15th INTERNATIONAL CONGRESS ON IRRIGATION AND DRAINAGE

COUNTRY PRESENTATIONS BY DELEGATES OF THE RIPARIAN COUNTRIES OF THE LOWER MEKONG BASIN

MEKONG SECRETARIAT

BANGKOK, THAILAND

WATER RESOURCES AND IRRIGATION MANAGEMENT IN LAO PEOPLE'S DEMOCRATIC REPUBLIC

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Lao PDR

1. BACKGROUND

Topography

The Lao PDR is a landlocked country in South East Asia. It has five neighbouring countries. To the north it has a common border with the People's Republic of China; to the northwest with the Myanmar, to the west and south with the kingdom of Thailand, the greater part of the border being formed by the Mekong River, to the South with Kampuchea and to the east with the Socialist Republic of Viet Nam, the border here follows the Annamite mountain range. The surface of Lao PDR measures 236,800 km^2.

The country is divided into three major zones:

Northern highlands

The Northern part of the country is a mountainous area where erosion has caved a highly complex and dissected relief. The highest peak exceeds 2,800 m above sea level. Crest elevations are generally more than 600 m above adjacent valley floors, and most slopes exceed 30%. The relief limits the agriculture of a relatively sparse population to lowland rice cultivation in the narrow valley bottoms and the shifting cultivation of upland rice and other crops on the slopes. The potential for hydroelectric power development is substantial, but the potential for irrigation is markedly less than in other parts of the basin.

Eastern highlands

The Eastern highlands, 50-300 km wide and generally called the Annamit Chain, form the mountainous backbone of the Lao PDR, an area of complex relief. In the north the highlands are narrow, further south, they broaden presenting to the east a steep and abrupt descent to the narrow coastal plains in Viet Nam, and to the west are more gentle slope from the watershed at the crest down to the Mekong river.

The northern and the southern of the eastern highlands are better suited to hydroelectric power development than the less accented relief of the centre, which provides opportunities for irrigation development in the tributary valleys.

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1. **Assistant to the Chief of Technical Sector, Department of Irrigation**

Lowlands

The lowland is separated from Thailand by the Mekong river. At the southern edge separates the lowland by the Kampuchea boundary. To the east and north the lowland is bounded by the foothills of the eastern and northern highlands respectively.

Natural levee begin in the section of the Mekong upstream of the Vientiane. The river profile is gentle and the valley broad, except where the river swings close to the eastern highlands. Then rock outcrops occur in the bed and the river is confined in the narrow gorge.

More than half the lowland is drained by the Se Bang Fai, Se Bang Hieng, Se Done and Sekong; these tributaries, with the Nam Ngiap and Nam San to the north, have gentle profiles which tend to delay the evacuation of monsoon rainwater. The Nam Ngum and the Nam Lik, which rise in the northern highlands, form a broad alluvial plain north and east of Vientiane.

The broad tributary valleys of the lower reaches of the tributaries support a considerable agricultural population. They offer substantial scope for further agricultural development by means of flood control, drainage, irrigation, and measures to reduce possible salinization.

Climate

The climate of Lao PDR is governed by monsoons, steady winds of low to moderate intensity that blow alternately from the northeast and the southwest, each for about six months of the year. The winds are caused by seasonal temperature and the resultant pressure changes over Central Asia and the India Ocean. During the winter a high pressure zone develops over outer Mongolia; simultaneously a zone of low pressure develops in the India Ocean near the Equator. The differential pressure causes a steady stream of air to flow over the land from the northeast to the southwest. In summer the situation is reversed: a high pressure zone forms at about latitude 30 south with zones of low pressure over northern India and central China; and the resulting air movement is then form the southwest to northeast. The southwest monsoon begins in May and continues until late September; then, following a brief period of instability, it is replaced by a reverse air stream,, the northeast monsoon, from November to mid-March. During march and April, winds become light and variable.

Wet season

Because of its long path over warm equatorial seas, the southwest monsoon is heavily laden which moisture and the period in which it blows, called the west season, its characterized by heavy and frequent precipitation, high humidities, maximum cloudiness and tropical temperatures. A short dry period of one to two weeks is normally experienced between June and July due to the influence of high altitude anticyclonic circulation. After the dry period, rainfall becomes more frequent, and heavy rainfall is experienced in tropical storms and typhoons, which frequently enter the Lao PDR from the east in the wet season. Flooding usually occurs when two or more or these tropical disturbances occur in rapid succession or when the forward edge of the southwest monsoon has passed into one of its more active stages and a tropical disturbance follows shortly thereafter.

Dry season

The air of the northeast monsoon, which originates in the cold air masses occurring in the winter in mainland China and the polar region, is relatively dry. In the period when this monsoon blows, called the dry season, very little precipitation occurs, humidities are low, the sky is clear and temperatures are relatively low.

Rainfall

The mean annual rainfall ranges from 1,200 mm near the northwest, to 3,500 mm in the Boloven plateau. Between 80 per cent and 90 per cent of the precipitation occurs in the west season. In that season the dew-point of the atmosphere is only a few degrees below the air temperature and a moderate uplift of the air caused by topography or convection is sufficient to induce precipitation.

The effect of the topography is clearly seen in the rainfall distribution over the country and adjacent areas. Rainfall is highest on the windward side of mountain ranges lying across the path of the southwest monsoon.

On average, the rainfall in the west season is sufficient to grow rice, the main crop of the country. However, the rainfall is very unevenly distributed over the growing season and drought damage occurs nearly every year at all locations in the country. The extent of the damage depends on the amount of rainfall; at location with an annual rainfall of 2,000 mm and more there is very little drought damage. However, in most of the agricultural areas in the country, the rainfall is only 1,200-1,500 mm/year and the provision of an adequate water supply could double the paddy yield.

Temperatures

The air temperature is remarkably uniform throughout the basin. Small differences can be traces to variations in elevation and to seasonal and maritime influences. The effect of the sea on mean temperature is very slight. Temperatures are high except during the early part of the northeast monsoon when occasional outbreaks of cool air from central Asia sweep over the land. These generally last for no more than a few days at a time but sometimes persist for several weeks. Cool spells interspersed with periods of warmer weather continue until the end of February when, under influence of light southerly winds, the weather becomes very hot. These conditions last until the southwest monsoon commences in May.

The mean relative humidity of the atmosphere is highest in September at slightly more than 80% and lowest in March at just over 60%.

The small seasonal variation temperature gives rise a corresponding variation in the evapotranspiration requirements of vegetation, varying from 80 mm in January up to 160 mm in July. From May to September rainfall is in excess of plant requirements and soil infiltration: what can not be stored in the soil run off the land as streamflow. In October moisture within the root zone is usually sufficient to satisfy requirements. From mid-November until the end of April there is, however, a moisture deficiency with averages 300-600 mm.

Flow

The Mekong, one of the world's great rivers and tenth largest in terms of annual flow, begin its 4,200 km journey to the sea in the mountains of Tibet.

The total drainage area of the Mekong is 795,000 km^2, of which some 27%, or 212,800 km^2 is almost 85% of the country's total land mass, lies within the Lao PDR, supplies water from the north to the south along its 1,870 km traverse through the country. Abundant rainfall combined with a high density river system (with a total water course length of 30,000 km) produces an annual runoff volume discharged into the sea of 223,000 million cubic metres. Major tributary basins are, from upstream to downstream, Nam Tha (8,170 km^2), Nam Ou (26,,160 km^2), Nam Souang (6,290 km^2), Nam Khan (7,620 km^2), Nam Ngum (16,640 km^2, LB), Nam Theun (14,650 km^2), Se Bang Fai (9,470 km^2), Se Bang Hieng (19,600 km^2), Se Done (7,170 km^2) and Sekong (21,900 km^2).

2. CURRENT SITUATION

Irrigation

As much as 30,000 hectares are estimated to have been put into irrigation by farmer or government projects at some time during the last 3 decades. It is estimated that 88 per cent of the currently irrigated area consists of small systems run by farmers.

Farmers view irrigation first in terms of this reduction. They have learned also that obtaining major production technologies and inputs that have not been available or affordable. The first objective of the subsistence rice farmer is to reduce risk, and the best insurance is an assured water supply for wet season supplement has the highest possibility of success on irrigated land where productivity potential is highest and risk lowest.

The Lao PDR has a vast potential for irrigation development. The Mekong river and its tributaries in the Lao PDR could be used to irrigate some 650,000 hectares. However, due to insufficiency of budget, only small portion of this potential has been developed mostly in Vientiane plain.

Supplemental irrigation during the wet season is available to about 90,000 hectares, mostly from small diversion weirs with very little water delivery capacity or control. Another 20,000 to 50,000 hectares that has received some development for irrigation is apparently not used. About 45,000 hectares receives relatively reliable water supplies with improved primary and secondary systems, permitting water control to some extent. Most of this area, including about 20,000 hectares served by pumps on the Mekong and some major tributaries can be irrigated during the dry season, albeit with low efficiency because of incomplete structure and tertiary systems. Because of poor management and lack of incentives to farmers, only about 13,000 hectares have been cropped during 1993 dry season.

Micro-hydropower potential in the Lao PDR

Laos is in water resources. The many tributaries of the Mekong river flowing down from the Annamite Chain in the east have tremendous potential for hydro-electricity. The natural features of the country and abundant annual rainfall provide almost limitless opportunities for development of micro-hydropower. In the upland areas a small 10 sq.km. watershed could, on average, provide sufficient run-of-the-river flow to generate 30 KW through a static head of 30 metres. This would be enough power to drive a small sawmill or ricemill and some lighting.

This potential is still largely untapped. Some small scale systems have already been started and others are planned. In some areas, individual rural families have installed Chinese-made hydropower generators for private use. The primary constraint to exploiting these resources continues to be a lack of investment capital and trained staff.

Until now the Department of Irrigation and Micro-hydropower under the direction of the Ministry of Agriculture and Forestry has collected data for the construction of eight micro-hydropower projects totaling 1,200 KW. Two of these projects are in the preparation stages and one is under construction. In addition, there are more than 50 projects totaling over 7,500 KW which need further study and data collection in order to draw up plans.

Agriculture under irrigation

The irrigated rice system should receive high input to full exploit the costly investment for irrigation system. However, it should be noted that in locations were water holding capacity is low and where water head is too deep below the ground surface, upland short duration cash crop should be planted instead of rice the following recommended technology should be considered:

1. Using new improved varieties;
2. Transplanting at optimum density and seedling age;
3. Applying balanced fertilization techniques (nitrogen plus phosphorus);
4. Keeping field free of weeds;
5. Practicing better insect and disease control;
6. Harvesting and processing timely.

Institutions

The Ministry of Agriculture and forestry (MAF) consist of one Cabinet and six Departments: Agriculture and Extension, Livestock and Veterinary, Irrigation and Micro-hydropower (DIMH), Forestry and Environment, Meteorology and Hydrology, and Institution and personnel.

The role of the Department of Irrigation and Micro-hydropower (DIMH) has been formulated in Decree No. 0358/KP of 23 June 1992 as: "to analyze and implement strategic lines, strategic plans, laws and regulations concerning the establishment, management and development of water resources for the promotion of agriculture in the whole country".

Like the other department of MAF, the DIMh organization consist of three divisions: (i) the Administration Division; (ii) the Planning, Finance and Cooperation Division; and (iii) the Technical Division. Linked to the DIMH is also the Institute of Water Resource Development (IWRD). This is a state-owned enterprise, established to provide survey and design services on a contractual basis and against more or less commercial prices.

The DIMH works through the Provincial Agricultural Services (PAS). Their set-up differs. In the larger provinces there is a special office for irrigation within the PAS.

In the smaller provinces, irrigation is part of the Agricultural, Livestock and Irrigation Office. A policy of "vertical integration" is implemented at present which places the PAS under more direct supervision of the MAF and the departments. The PAS has an activity and control network through District Agricultural Services (DAS). In the larger provinces are again divided in zones.

3. CONSTRAINTS/PROBLEMS IN IRRIGATION AND WATER MANAGEMENT

Natural constraints

Flood

The Mekong carries an enormous volume of excess water during wet season, resulting in severe flooding and substantial damage almost very year in the fertile flood plains along the mainstream and the major tributaries, as well as the flood plains of the Se Bang Hieng plain, Se Bang Fai plain and Nam Hin Boun plain in the centre of the country. In the contracts, during the dry season a serious reduction inflow often leads to drought, with a resultant shortage of water for domestic and agriculture use.

Technical constraints

Project studies and design

The irrigation development in our country is faced with many problems: lack of basic data, difficult access to sites, short of technical staff, high construction cost due to imported required materials and equipment.

