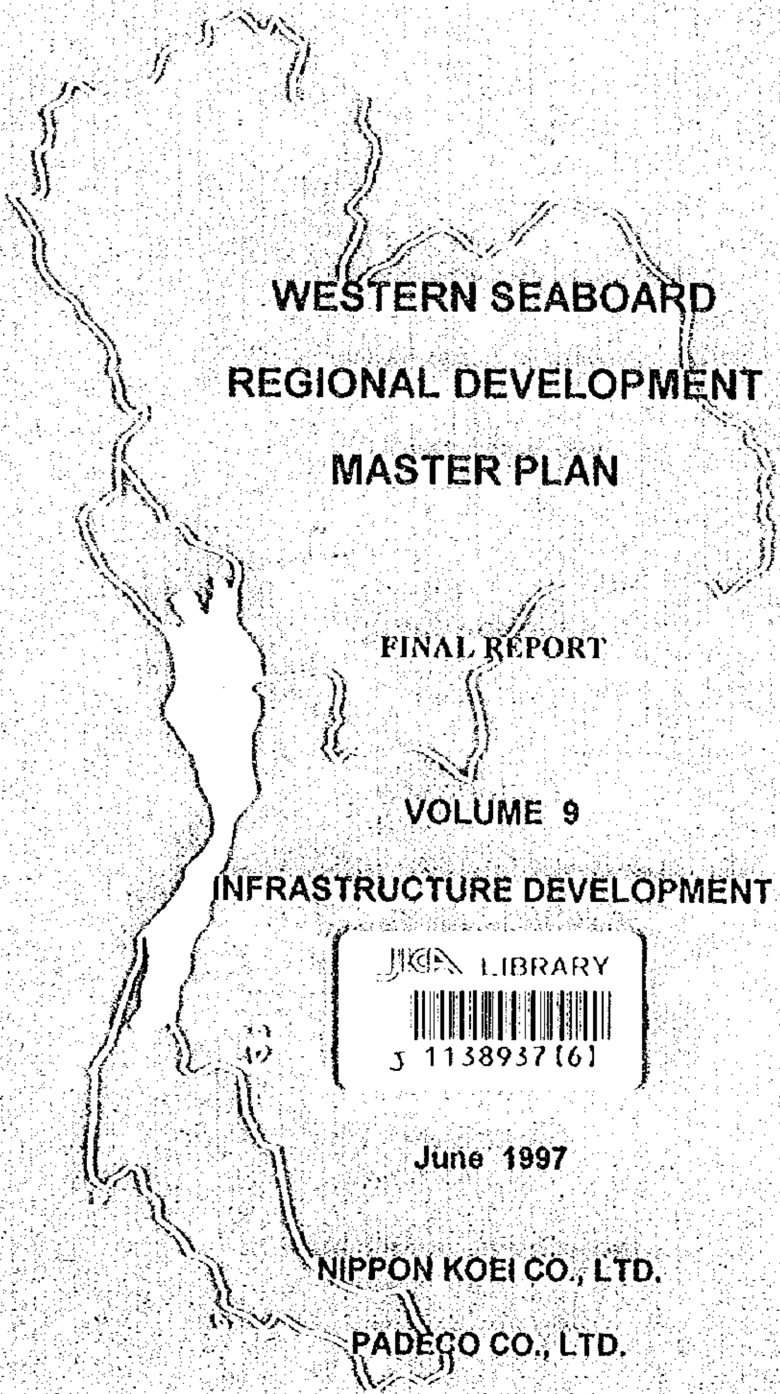
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

NATIONAL ECONOMIC AND
SOCIAL DEVELOPMENT BOARD (NESDB)
OF THE KINGDOM OF THAILAND



WESTERN SEABOARD
REGIONAL DEVELOPMENT
MASTER PLAN

FINAL REPORT

VOLUME 9
INFRASTRUCTURE DEVELOPMENT

June 1997

NIPPON KOEI CO., LTD.

PADECO CO., LTD.

