from ground water sources. These problems and conflicts were solved by many

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[59]Harold E. Thomas, The Conservation of Ground Water (New York: McGraw-Hill Book Company, Inc., 1951), pp. 37-38.

agencies by converting a surface water course to replenish the ground water source.

> Municipal pumpage in Kalamazoo increased from 300 million gallons in 1880 to 4.6 billion gallons in 1957. Despite the fact that billions of gallons are pumped annually from well fields in the Axtell Creek area, water levels have declined only a few feet, as the discharge of the fields is compensated by recharge from precipitation and surface water, and the programs are set as Morris Deutsch in an article for the Journal of the American Water Works Association for February, 1962 says:
>
> 1. Dispersed its well fields.
> 2. Determined through a detailed study, the geology and hydrology of the area; implemented that study with an extensive test drilling program to locate and delineate the best available aquifers.
> 3. Maintained a continuous well maintenance and well reconditioning program.
> 4. Limited pumping at each well field to an amount not in excess of recharge as indicated by long-term hydrologic records, and
> 5. Constructed induced-recharge facilities at the sites of several well fields, including the city's largest pumping station complex.[60]

Although the great improvement in the water resource picture at the Eloy area and the city of Kalamazoo cannot be ascribed to any single one of these measures, the induced recharge operation and the set up of regulations have been especially effective.

Thus, every individual has a stake in our ground water resources, whether he is a well owner or not.

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[60]J. G. Rulison, "Ground Water--Michigan's Subterranean Reservoirs Help Maintain Levels of Lakes and Streams," Michigan Challenges (Michigan's Water Resources: published by the Michigan State Chamber of Commerce, April, 1963), p. 50.

Groups of individuals in a community or government agencies will have to concern themselves and make decisions which may be effected by man's uses in order to avoid the problems and conflicts of overdraft of ground water wells that caused the serious problems of "cone of depression" and ground water well depletions.

6. Thailand needs more farm demonstrations. Sprinkler and furrow irrigation methods are new things to Thai farmers. It is necessary that the innovators should consider the farm demonstration plots for showing farmers the realities of irrigation techniques. In various areas which may be different in soil structure, furrow irrigation may not be suitable for sandy soil because a great amount of water is wasted by seeping away through the subsoil surface before it is used by the crops. Timing and water requirements for each crop are based on soil structure. Excess of water may damage the crops and lack of water may affect the yield.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

In the less advanced countries such as Thailand, skill and capital are limited and we have 81 per cent of the population as farmers already in their fields. But Thai farmers are in a position of partial changes. The traditional methods of farming refer to the cultivation practices inherited by farmers from the experiences of their ancestors and are still in use. To improve and increase agricultural productivity, in order to lay a ground for other sector developments, ground water is one of the factors to be developed to economic efficiency depending on the goals and objectives pursued.

A study of ground water sources in Thailand and the evaluation of costs and benefits of drilling ground water wells for irrigation were determined at the end of this study.

The following conclusions were drawn:

1. The minimum capacity of a ground water well was 5 gallons per minute and the maximum was 5,000 gallons per minute. The average capacity was approximately 35 gallons per minute which had proven satisfactory for such farm sizes.

2. In general, water from aquiferswas suitable

for irrigation under most ordinary conditions. Most of the brackish and salt water had not exceeded 250 mg/l of chloride content.

3. Drilling ground water well for use for vegetable production at Ban Nakah village was appropriate for rural agricultural development.

Analyses of costs and benefits of vegetable production, without deducting the labor costs and by deducting labor costs, showed that the rate of return on capital ranged from 76 to 88 per cent and from 41.50 to 53.50 per cent per annum respectively.

4. Drilling ground water well to use for rice production as a supplemental irrigation of upper rice paddy fields or application to growing rice out of season without depending on annual rainfall or surface water irrigation.

a. Ground water well capacity of 400 m^3/hr could supply water to cover 800 rai. The rate of return on capital without deducting the labor costs ranged from 153.65 to 166 per cent per annum.

b. Ground water well capacity of 200 m^3/hr could supply water to cover 400 rai; the rate of return on capital without deducting the labor costs was from 82.91 to 95.5 per cent per annum.

c. Ground water well capacity of 100 m^3/hr could supply water to cover 200 rai; the rate of return on capital without deducting the labor costs was from 44 to 57.5 per cent per annum.

d. Ground water well capacity of 50 m^3/hr could supply water to cover 100 rai; the rate of return on capital without deducting the labor costs ranged from 19.5 to 34 per cent per annum.

5. Ground water use for irrigation made Thai farmers earn more income and this measure also changed the composition of income and labor use.

Emphasis on ground water use for irrigation is only one of the factors of rural agricultural development in Thailand. The effectiveness of this measure depends on cooperation with other innovations. At least this measure is compatible with maximum social product and optimum income distribution. A factor of ground water use for irrigation should be shifted from farming the low to the high marginal products. And Thai farmers should grow up and live in an environment of at least minimum adequate standards of health, nutrition, clothing, shelter and education. If the welfare of farmers in the rural area is taken into consideration, such a measure as mentioned above, the ground water well development for agricultural purposes, it would be further strengthened. And this will put pressure on the industrial and commercial sectors of the economy to expand.