As far as basic data are concerned, topographical maps are available at 1/50,000 scale with inaccuracies ranging between 5 to 10 m. Hydrological and geological data are practically nonexistent.

The major constraints on this sector can be summarized as follows:

(a) Lack of technical capability for conducting investigation and feasibility studies on new projects;

(b) Lack of experience in certain specific fields of design, construction, supervision of dams and diversification;

(c) Shortage of equipment and spare parts, and difficulties carrying out repairs and maintenance;

(d) Lack of multi-purpose plan for irrigation development and a strategy for effective water use;

(e) Poor design and inadequate maintenance of traditional irrigation systems;

(f) Inadequate drainage system.

4. PAST AND CURRENT PRACTICES

Measures/Strategies adopted for improvement of irrigation and water management

Water policy and legal aspect

With the population increasing at an annual rate of 2.9 per cent, the government of the Lao PDR has set stabilization of the food supply as top priority. As part of its strategy the ministry of Agriculture and forestry has set a course to reduce the effects of drought and flooding by establishing various irrigation schemes aimed assuring stability in the production of food crops. Plans are to gradually turn large scale irrigation projects over to farmer groups and to provide management and technical training and support to increase operational efficiency and farm profitability. Investment priority will be given to small scale gravity and pump projects. The objective in the medium term is to make existing projects fully operational and efficient.

For 1993 a goal of 140,000 hectares of total land under irrigation in the wet season has been set. Of this, 18,800 hectares may also be used for irrigated rice production during the dry season. It is projected that by 1996, 150,000 total hectares will be under irrigation during the wet season as well as 26,000 hectares during the dry season.

The Lao Ministry of Agriculture and Forestry has placed priority on small scale projects that can be done in the short term. Less efficient long term projects will receive a lower priority. Every province has been directed to establish its own irrigation development plan. Responsibility for planning, implementation and management will lie with the appropriate local authorities to streamline implementation and make irrigation units more efficient. Attention will be given to upgrading the proficiency of local irrigation units to implement projects successfully.

Projects will focus on the rehabilitation of existing traditional systems and to schemes aimed to opening new irrigated paddy land. In addition to construction, a major emphasis will be given to the training of personnel at all levels. A lack of competent trained staff is considered a major constraint to effective management of irrigation throughout the country.

Investment policy

Plans are also being divided to provide incentives to encourage the private sector become involved in irrigation development. These include easing of restrictions on the importation of foreign construction equipment.

Financing of projects will come from a number of sources. In many areas farmers are able to invest their own resources in improving existing systems. Farmers are also encouraged to secure bank loans when funds are lacking. With stable water supplies a surplus production of rice and cash crops will be possible which will raise capital to pay off loans quickly. Side benefits from the additional water include reservoirs to store water for fish raising and agricultural production as well as micro-hydropower.

Presently the Lao government is encouraging foreign aid and investment for projects in many of the provinces. Numerous foreign organization have expressed interest or are now involved in various projects. The policy is aimed at concentrating

foreign investment on, food crop production, cash crop production, irrigation construction, the training of the technicians and reducing slash and burn.

The Lao PDR, also has significant underground water reserves that have yet to be exploited for agriculture. It is hoped that assistance can be secured to develop this valuable resource.

Crop diversification

Growing a cash crop after rice: Most soils in Laos fortunately are suitable for multiple cropping with rice. However, to grow some crop after rice in Laos depends so much on the market and the labour beside the technical aspects.

Technical aspects: Generally, upland crop rotation after wetland rice is often more difficult technically compared to after upland rice. The main technical problem is the stand establishment of the upland crop. Wetland soils have their natural structure destroyed during the process of wetland preparation (puddling) while seedlings grow the structure of puddled soils must first be regenerated into granulated form. This remains still a problem yet to solve with regard to heavy clay soils in the plains behind levees the Mekong river. For sandier soils, this technical problem diminishes. Therefore, based on soil physical aspects, upland rice fields are best for rotating upland crops after rice. However irrigation water is one limiting factor. Annual rotation during the years then plant upland rice again may be a good practice. Some farmers in Luang Prabang were practicing this is system at a very extensive way, that need to be improved.

Training for technical staff

Presently there is one training school to prepare staff on the national level. Middle level technicians are trained in are three years course while upper level engineers study for four years. So far eleven middle level classes and three upper level classes have been graduated and are serving in the field but a severe shortage of qualified workers still exists. The training center lacks equipment and facilities as well as opportunities for students to gain valuable field experiences.

Emphasis must be placed on upgrading the skills of provincial and district irrigation personnel and to training village Water Users Groups (WUG). There is a great need to built up a corps of skilled field trainers who can provide training a the village level. Villagers need to gain the sills to plan projects, secure financing and implement projects on their own.

5. FUTURE OUTLOOK: SHORT AND LONG TERM PERSPECTIVES

Understanding of project objectives, components and rationale

The medium-term policies for irrigated agriculture as formulated through the ADB sponsored Programme for Adjustment and Development in Agriculture, indicate as overall medium-term subsectoral goal:

"To improve productivity and performance of sustainable irrigation systems by focusing on farmer and community managed schemes and reorganizing the role of the public sector to provide support services to the subsector".

Long term large scale projects

The following 8 potentials projects are proposed for a long term programme, all of which are gravity irrigation projects by reservoir. For the implementation of the above projects, a detailed investigation and study about the nature and social effects caused by the projects will be required because of large submerged areas by reservoir.

Irrigable areas of each large scale project are as follows:

1.	Nam Lik	30,000 ha
2.	Nam Mang	14,000 ha
3.	Nam San	24,000 ha
4.	Nam Theun	04,000 ha
5.	Se Bang Fai	70,000 ha
6.	Se Bang Hieng	71,000 ha
7.	SE Done	26,000 ha
8.	Xe Kaman	36,000 ha
9.	Xe Sou	35,000 ha
10.	Nam Kong	12,000 ha

8 large scale Hydro-power projects:

1.	Nam Theun I	2,000 MW
2.	Nam Theun II	600 MW
3.	Nam Ngum II	400 MW
4.	Pa Mong	2,700 MW
5.	Xe Kaman I	400 MW
6.	Xe Nam Noy	300 MW
7.	Nam Kong I	150 MW
8.	Nam Ngum III	700 MW

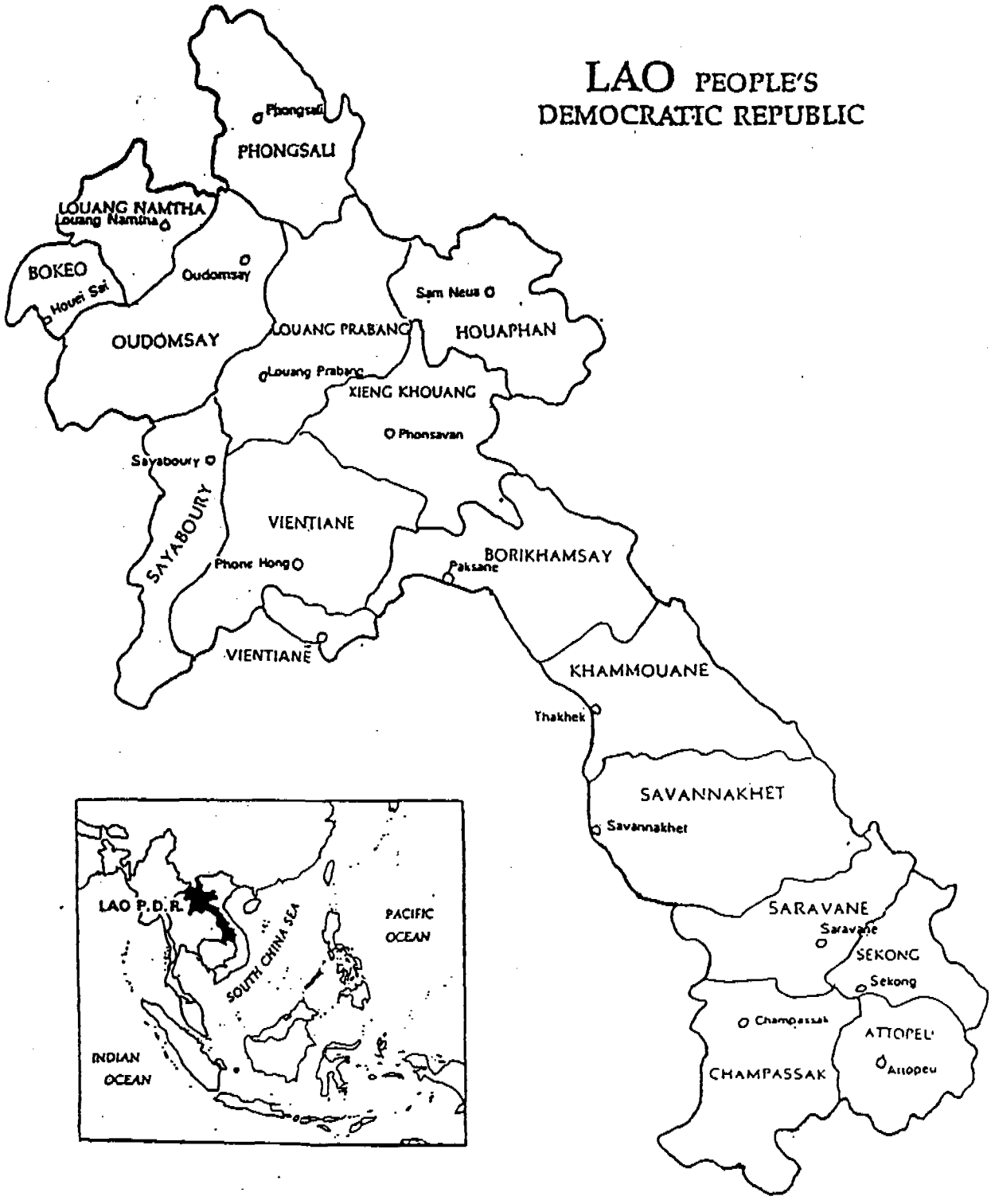
6. CONCLUSION

From the beginning a new regime, there was urgent need to implement the irrigation schemes everywhere in the country and it has got to be done.

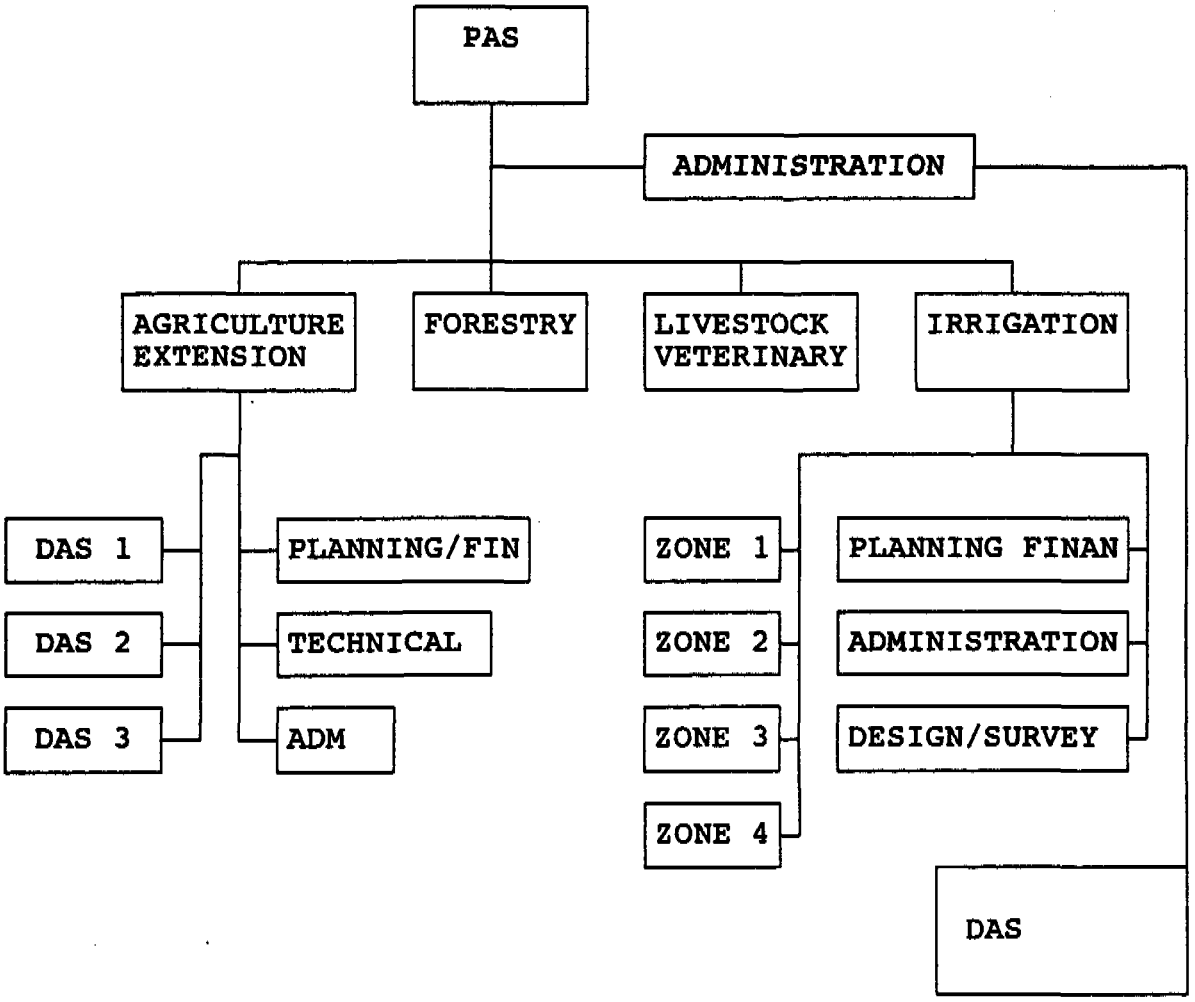
Lack of funds is a major constraint to irrigation development in Lao PDR. Loan and grant aid programmes are being sought from donors to overcome this problem.