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LIST OF REPORTS

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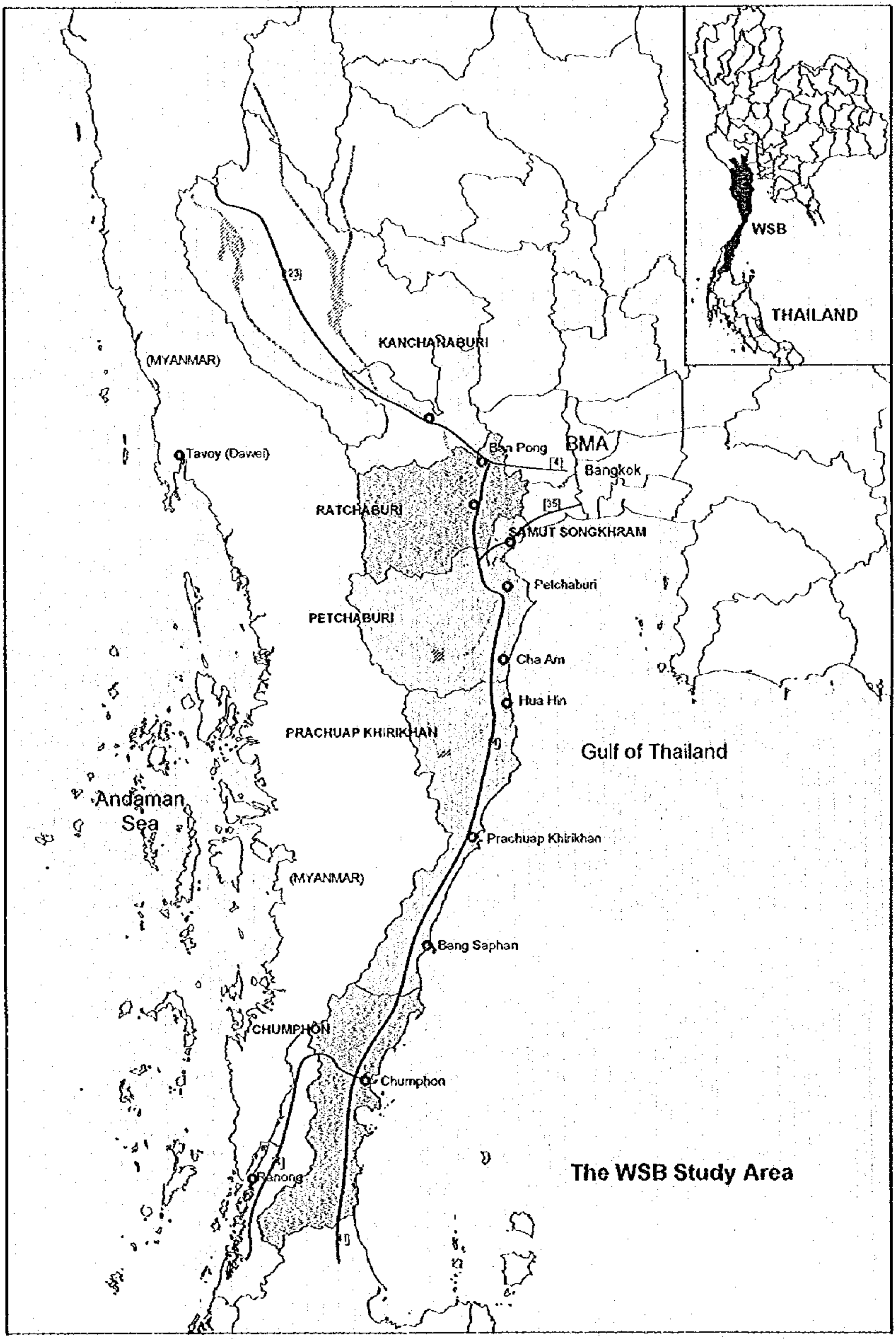
Currency Equivalents

US$ 1 = 25 Baht
1 Baht = US$ 0.04

(As of Mid 1996)



WSB
THAILAND
KANCHANABURI
(MYANMAR)
Tavoy (Dawei)
Ban Pong
BMA
Bangkok
RATCHABURI
SAMUT SONGKHRAM
Petchaburi
PETCHABURI
Cha Am
Hua Hin
PRACHUAP KHIRIKHAN
Gulf of Thailand
Andaman Sea
Prachuap Khirikhan
(MYANMAR)
Bang Saphan
CHUMPHON
Chumphon
Ranong
The WSB Study Area

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Chapter 1 RESOURCES MANAGEMENT AND THE ENVIRONMENT

1.1 Environmental Constraints

The rapid economic expansion in Thailand in the recent past is partly a result of intensive exploitation of natural resources. However, Thailand's natural resources, which had once served as key contributors to economic prosperity, have now become constraints on future development.

A comprehensive policy of systematic management and rehabilitation of natural resources in the fields of land, water, and forestry resources, as well as environmental quality improvements, should be considered in order to achieve sustainable development in the WSB region.