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APPENDIX

Table 23. Vegetable Production by Ground Water Use, 1970-1971, of 34 Members of the Udon Thani Farm Management Project

	Mar 70	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan 71	Feb 71	Total Kilogram	Total %
Lettuce	5331.1	2311.9	2668.4	1467.7	687.6	815.2	718.6	1705.3	2581.3	6692.5	9412.9	9950.1	44,342.6	59.86
Onion	280	1053.4	969.1	1163.4	670.5	576	68.5	210.5	395	385.5	197.9	1077.6	7,047.4	9.52
Chinese Kale	504.5	419.7	191.5	7.	---	---	---	53.6	184	361	236.8	124	2,082.1	2.82
Parsley	154.3	289.4	64.9	18.9	1.3	---	4.5	64.5	111.6	257.	227.2	431.3	1,624.9	2.19
Cabbage	---	---	---	---	---	---	---	---	32.8	81.5	314.	385	813.3	1.10
Morning Glory	85.	447.6	212.5	160.5	52	---	135	373	154	124.5	270	179	2,193.1	2.96
Chinese Green	230.5	356.5	419.0	44	---	7	33.5	295	300.5	559.5	34.5	145	2,425	3.27
Chinese Cabbage	566.5	835.6	856.1	102.5	---	21.5	79.1	673	1295	1851	1162	822.5	8,264.8	11.16
Coriander	2.9	80.8	16.3	3.5	---	8.5	---	2.9	13.5	6.5	25.3	70.9	231.1	0.31
Carrot	120.2	162.5	60	69.7	14	15.5	14	11	11.5	10	11	11	510.4	0.69
Radish	36	166	78	---	---	---	---	---	12	6	---	6	304	0.41
Kunchai (native)	26.1	25.3	---	1.7	---	---	---	---	13	62	6.5	134.8	269.4	0.36
Chinese Mustard	254.3	342	574	36	---	---	---	27	210.8	515	511	475	2,945.1	3.98
Celery	9.	4.	10.1	---	---	---	---	---	---	13.5	20.2	13.1	69.9	0.094
Red Onion	14	---	---	---	---	---	---	---	---	---	---	---	14	0.019
White Cabbage	---	---	---	---	---	---	---	---	3	---	164.5	25	192.5	0.26
cow-pea	17.8	8	47.5	16	---	---	---	---	46	131	70.2	---	336.5	0.45
String Bean	20.5	---	14.2	---	---	---	---	20	---	84	78	---	216.7	0.29
Garlic	---	60	110	---	---	---	---	---	---	---	---	17	187	0.253
Cucumber (small)	---	---	---	---	---	---	---	3	---	---	---	---	3	0.004
Cucumber	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Table 24. The Average Farm Price of Vegetables (1970-1971) (Kilogram/Baht)

Kinds of Vegetables	Mar 70	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 71	Feb 71	Avg. Price
Lettuce	1.47	2.96	3.99	9.79	3.75	3.	---	---	2.94	2.15	2.46	1.05	3.36
Onion	2.32	2.76	2.68	3.90	3.28	---	---	---	2.32	1.93	2.73	1.71	2.64
Chinese Kale	1.30	1.68	2.05	---	---	---	---	---	---	1.	2.22	1.83	1.68
Parsley	4.23	8.40	5.54	---	4.43	---	---	---	5.03	5.70	7.15	1.40	5.24
Cabbage	---	---	---	---	2.	---	---	---	---	---	1.69	---	1.85
Egg-plant	---	---	2.46	---	1.	---	---	---	---	---	---	---	1.73
Morning glory	1.48	1.45	1.22	1.50	---	---	---	---	1.42	1.54	3.36	1.37	1.67
Chinese green	1.05	1.54	1.50	---	---	---	---	---	1.08	1.14	1.39	0.90	1.23
Chinese cabbage	1.28	2.07	2.47	1.52	2.14	---	---	---	1.44	1.15	1.91	1.12	1.68
Coriander	3.51	5.23	---	---	---	---	---	---	---	2.63	5.25	5.	4.52
Carrot	---	---	1.35	2.	---	---	---	---	---	---	---	---	1.68
Radish	---	1.	---	---	---	---	---	---	---	---	---	---	1.
Kuchai (native)	---	---	2.67	9.	---	---	---	---	---	1.	5.12	2.96	4.15
Chinese mustard	0.62	1.23	1.55	---	---	---	---	---	1.	0.79	1.21	0.67	1.01
Celery	---	---	---	---	---	---	---	---	---	5.71	3.	---	4.36
Pepper	---	---	---	5.	---	---	---	---	---	---	---	5.	5.
White Cabbage	---	---	---	---	---	---	---	---	---	---	---	---	---
Garlic	3.50	---	---	---	---	---	---	---	---	---	5.	---	4.25
String bean	2.05	---	---	2.61	2.	2.	---	---	---	1.26	2.73	2.	2.15
Cucumber (small)	---	---	---	1.07	---	---	---	---	---	---	---	---	1.07
Cucumber	---	---	---	---	1.20	---	---	---	---	---	---	---	1.20

Table 25. The Average Quantity of Water Requirement for Paddy Field, the Time of Water Requirement and the Time of Water Pump Use for Growing Rice

Items	Quantity of Water Requirement Per Rai	Time of Water Requirement	Time of Water Pump Use Per Rai
	Cubic Meter	Month	Hour
	1,800	5-6	
Water pump with 400 m^3/hr -120 feet in capacity			4.5
Water pump with 200 m^3/hr -120 feet in capacity			9
Water pump with 100mm^3/hr -120 feet in capacity			18
Water pump with 50 m^3/hr -120 feet in capacity			36