Lack of skilled personnel at all levels, only a sustained programme of formal and informal training can give our people the necessary qualifications and experiences.

LAO PEOPLE'S DEMOCRATIC REPUBLIC

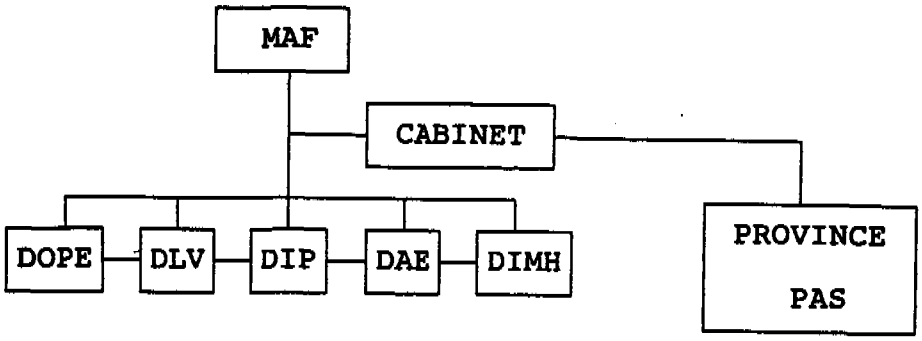


The Provincial Agricultural Services (PAS) organization is specified below

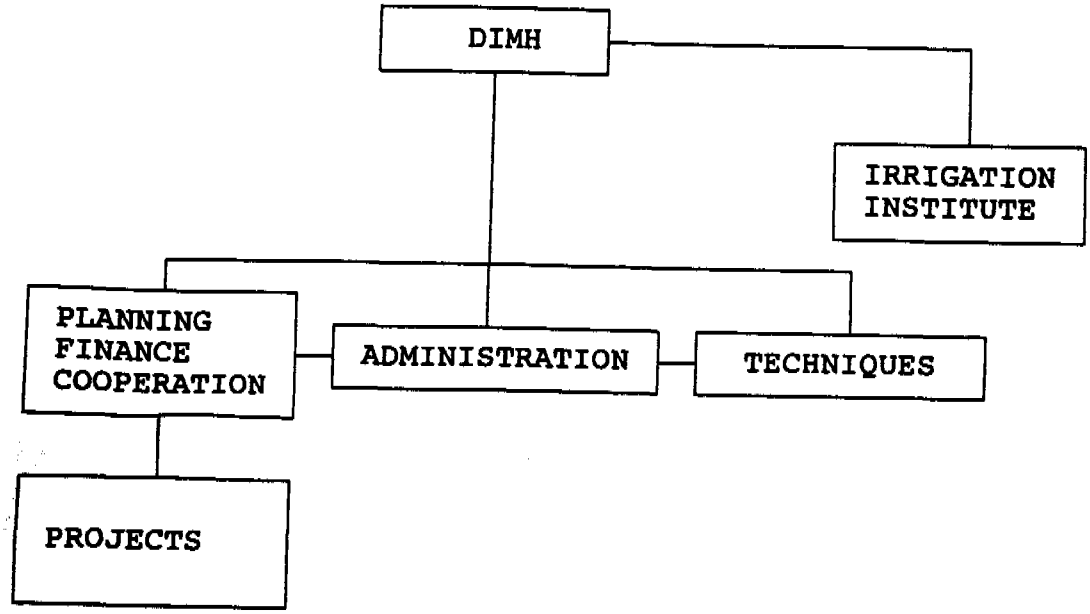


ORGANIGRAMS OF MAF, DIMH AND PAS

The organigram of the Ministry of Agriculture and Forestry (MAF) is shown below



The organigram of the Department of Irrigation and Micro-Hydropower (DIMH) is presented next



IRRIGATION AND WATER MANAGEMENT FOR SUSTAINABLE AGRICULTURE AND RURAL DEVELOPMENT IN THE MEKONG SUB-BASIN IN NORTHEAST THAILAND

PUMPED IRRIGATION SCHEMES OF THE DEPARTMENT OF ENERGY DEVELOPMENT AND PROMOTION

Somchet Swangnetr[1]

Thailand

1. BACKGROUND

The Northeast is the largest, but poorest, region of Thailand and covers an area of 168,000 km^2. With a population of 18 million people, (one-third of the total country), the regional economy is dominated by a rice growing agriculture with limited opportunities for farmers to increase or supplement their incomes in their villages. Additional income is earned through off-farm employment in the cities with a large migratory population working in Bangkok.

The Northeast is predominantly a flat plateau ranging in elevation from 100 to 200 m msl, which is drained by the Chi and Mun Rivers. Although representing 15% of the Mekong River catchment area, it contributes only 5% of the annual flow. The monsoonal climate brings average temperatures which range from a low of 23.7°C in the cool season, (December-February), to a high of 32.5°C in the hot season, (April to June), and average annual rainfall which varies from 1,000 mm in the southwestern areas to 1,650 mm in the northeastern areas. About 80% falls in the wet season, between May and October.

However, the rainfall is unreliable and highly variable, both spatially and temporally, with prolonged periods of no rainfall even during the wet season. The construction of irrigation schemes is necessary to reduce the risk of failure of the rice crop in the wet season and to provide a reliable water supply for growing a dry season crop. Since 1965, pumped irrigation from the Mekong and tributary rivers has been recognised as a solution to the farmers needs in the Northeast and since 1968 DEDP has been actively undertaking the installation of pumped irrigation schemes. To date, DEDP has constructed 611 schemes in the Northeast, of between 240 and 480 ha each, supplying water to a total area of 0.27 Mha.

To assist DEDP with sustainable agricultural development and improvement within these irrigation systems, the Netherlands Government provides funds, through the Mekong Secretariat, as part of the Mekong Irrigation Programme (MIP). The first project, MIP1, ran from 1988 to 1992, followed by a second project called the Sustainable Irrigated Agriculture Project (SIRAP), which began in October 1992 and runs until May 1996.

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2. CURRENT SITUATION

The present land use within the Northeast Region is given in Table 1.

Biwater (1987) estimated that out of the 8.6 Mha of arable land area in the Northeast, only 0.7 Mha (8 %) is served by irrigation. However, the agricultural land resources base has now reached a maximum area and future expansion of agricultural output must therefore come from productivity improvements from the existing areas including increased irrigation. Expansion of the irrigated areas within the present agricultural area is necessary and estimates of potential irrigation development provide for a further 0.8 Mha, increasing the total to about 18 % of the total arable area.

However, existing irrigation systems are under-utilised and the economics of government investment in new irrigation schemes is becoming unattractive. In addition , the farmers financial benefits remain low and continued financial support by the government for operation and maintenance is necessary.

Table 1. Land Resources, Northeast Thailand (Biwater, 1987)

Land use	present use (Mha)	suitability (Mha)
Forest existing	2.4	6.8
-encroached	3.0	
Marginal agriculture	1.5	
Farm holdings	8.6	8.6
-paddy non-irrigated	5.4	
-paddy irrigated	0.5	4.6
-upland non-irrigated	2.5	
-upland irrigated	0.2	4.0
Urban area, water bodies, other	1.3	1.4
Total	16.8	16.8

Crop production in irrigated areas has not achieved expected output levels for several reasons. These include:-

- incomplete irrigation system infrastructure
- poor water management
- poor soils
- poor crop management
- lack of agricultural inputs (seed, fertiliser, chemicals and credit)
- insufficient coordination of government support services

The potential for additional pumped irrigation schemes was provisionally estimated at 0.05 Mha, (DHV 1991), but given the present situation of under-utilisation and low crop production, DEDP recognises that the biggest improvement in production must come from working within the existing schemes. To this end, it has set about working with other government agencies to concentrate on development of the resources within the existing schemes through building the capacity of the farmers to undertake more of the development, operation and maintenance activities.

The policy of DEDP is to increasingly hand-over the control of operation and maintenance of the irrigation schemes to the water user groups, by working in close cooperation with DOAE, to provide increased extension support, CPD, to provide support for the farmers organisations and BAAC, to provide improved credit arrangements for the farmers.

3. CONSTRAINTS / PROBLEMS IN IRRIGATION AND WATER MANAGEMENT

In general, within the pumped schemes of DEDP in NE Thailand, water shortages are not experienced, because the sources of water are the Mekong, Mun and Chi River catchments, which flow all year, (the latter with reservoir control). There are also generally no problems with water quality, but flooding of schemes can be a severe problem in the monsoon season. However, soil salinity and soil acidity is a major problem with water and crop management in some of the schemes. Farmers report one of their biggest problems is "water shortage", but this is a more a function of scheme operation rather than water source. To conserve water through good distribution efficiency and to limit canal seepage losses because of the sandy nature of the soils, all canals down to tertiary level are concrete lined.

Investigations during MIP1, identified several constraints and problems with the operation and water management of the systems, which can be summarised as follows:

(1) **System Design.** Many of the systems have been designed for continuous flow operation, with the canal size decreasing in proportion to the quantities of water assumed to be drawn off. This is often acceptable in the wet season when irrigation is used to supplement rainfall and many gates can be opened simultaneously within a number of blocks. However, because of the "fixed" capacity of the pump sets, management problems occur in the dry season when more accurate control of water by rotational operation is required to the downstream blocks. The canal capacities are less than the flow from a single pump and are easily overtopped. Re-design to permit even the tertiaries to convey the flow from a single pump is necessary.

(2) **Scattered crops.** In the dry season, farmers grow crops scattered throughout the scheme area and not all land is utilised due to total landholding per household often exceeding the management capability or labour availability. This makes irrigation management very difficult. Typical dry season land utilisation is 25 - 50 %.

(3) **Diversity of crops.** In the dry season, the increasing diversity of the crops grown creates increasing complexity of water management. The timing of the crop, its duration, its water requirements (timing and depth of application) all increase the need for good coordination amongst the farmers, water user organisation and scheme operators.

(4) **Poor canal maintenance.** The lack of routine maintenance causes the system to perform below its design and desired water distribution cannot be achieved. Principal problems are with sediment accumulation, weed growth and damaged concrete lining, increasing effective surface roughness and causing overtopping which exacerbates damage.

(5) **Pump performance.** Tests have shown that the pump operating heads are much lower than were designed for and flows often exceed the capacity of the canals.

(6) **Incomplete systems.** The main, secondary and tertiary canals are constructed by DEDP, but the farm ditches are the responsibility of the farmers. Many schemes do not yet have farm ditches, which limits the command area, particularly in the dry season.

(7) **Inactive Water User Groups and Cooperatives.** Low economic returns on most crops (low productivity coupled with low quality and low prices) and the attitude that responsibility for the scheme should be the government's, has led to inactivity by the farmer organisations in scheme operation and maintenance.

(8) **Interrupted Pumping.** Pumping is not permitted at peak electricity demand periods, (5 - 7 am. and 6 - 9 pm.), which disrupts scheme operation.

Some of the constraints to good water management are technical and for which modified system design and construction has now been adopted by DEDP, but the majority of problems relate to the lack of continuing support by the farmers in the care of the scheme. Limited staff and resources of DEDP mean that support to the farmers for timely routine maintenance has not always been carried out according to the division of responsibilities between the farmers and DEDP. There must be a greater feeling of responsibility towards the scheme by the farmers if these constraints are to be removed. The MIP1 and SIRAP projects are providing support for DEDP in encouraging greater participation by the farmers in scheme activities through providing training in routine maintenance activities, improved water management techniques and farmer group development.

There are also human resources and institutional constraints to the smooth operation and development of the agricultural activities in the irrigation schemes. All DEDP irrigation schemes are served by officers of the DOAE on the sub-district level. However, in many cases schemes cover more than one sub-district which causes communication problems and effective cooperation. As with staff in all government agencies, sub-district extension workers face many problems in fulfilling their work, as they have many administrative duties to perform, and are charged with implementing centrally established government programmes. However, in some schemes, one extension person to cover the whole area has now been specifically appointed. Although these persons are often new graduates with little experience, through a training programme and with good support from more senior staff, this will provide improved extension and encouragement for the farmers.

A new extension programme of DOAE called the "Farmer Farm Plan" programme has also meant that more farmer input into the planning of the government sponsored programmes is taking place. This has increased the motivation of the farmers in the schemes to request assistance for growing new or improved crop varieties.

Constraints in obtaining credit from the banks by the farmers, are also addressed under the MIP Projects. Working in close cooperation with CPD and BAAC, the farmer groups within the DEDP schemes now have better access to credit than was the situation

previously. Coupled with good extension, improved credit means that improved crops requiring higher inputs or technologies can be produced.

4. PAST AND CURRENT PRACTICES

The achievements attained in improved water management over the past few years with the assistance from MIP1, have been very significant. Working in some selected schemes as examples under a special support programme, strategies have been developed for improved system infrastructure, improved agricultural extension, improved farmer organisation, improved understanding of relevant socio-economic factors, and improved credit facilities, all of which lead to better scheme operation and maintenance.

Investigations and studies undertaken during MIP1 showed that if irrigation schemes are to be made sustainable and economically viable, a special "intensive support" approach is required. This approach involves the injection of extension service support over and above that able to be provided by the normal government extension services available, to enable higher cropping intensity and higher yield to be obtained within a shorter period of time than would normally be expected. From the experience in 5 schemes, the special support is considered required for a period of 4 years.

The aim of the special support is the:

- promotion of better water and crop management
- training of field workers, government staff, farmers, and farmer leaders
- formation of viable farmers organisations
- acceleration of on-farm investment in ditches, land levelling, rebounding and access roads

SIRAP is now continuing this approach with DEDP, using the "participatory" concept in working with the government officials and farmers in 34 schemes. The primary objective is first to build strong farmer organisations capable of;

- managing their own irrigation system i.e. responsible for organising all the maintenance and operational activities of the scheme
- securing supply of credit and inputs i.e. able to negotiate and make decisions on the sources of credit and inputs required for crop production
- having access to markets and market information i.e. able to make decisions on which crops to grow for which market and negotiate contracts with buyers based on good market information, and
- adapting to changing economic and social changes, i.e. able to change ideas and cropping systems in line with economic and social developments.

The special support team requirement identified under MIP1 consists of a community development/training specialist, an extension agronomist, a water management specialist and one field worker per two schemes. Based on the studies of MIP1, the economic benefits more than justify the costs of the team.

Within SIRAP, the training specialist, agronomist and water management specialist are provided through the Project, with the field workers (one per scheme) from the DOAE. The role of the Project is to train select government staff to be trainers themselves to enable this additional support to be institutionalised. In future, this support team would comprise government staff on special assignment.

In terms of the cost recovery expected from the farmers in return for this support, no additional charges to the present policy of charging a water fee amounting to 50 % of the electricity pumping costs, would be made. At current rates, this works out to $US 0.024 per kWh, for the farmers. In practice, water fee rates are set by the water user groups/farmers and in some schemes are applied on an areal basis and in others on a kWh basis. The fee is often set above the actual power costs, to create some capital fund for the WUC, or to create a maintenance fund and to offset losses.

With the increasing emphasis being placed on the farmer groups to play a greater role in the operation and maintenance of the schemes, SIRAP is continuing the MIP1 support for DEDP with a training programme to transfer over the knowledge required to undertake this work. Operation manuals have been prepared and DEDP staff trained in how this can be achieved.

Currently the division of responsibility for maintenance is as follows:

(1) Pumping Irrigation Service Centre, DEDP

- maintaining concrete canals, transmission lines and distribution structures,
- water pump and components
- electrical switchgear
- embankment damaged by natural events
- maintaining sub-lateral canals if not concrete lined

(2) Farmers

- cleaning ditches and canals before each pumping season
- clearing grass along the canals
- digging on-farm ditches
- connecting/disconnecting the main pump hose with changing river levels
- routinely maintaining the embankments along the canals.

In assisting with the strengthening of the farmer groups, the policy of DEDP is to establish the many presently "informal" water user groups into Water User Cooperatives (WUC), under the guidance of the CPD, Ministry of Agriculture and Cooperatives. The advantage of the WUC is that they have legal status. They are trained in irrigation scheme management and cost recovery, and effective crop planning, production and marketing. Also included is training in farm cash-flow management and credit, provided by the BAAC.

In the future, as the schemes become more developed, those which are operating economically will be responsible for a greater share of the operating cost. The target policy is for the WUCs to take 100% responsibility of the scheme, after 8 years of successful group operation. So far, however, no schemes have achieved this status.

5. FUTURE OUTLOOK: SHORT AND LONG TERM PERSPECTIVES

Given the present economic climate of low crop prices and high off-farm opportunity costs for labour, the economic calculations of constructing new pump irrigation schemes in Northeast Thailand, show that with only the normal support available from government agencies, an unacceptable IRR of -1.7% is produced. However, with an intensive support approach, as promoted by MIP and SIRAP with DEDP, an IRR of 6.8% is achieved. This latter value is still below the desirable IRR of 12.5% for new schemes, but may be considered acceptable by the government if more than just "economic" issues are included i.e. social issues must also be considered.

However, with the present under-utilisation of schemes and an already large sunk capital cost, the economics of improving existing schemes under an extensive support programme are more attractive. The emphasis in the short term must be to work with strengthened farmer groups to upgrade the infrastructure, improve water management, improve crop production and marketing, based on the existing crops (low technology) in order that these groups can take more control of the scheme operation and management. Once this is achieved, new technologies i.e. different crops requiring higher levels of skill can be promoted with normal support, as the farmers already will possess the basic skills in good water management.

In the longer term, farmers will have to be growing higher value crops in order to generate higher incomes. This is not an easy task as the risks are higher and credit support becomes more critical. For example, there is an increasing demand for crops for processing and for crops for livestock raising. Both require skills which take time to acquire and extended credit. It will be only with the cooperation of the government agencies and private sector in this work, can the farmers have sufficient knowledge and confidence for it to be undertaken.

6. CONCLUSION

On the basis of the MIP experience, it is possible through a 4 year special support programme in the DEDP pumped irrigation schemes:

- to develop present schemes to be effective irrigated agricultural areas,
- to boost dry season production yields by 30 - 50%,
- to boost dry season cropping intensities from 20 - 30% to greater than 60%, and
- to establish active farmer organisations capable of effectively organising their water management, input supplies and marketing.

An effective farmer organisation is crucial to scheme development, but to remain viable must operate according to simple rules. To be sustainable, it must take the responsibility given to it by DEDP, to operate and maintain the scheme in accordance with the plans prepared by the farmers it serves. It must also take the initiative in seeking the knowledge for improvement of production and not become reliant on external support for its existence.

DEDP is committed to a programme of support to the farmers in its pumped irrigation schemes, to make agriculture viable and sustainable.

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IRRIGATION AND WATER MANAGEMENT FOR SUSTAINABLE AGRICULTURE AND RURAL DEVELOPMENT IN THE MEKONG DELTA OF VIETNAM

Do Manh Hung[1]

Vietnam

1. BACKGROUND

After running through some upstream countries, the Mekong river enters to Vietnam by the two main branches namely the Tien (Mekong) and the Hau (Bassac). Together a dense system of canals and tributaries, total length of waterways in Vietnam is about 6,700 km which are not only favourable for navigation but as an abundant source of water supplying for domestic use as well as development of agriculture.

The Mekong Delta in Vietnam covers an area of 3,957,993 ha in which agricultural land is 2,464,251 ha accounting for 62.26 % of total area or 35.24 % of whole agricultural land of entire country.

Topographically, the Delta has a low and flat terrain slopping from North-west to South-east with general elevation from 0.5 to 1.0 m. The highest area can be found at the boundary with Cambodia meanwhile the lowest (equal or lower than MSL) is in Ha Tien coastal (see Figure 1).

The soil in the Mekong Delta of Vietnam is alluvial. Varying from area to area, soil may be non-acid, acid-sulphate or saline acid-sulphate etc... (see soil map).

Regarding the climate, the Mekong Delta of Vietnam is located in the tropical monsoon region. Average annual temperature is 27^{o}C. There are two distinct seasons a year i.e. dry and wet ones. Heavy precipitation is recorded in the wet season which is normally from May to November. In contrast, during the dry season from December to April, there is almost no rain. Annual rainfall varies from 1,500 to 2,000 mm of which 85 to 90 per cent concentrated in the wet season and is irregularly distributed in space. A gradual increase of annual rainfall from the East to the West is observed (see Figure 3) which corresponds to a similar increase in average monthly rainfall from 150 to 300 mm during the seven months of the wet season. In the dry season, rainfall amount accounts for about 10 - 15 % of the annual value.

In terms of flow, the surface waters of the Mekong river in the wet and dry season are different. In dry season, inflow at the entering point to Vietnam is about 2,385 cubic metre per second and its distribution into the Delta was calculated by the TIMOD developed by the Netherlands' experts as in Figure 4.

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1. **Irrigation Engineer, Institute of Water Resources Planning and Management**

Since plenty of surface waters, ground waters in the Delta are so far not exploited for irrigation but some activities for drinking or domestic uses.

Following is a table showing the existing land use in the Mekong Delta of Vietnam:

Table 1. Existing land use in the Mekong Delta of Vietnam

Items	Area (ha)
Total	3,957,993
1. Agriculture:	2,464,251
- Cultivated land	1,169,802
- Rice crop land	1,826,760
- Upland + short term industrial tree	126,579
- Long-term industrial tree	139,616
2. Forestry:	348,673
3. Unused land	497,166
4. Other land	647,903

2. CURRENT SITUATION

Thanks to the efforts of people and authorities concerned, many water resources projects in the Mekong Delta have been implemented resulting in increasing the yield of the agricultural production there.

In terms of irrigation, many kinds of measures have been applied here of which embankments and/or dikes to protect the fields from floods and pumping to facilitate the drainage of water logging have been largely resorted.

Parallely, the measures of agricultural techniques have been applied to increase production such as the use of new seeds, application of fertilizers and pesticides, modern tillage etc.

For more details see Annex 1: "Details on the Plain of Reeds"

3. CONSTRAINTS/PROBLEMS IN IRRIGATION AND WATER MANAGEMENT

Despite of the fact that in terms of natural conditions, the Mekong Delta has great potential for agricultural development, as of 1990, with the capacity of irrigation systems was 1.228 million ha, the actual irrigated area was only 781,000 ha. Why ?

The main reasons are:

1) Flooding in the Delta

Annually about 1.2 - 1.4 million ha are flooded for from two to six months by the floods from the river which some times are combined with heavy rain and/or high tide. Due to big flood, the following areas are frequently inundated: Plain of Reeds, Long Xuyen Quadrangle, North Cai Thuong etc.

2) Salinity intrusion

Right after flood season, salt water starts intruding far inland and approaches the maximum value in March/April or some times in May.

Salinity intrusion impacts the water source for 2.1 million ha of natural land. At the salinity concentration of 4 %, about 1.7 million ha of land can be affected.

3) Water logging

Normally water logging takes place once there is heavy rain in the field which is combined with flood in the river and/or high tide.

The typical areas often sufferred from this phenomenon are U Minh, Quan Lo-Phung Hiep, Long My.

4) Acid-sulphate water in canals

In total there are about 1.89 million ha of land are affected by acid-sulphate water and acid-salt water. In the dry season, acid-sulphate water from the underground stratum is capillarized to the surface. Then, in the beginning of next rainy season, acid-sulphate water discharges into canals resulting in impact to large areas such as the Plain of Reeds, Long Xuyen Quadrangle and Ca Mau Peninsula.

Water affected by acid-sulphate is the reason to harm the agricultural development.

5) Limitation of fresh water sources

The fresh water sources in the Mekong Delta are rain water, water from the Mekong river and underground water.

As mentioned above, more or less these sources are limited by some factors concerned which need to be improved with the aim at promoting the agricultural development.

Beside the above reasons, some other constraints concerning the technical matters as well as human resources and institutional aspects have also influenced to the development.

- Regarding the technical issues, the lack of necessary studies such as pre-feasibility studies and feasibility studies of some projects areas is also the reason why some projects could not be implemented.

- The lack of qualified or well trained personnel in these provinces is also another reason to smoothly carrying out the projects.

- That many national agencies are dealing with the same subject but not being appropriately coordinated also influences to the development.

4. PAST AND CURRENT PRACTICES

4.1. Achievements

Irrigation and water management for sustainable agriculture and rural development in the Mekong Delta of Vietnam conducted so far have achieved the certain results, especially the process of transferring from one floating rice cropping to double high yield rice cropping, and the increase of rice production of the whole area.

In terms of favourable natural conditions, suitable temperature and year-round sunshine in the Mekong Delta are suitable for growing crops. However, due to the shortage of fresh water, in the past a lot of cultivated areas in the Plain of Reeds are single crop areas of floating rice. Normally, the lack of fresh water occurs in Winter-Spring crop meanwhile flooding often appears in Summer-Autumn crop during flood season from July to November. Since 1976, the embankments have been built for protecting Summer-Autumn rice crop in shallow flooded areas early flood season. Besides, many canals have also been dug for fresh water supply and for flushing acid sulphate water which have contributed to reclaim acid sulphate soils for rice cultivation in the Mekong Delta (see Map on Current Situation of Water Resources). According to the data collected from various provincial agencies, together thousands kilometres of dikes/embankments for prevention of the August Flood, hundreds secondary and on-farm canals have been built.

The following table on the rice production in the Mekong delta of Vietnam during the period from 1976 to 1990 reflects partly achievement in the agricultural field:

Year	Yield (million ton)
1976	4.6
1985	7.0
1990	9.48

4.2. Measures for improvement of irrigation and water management

The Vietnamese Government's policy on water resources development and management is to encourage farmers in effective utilization of water to boost agricultural production. According to the new policy, farmers shall pay water fee during two main crops a year but cash crop. Up to now, however, there is no concrete regulation for collecting water fee but the rate of 6 - 7 % of agreed yield of two main crops (between farmers and respective Irrigation Management Company).

The water fee at present aims to support partially the expenses spent for improvement of irrigation systems, electricity consumption, salary of Company's staff. In

fact, the fee obtained is still lower than planned. Otherwise speaking, the deficiency has to be met by the Government budget.

Regarding the investment for capital construction, not similar as in the past, instead of Governmental subsidy, those costs shall be partly contributed by the farmers. The different rate is applied for different regions.

Normally the Government bears 60 - 70 % costs of capital construction while local people contribute 30 - 40 % in kind or by labour forces.

Thanks to this renovation, a system of major canals in the Mekong Delta has been built to discharge fresh water from the river into the fields for irrigation and improvement of soils such as Hong Ngu canal, Bao Dinh canal .... Many sluices with double purposes of separating salt water and taking fresh water have been constructed as Xuan Hoa sluice.

Data collection: Besides a permanent network of the General Department of Hydro-Meteorology, the Ministry of Water Resources has established a sectoral hydrological stations for observation of salinity, acid- sulphate concentration, flood depth etc. The factors concerning water quality are also measured in some mainstream stations.

All these measures and other application of progress technologies in agriculture (new seeds, diversification of crops etc.) have contributed to the increasing yield of crops in the Mekong Delta of Vietnam.

Concerning the institutional aspects, many provincial irrigation management companies have been established aiming at strengthening the capacity of water supply for domestic, industrial uses as well as for other economical sectors. The provincial irrigation company is responsible for management and exploitation of the existing irrigation systems, especially for those systems which irrigated areas cover many districts. Generally, the company is in-charge for headworks and main canal. the secondary canal and on-farm ditches are managed by district irrigation management companies under instruction of the respective provincial irrigation company.

The local personnel in the districts, communes have been trained on the techniques of management and development of water resources projects so that the operation of projects concerned step by step is well technically conducted resulting in effectiveness in water use.

5. FUTURE OUTLOOK

In the draft report of the Mekong Delta Master Plan (VIE/87/031), the secondary canal project is one of five priority ones which will be studied at the feasibility level in the second phase of the Delta Master Plan. The project dealing with 300,000 ha located in three sub-regions of the Plain of Reeds, Long Xuyen Quadrangle and the West Hau river has been officially approved by the Vietnamese Government, UNDP and WB with the participation of NEDECO and the Mekong Secretariat. According to the assignment of the Ministry of Water Resources, the Sub-Institute of Water Resources Planning and Management in the South is main agency in charge of this feasibility study.

Since the establishment of 11 separated studies for 11 respective sub-areas covering 300,000 ha is not an easy task, only three sub-areas have been selected as priority ones over which the feasibility study for development of the secondary canals

will be conducted. They are Bac Dong (in the Plain of Reeds), Ba The-Tri Ton (in Long Xuyen Quadrangle) and O Mon- Xa No (in the West Hau river).

Of course, in long-term, all 11 sub-areas will be studied at feasibility level. Basing on results recommended by these studies, all necessary infrastructures as well as settlement facilities will be established which create the foundation for development of the entire Delta.

6. CONCLUSION

Water resources development in the Mekong Delta of Vietnam which has been paid much attention by not only the Government but also the local people is approaching the encouraging results. It has contributed in enlarging the cultivated areas, especially rice crop areas, increasing intensively the crops, boosting yield, construction of infrastructures, transport/communication system which all result in improvement of living standards in the Mekong Delta.

With the continuous assistance of the Mekong Secretariat as well as other international organizations, with the cooperation among the riparian countries, the water resources development in the Mekong Delta will certainly get the success which will meet the increasing demand on economical development of the country.

Annex 1

DETAILS ON THE PLAIN OF REEDS

The Plain of Reeds is a closed low land area located in the North of the Mekong Delta and covers a natural area of 630,000 ha of which 356,000 ha has been affected by acid sulphate waters.

Before 1975, due to shortage of fresh water in dry season and inundation resulted from flooding from Tien (Mekong) river and from Cambodia-Vietnamese border, almost area was cultivated with floating crop (see the Map of water resources projects in 1976).

From 1976 to present, improvement of water resources system has been paid mush attention. Many new canals for fresh water supply and flushing acid sulphate waters have been dug of which the typical one is Hong Ngu canal... (see the Map of water resources projects up to 1990). The benefits derived from these new canal systems are as follows:

- Winter-Spring rice area: five times increased.
- Summer-Autumn rice area: three times increased.
- Floating area: a half time decreased.
- Whole year rice yield: three and a half times increased.
- The local inhabitant is added by more 200,000 population resettled from other areas.
- Over 100,000 ha of Malaleuca has been planted.
- Fishery developed.
- Fruit trees have been planted around the populated area.

However, due to the irrigation/drainage system in the sub-area of Bac Dong canal has not been developed yet, the present agricultural area accounts for only 23 % of whole natural area. In the Master Plan of the Mekong Delta, the feasibility study for this sub-area has been undertaken (see Tables 2, 3, 4, and the Figures 6, 7, 8, 9).

Annex 2

LEGEND OF THE MAP OF WATER RESOURCES DEVELOPMENT UP TO 1990 IN THE PLAIN OF REEDS:

1. Embankments for flood protection of August Flood:

- Total length:	4,451 km.
- Volume:	8.27 million m3
- Area to be protected:	356,222 ha

2. Main canals: Total length: 425.5 km

Name	Length (km)	Average Width (m)
- Cai Co	100	10 - 14
- Hong Ngu	44.3	20 - 40
- Dong Tien-Duong Van Duong-Lagrang	89.5	20
- An Phong-My Hoa	98.5	10 - 12
- Nguyen Van Tiep	93.2	15 - 30

Total excavated volume	50.6 million m3
Filling volume	13.8 million m3

3. Primary canal:

Total length:	1,445 km
Average width:	8 - 10 m
Excavated volume:	73.9 million m3
Filling volume:	17.6 million m3

Some primary canals:

- Binh Thanh	133.1 km
- Tan Dung Chi	145.9 km
- Tan Thanh	187.4 km
- Cai Bat	116 km

4. Sluice of Rach Tranh at the end of Nguyen Van Tiep canal for separating salinity and flushing acid-sulphate water.

Width:	21 m (3 x 7 m),
Bottom elevation:	- 3.5 m

Table 2. Future Area - Yield - Production of crops

No.	Crops	Alternative 1			Alternative 2			Alternative 3			Alternative 4		
		Area (ha)	Yield (ton/ha)	Production (ton)	Area (ha)	Yield (ton/ha)	Production (ton)	Area (ha)	Yield (ton/ha)	Production (ton)	Area (ha)	Yield (ton/ha)	Production (ton)
1.	Rice	71,080	4.58	325,646	44,070	4.73	208,386	58,7740	4.46	262,100	82,740	4.32	357,820
	W/S crop	34,440	5.07	174,627	21,940	5.25	115,277	23,030	5.25	120,900	31,030	5.13	159,100
	S/A crop	34,440	4.13	142,219	19,940	4.23	84,309	21,030	4.23	88,860	29,030	4.15	120,420
	A/W crop	2,200	4.00	8,800	2,200	4.00	8,800	14,680	3.57	52,340	22,680	3.45	78,300
2.	Jute	-	-	-	2,000	2.20	4,400	2,000	2.20	4,400	2,000	2.20	4,400
3.	Yam	-	-	-	4,500	15.00	67,500	4,500	15.00	67,500	4,500	15.00	67,500
4.	Sugarcane	-	-	-	3,500	29.34	207,700	3,500	29.34	207,700	-	-	-
5.	Pineapple	-	-	-	4,500	13.18	59,300	4,500	13.18	59,300	-	-	-

Table 3. Present land use (1991)

No.		Area (ha)	Percentage (%)
	Gross area	**50,438**	**100**
I	Agricultural land	11,515	23.0
	1. Annual crop land	10,395	
	a. Rice and upland crop	6,462	
	- Triple rice crop	956	
	- Double crop	4,068	
	two rice crops	4,029	
	one rice & one crop	39	
	- Single rice crop	1,085	
	b. Upland and industrial crop	3,933	
	2. Perennial crop land	1,076	
	3. Surfacewater areas	44	
II	Forestry land	13,402	27.0
III	Special use land	3,216	6.0
IV	Others	22,305	44.0

Table 4. Proposed land use alternatives (Unit: ha)

No.	ITEMS	Without flood control				With flood control	
		PL. use (ha)	Without project	Alter. 1	Alter.2	Alter. 3	Alter. 4
	Gross area	50,438	50,438	50,438	50,438	50,438	50,438
1	Agricultural land	11,515	13,390	33,350	33,440	33,530	33,530
	a. Annual crop land	10,395	13,390	33,350	33,440	33,530	33,530
	- Rice land	6,462	8,390	33,350	18,940	19,030	27,030
	Triple cropping	956	1,800	2,200	2,200	14,680	22,680
	Double cropping	4,029	6090	33,350	16,740	4,350	4,350
	1 rice + 1 upland	-	-	-	2,200	2,200	-
	Single cropping	1,477	500	-	-	-	-
	- Upland and industrial crop.	3,933	5,000	-	12,500	12,500	6,500
	b. Perennial crop land	1,076	-	-	-	-	-
2	Forestry land	13,402	13,000	7,000	7,000	7,000	7,000
3.	Special use land	3,216	4,250	7,820	7,820	7,820	7,820
4.	Others	22,305	19,789	2,268	2,178	2,088	2,088

Note: PL. use: Present land use

Without project: development without project activities

Alter. 1: maximal rice-oriented production

Alter. 2: crop diversification

Alter. 3: crop diversification with flood control

Alter. 4: maximal rice-oriented production with flood control

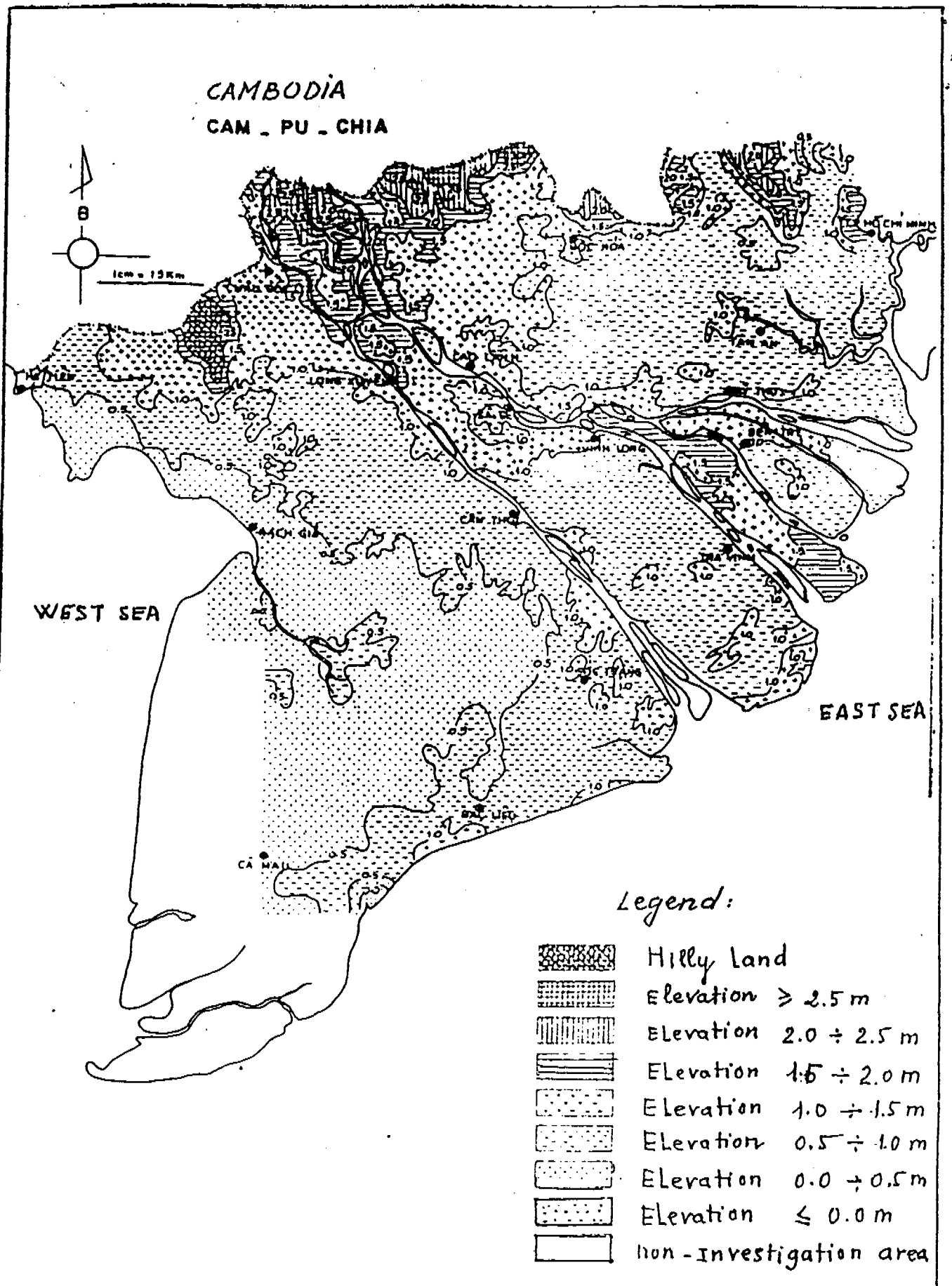

Figure 1. Topography map of the Mekong delta
Scale: 1 : 1,500,000

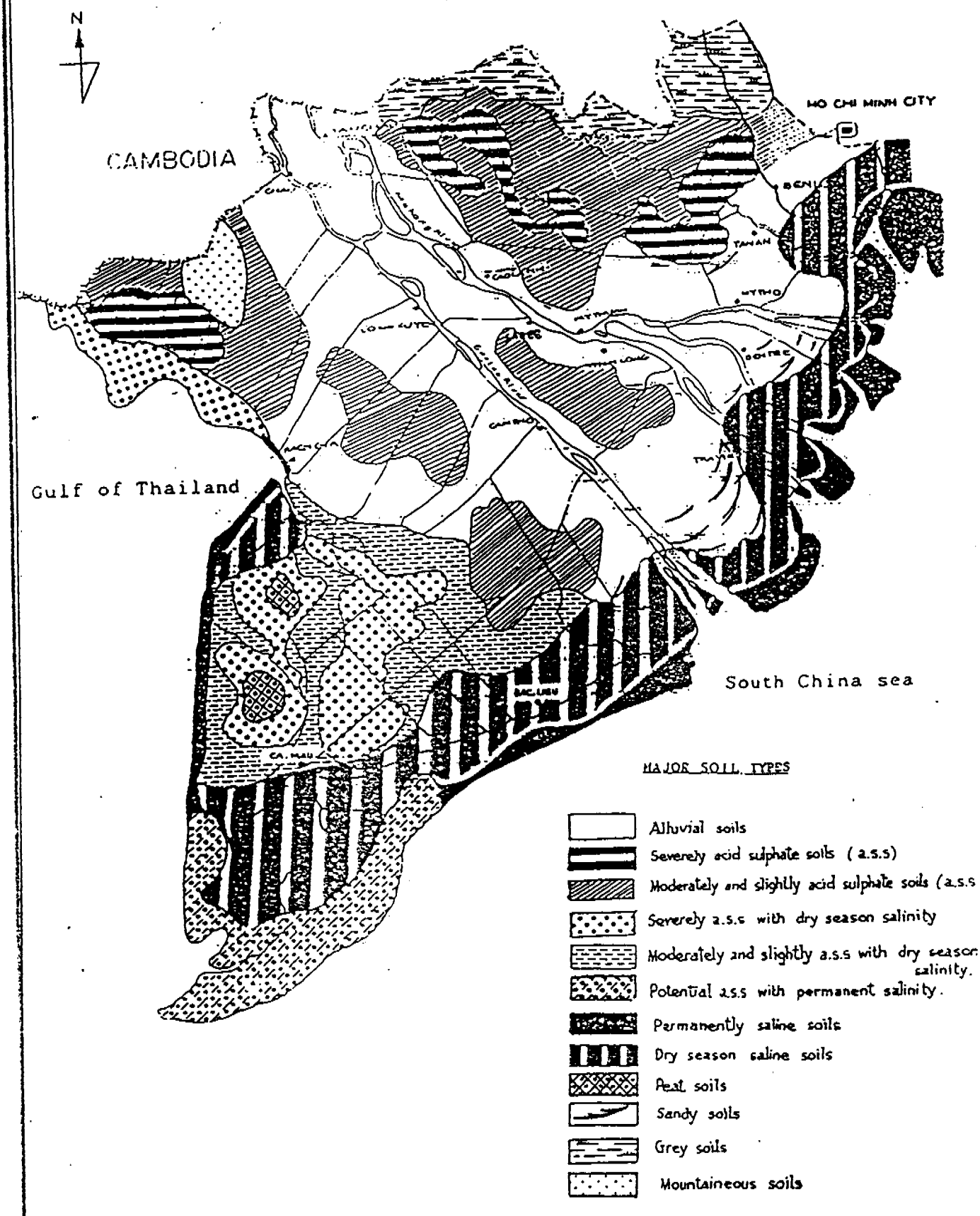

Figure 2. General soil map of the Mekong delta

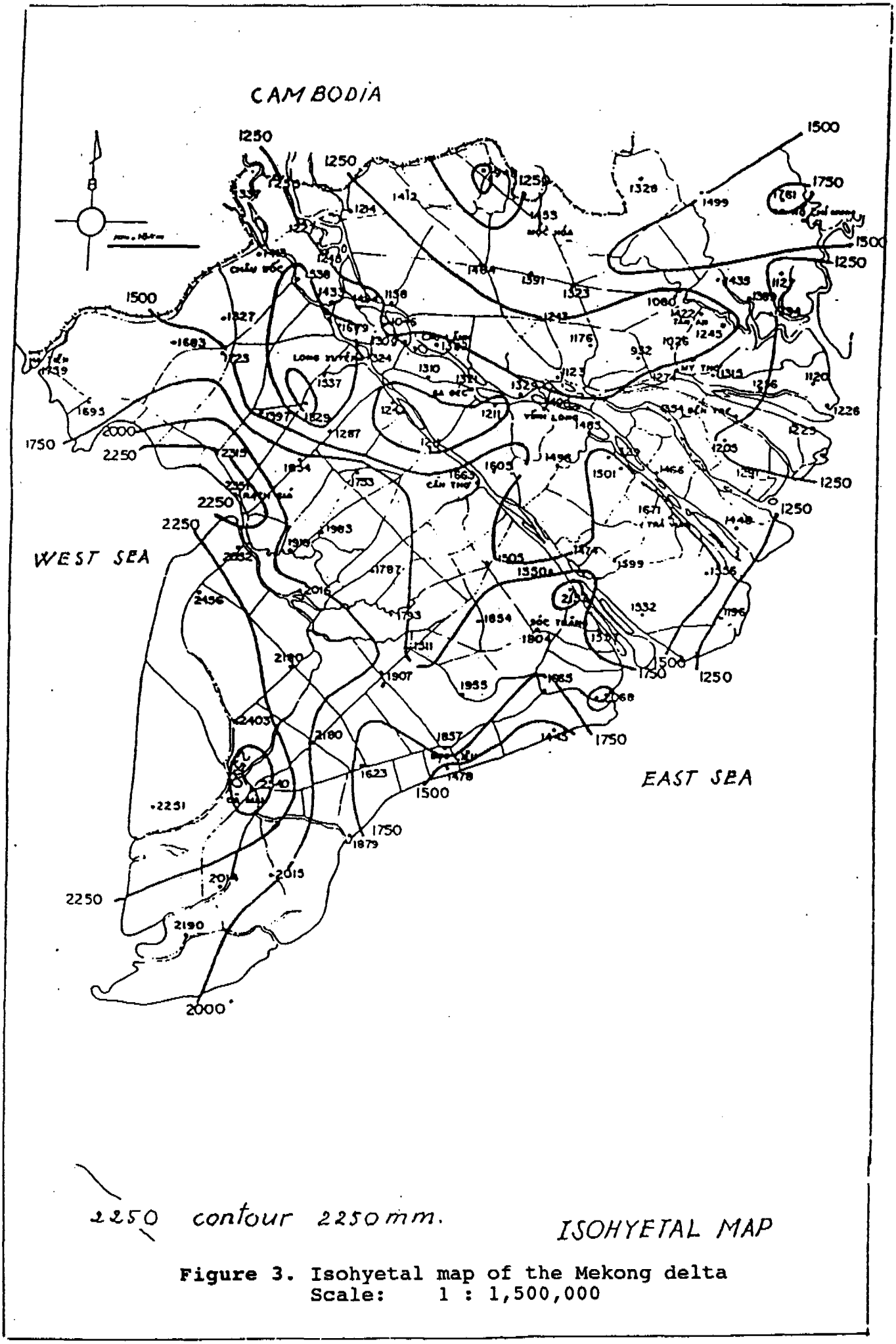

Figure 3. Isohyetal map of the Mekong delta
Scale: 1 : 1,500,000

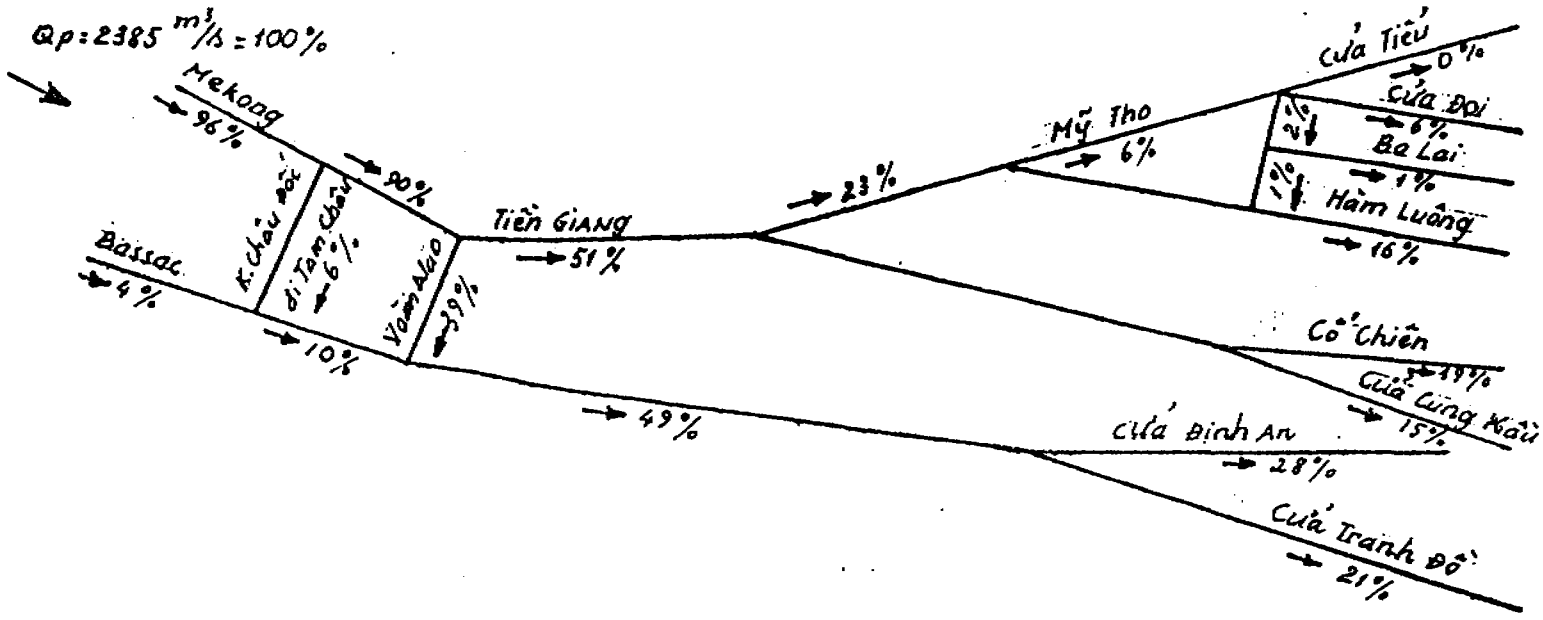

Figure 4. Flow distribution of main channels by Netherlands mathematical model

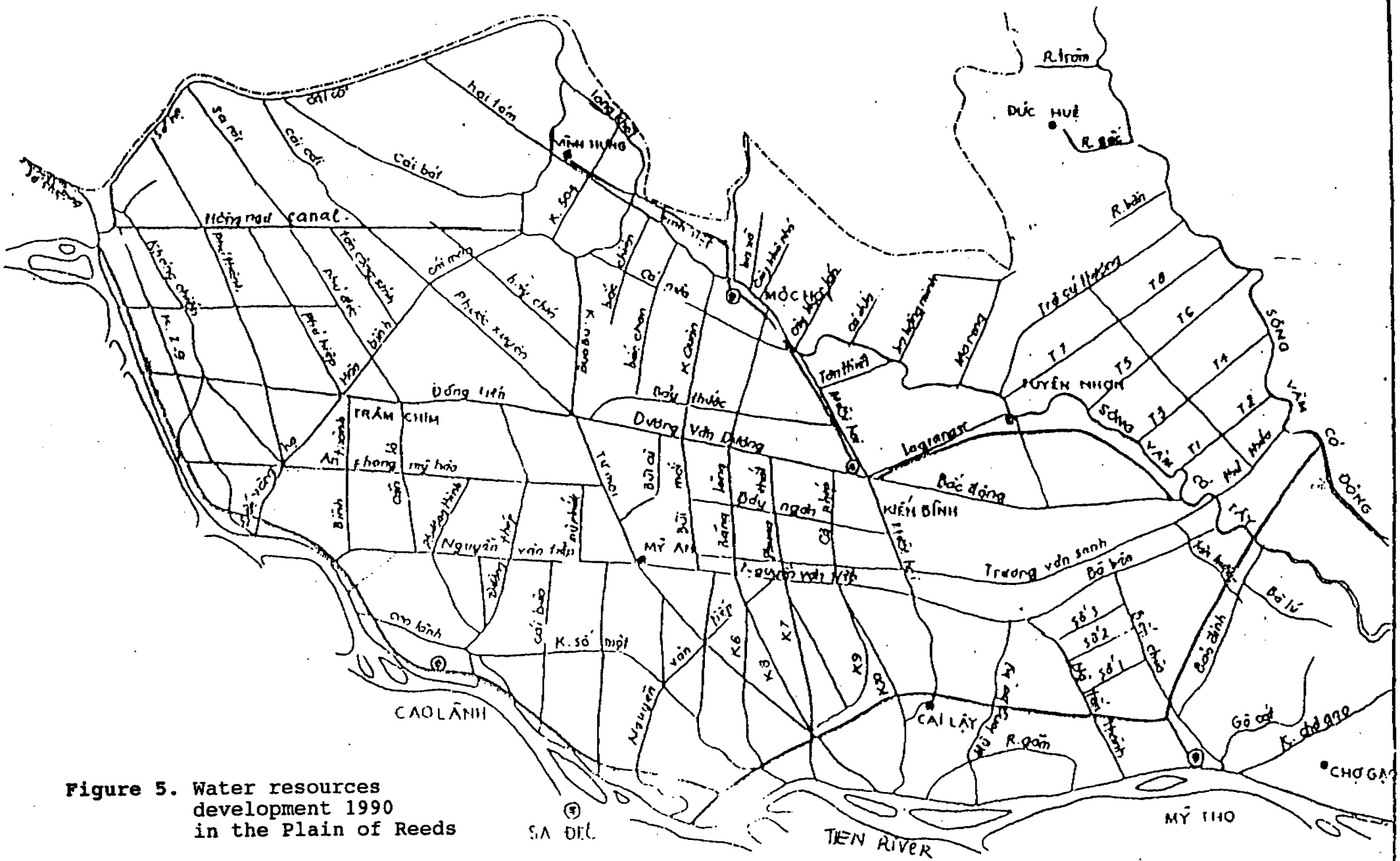

Figure 5. Water resources development 1990 in the Plain of Reeds

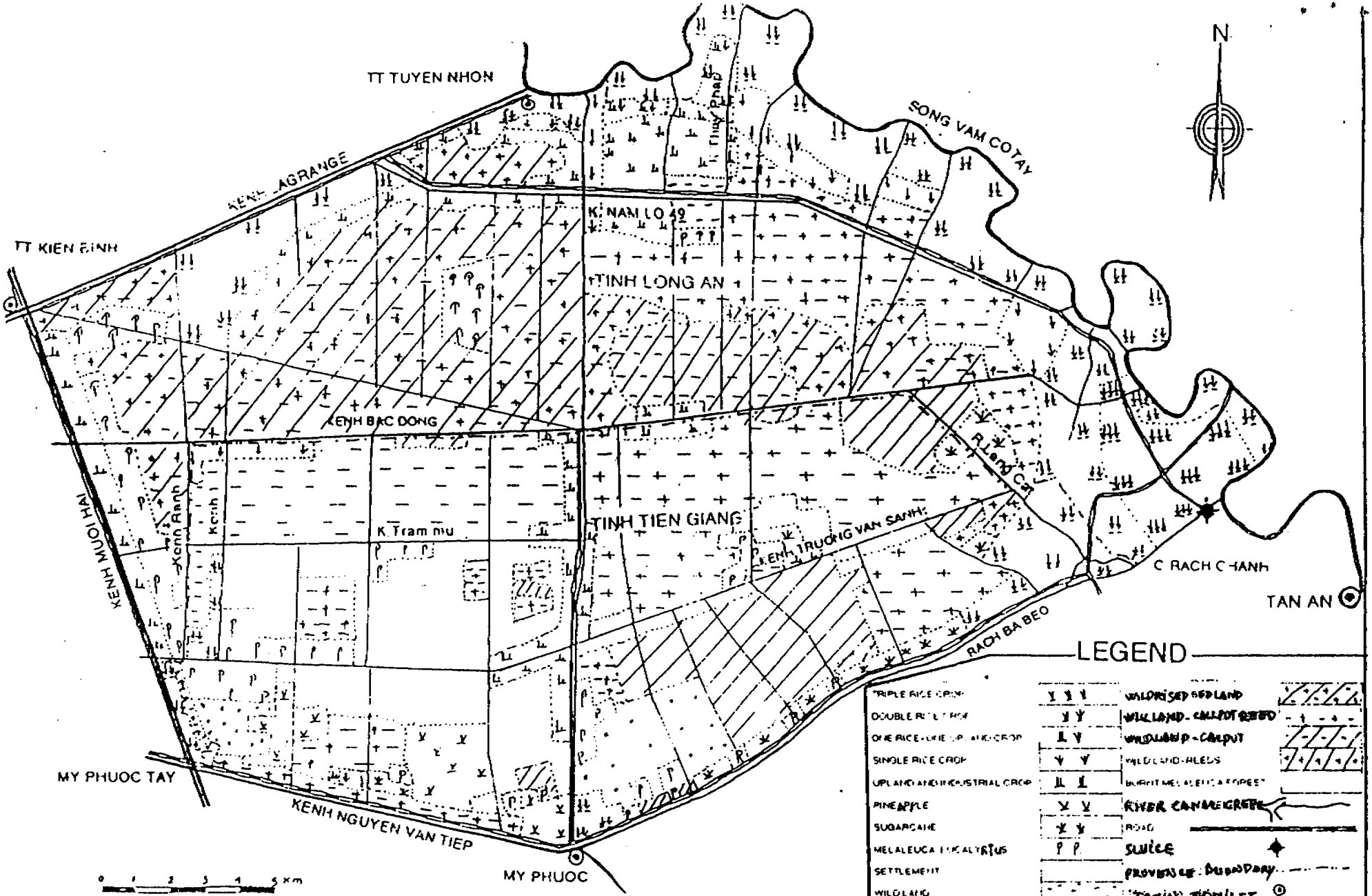

Figure 6. Present land use map in 1991 - Bac Dong Project

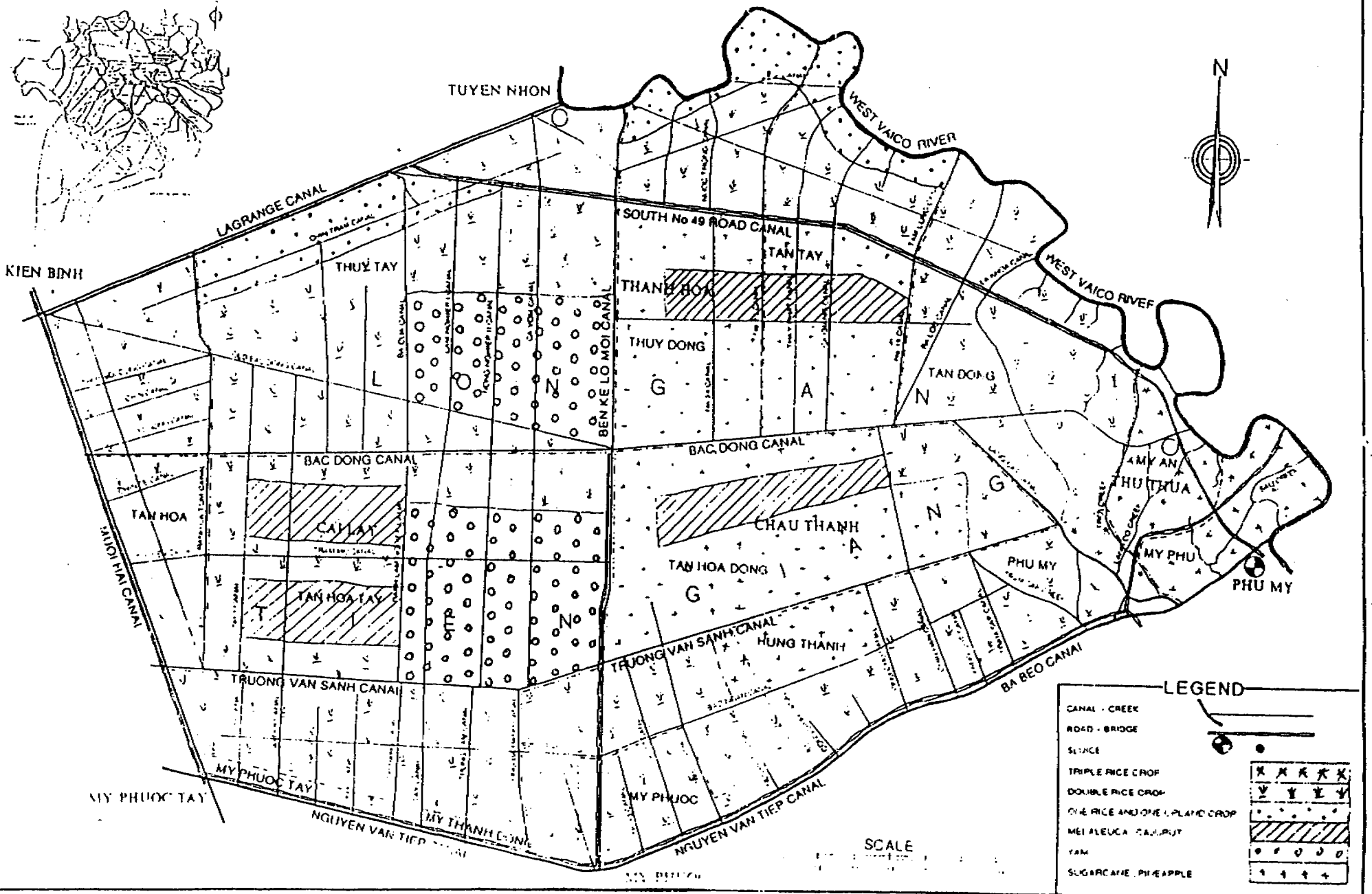

Figure 7. Proposed land use - Bac Dong Project

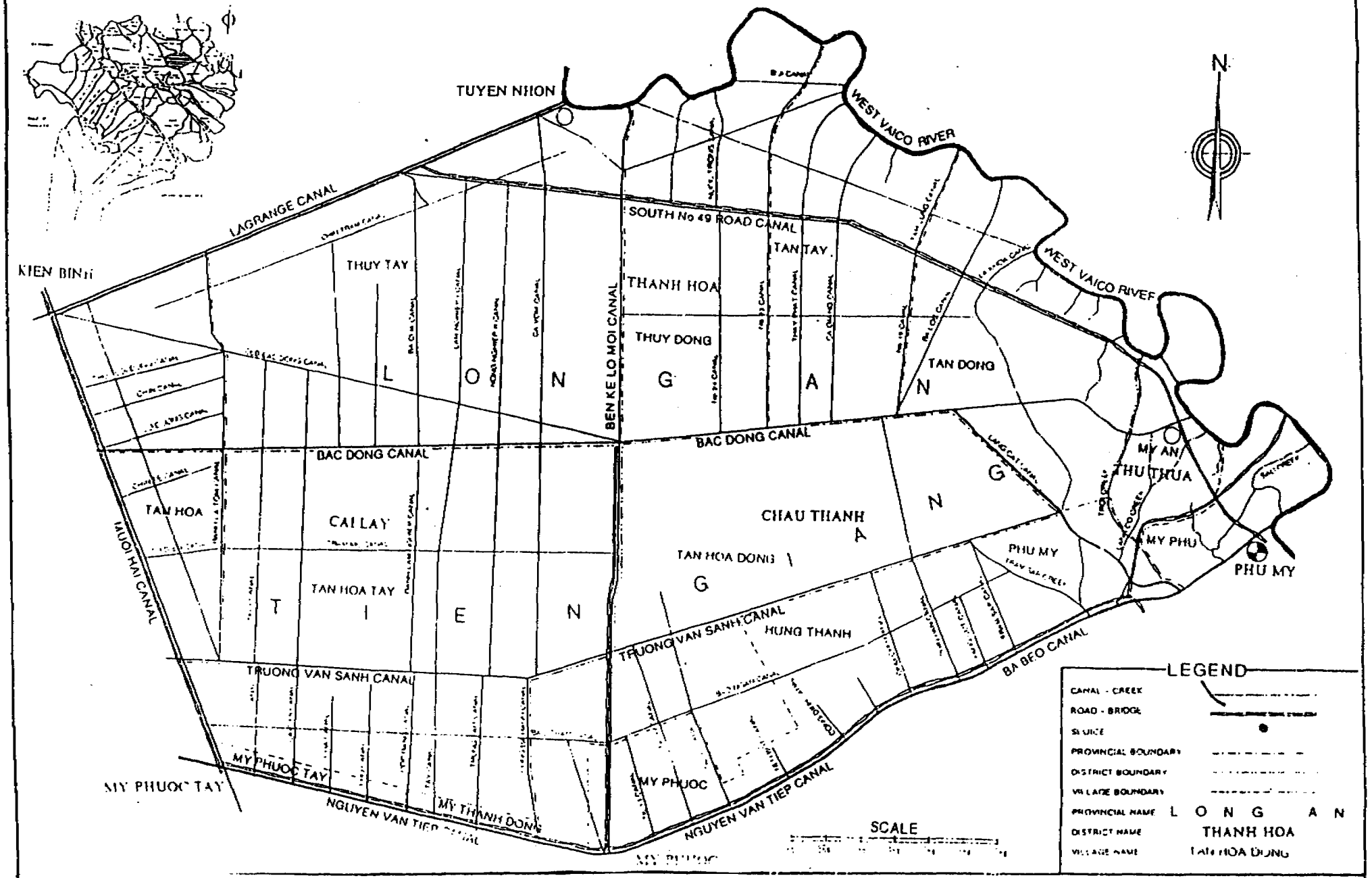

Figure 8. Existing water control system, 1991 - Bac Dong P.

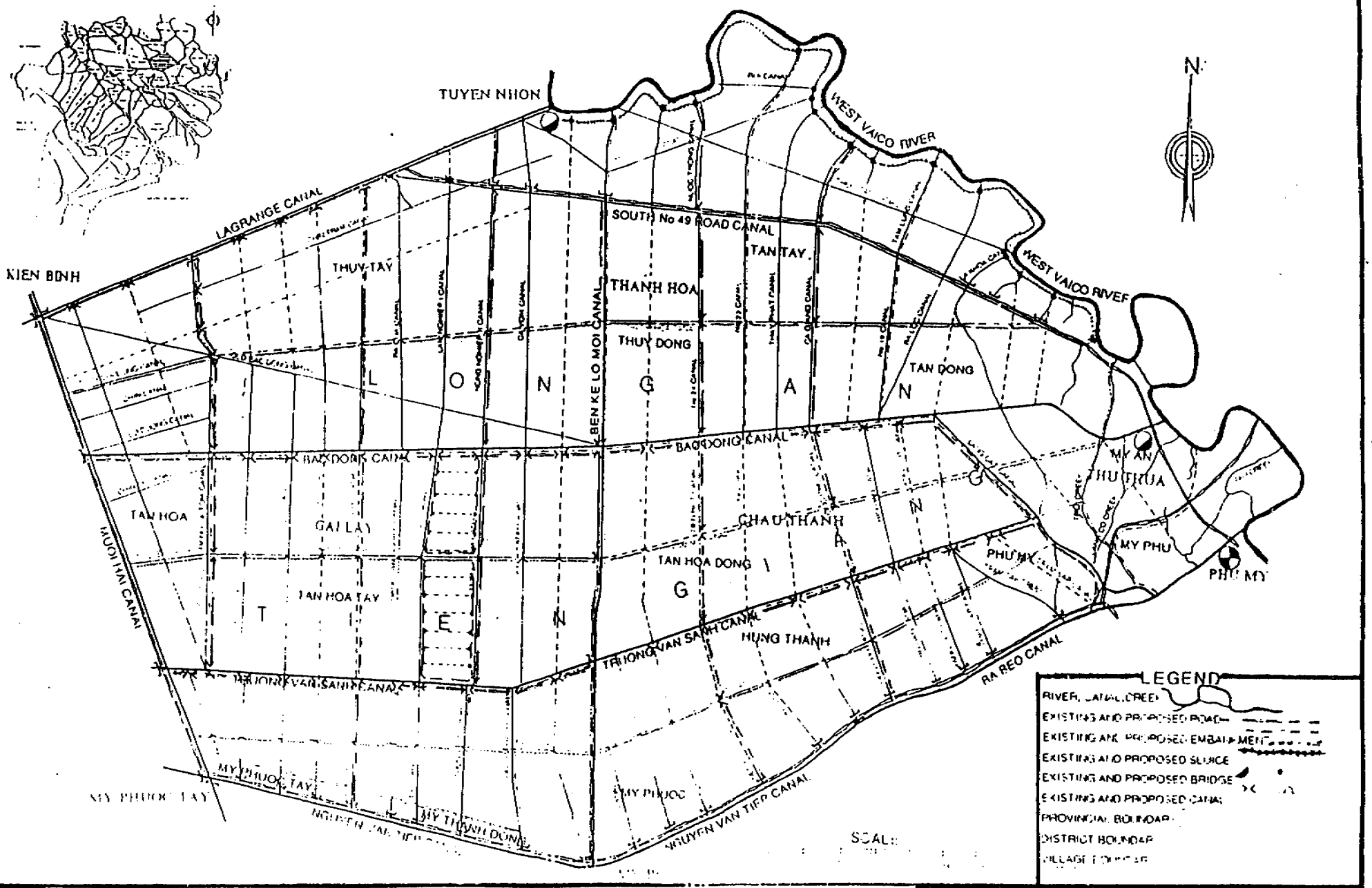

Figure 9. Proposed water control alternative 1 - Bac Dong P.

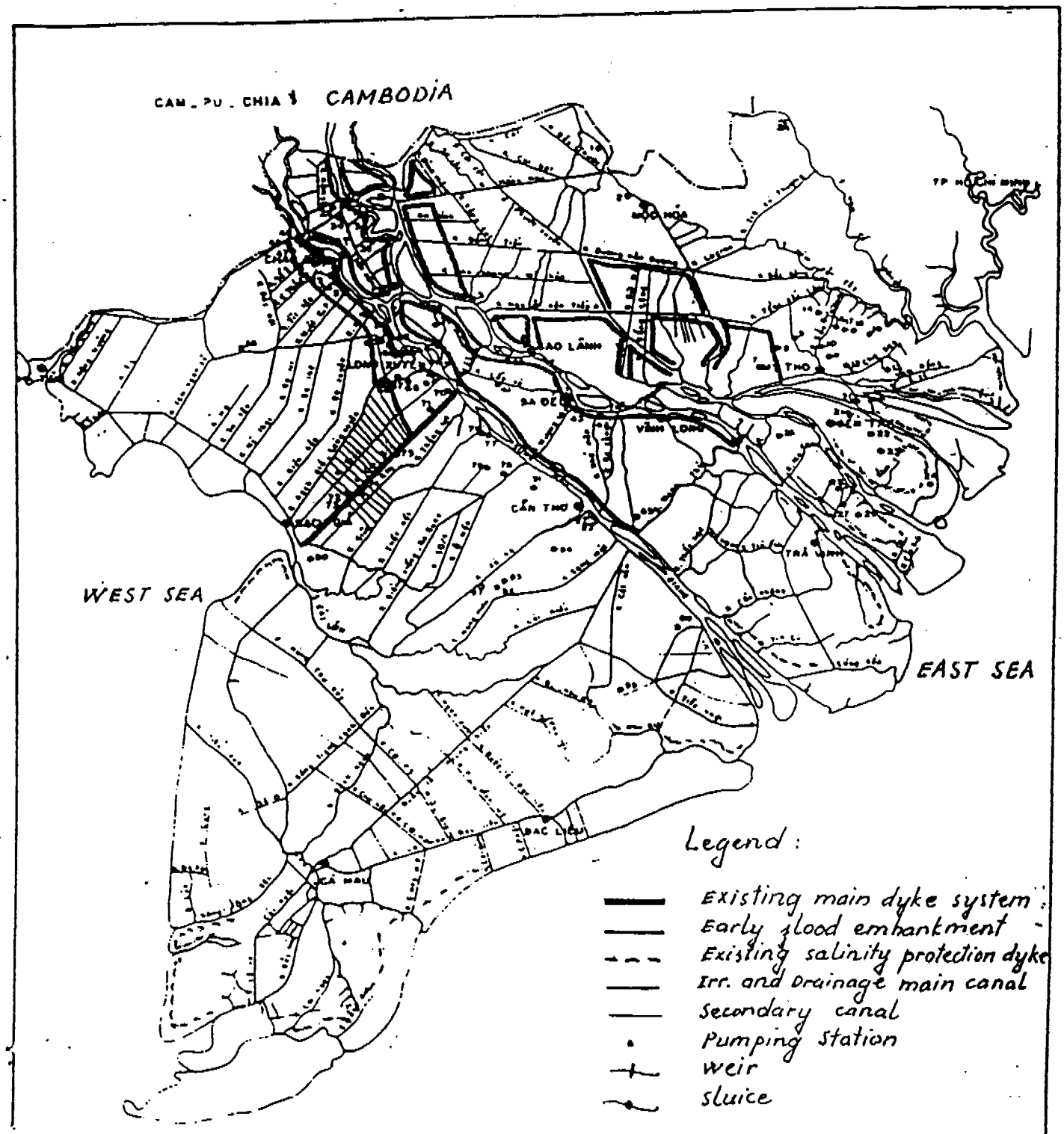

Figure 10. Existing irrigation map of the Mekong delta