(1) Land Resources

During the last three decades, the problems of land availability, land use, land development, and soil conservation have been gradually increasing in the WSB region. The major causes of these problems have included population pressure and a gradual shift in land use from forest to agriculture, particularly traditional shifting (slash-and-burn) cultivation.

It is generally understood that most of land suitable for agricultural use has already been utilized. The shift from forest highland to agriculture has been associated with land deterioration through inappropriate land use. As a result of these existing problems, some previously cultivated lands have been abandoned. An equally important factor responsible for the land-related problems is a lack of a solid land management policy, since a large number of government agencies and committees have overlapping responsibilities, and there are a number of laws, regulations, cabinet resolutions, and ministerial decrees.

Major land forms in the WSB region include the mountains in the west, consisting of part of the rugged central cordillera along the Thai-Myanmar border. Several subparallel ridges, divided by narrow and deep valleys, are observed. The westernmost of these ridges is the Tanaosi range. East of this ridge, in the catchment area of the Mae Klong river, lies an extensive area of rugged limestone hills.

The soils of the WSB are varied and the agriculture diversified, with the region having the most common soil types, i.e., Inceptisols, Alfisols, and Ultisols. Land for agricultural use can generally be considered suitable for paddy, upland crops, and perennial crops. It has been found through the GIS analysis undertaken in this Study that agriculture is the major land use type, accounting for 54.5 per cent, with 36.6 per cent for mixed upland crops, 7.1 per cent for rice, and the rest for other types of agricultural crops.

A field survey and the GIS analysis have revealed that there would be certain areas of problematic land that are unsuitable for agricultural use, such as land with acid soils, alkaline soils, and saline soils. Such problematic land is widely observed in the lower part of Petchaburi and the upper part of Prachuap Khirikhan provinces. Top soil erosion associated with infrequent rainfall, excessive evaporation, and sea water intrusion are considered major factors creating this problematic land. Remedial measures to vitalize such land should be considered in line with this Study's proposal for establishment of an amenity zone in order to foster development in the Central WSB.

In addition to natural phenomena, human-induced soil degradation is also a concern. One probable factor causing low soil productivity is the excessive use of chemical fertilizers for monoculture cultivation. It is well known that the loss of humus due to the excessive use of chemical fertilizers ultimately reduces soil productivity. The introduction of organic farming would be a solution for restoring the low soil productivity.

(2) Water Resources

Available water supplies are derived from two different sources, surface water and groundwater. As the name implies, surface water consists of the fresh water in rivers, lakes, and reservoirs that collects and flows on the earth's surface. Groundwater by contrast collects in porous layers of underground rocks known as aquifers.

Water resources are used by agricultural, industrial, and household users. The gradual economic expansion of the WSB region has led to increased demand for water in non-agricultural sectors, particularly the industrial sector. It is well known that Thailand suffers from a water shortage in the dry season; the WSB is not an exception. During the dry season, the levels of reservoirs and major rivers falls substantially. Groundwater levels have also been falling recently in some areas in the WSB region as a result of intensive pumping for mainly industrial uses.

Major rivers in the WSB region include the Mae Klong, Petchaburi, Pranburi, and Lang Suan. Among these four major rivers, the Mae Klong has a catchment area of about 30,800 km^2 while the other three rivers have catchment areas of about 5,600 km^2 (the Petchaburi), 2,900 km^2 (the Pranburi), and 1,600 km^2 (the Lang Suan). Water quality monitoring of key parameters, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Faecal Coliform, was conducted by the Public Health Department in 1995 and the results are given in Table 9.1.1.

The monitoring results indicate that water quality in the four major rivers in the WSB region is generally at acceptable levels for agricultural and industrial uses, but not at levels suitable for the purpose of drinking water or for ecosystem conservation so that basic living organisms can breed naturally. Based on the Classifications of Water Conditions and Objectives set by the Pollution Control Department (PCD), the Ministry of Science, Technology and Environment (MOSTE),[1] water quality conditions tested at 11 locations on the Mae Klong river are categorized in Class 2 (Very Clean) or 3 (Medium Clean) regarding DO and BOD, while the quality has fallen into Class 4 (Fairly Clean) regarding the Fecal Coliform indicator. These results indicate that a heavy load of organic waste water is discharged from households and commercial and industrial establishments into the Mae Klong river. The monitoring results also indicate that water quality in the lower stream of the Mae Klong river is more polluted than in the upper stream, implying the accumulation of waste water impacts on the water body. Mitigation measures should be taken to improve the water quality.

Major sources of water quality deterioration in the WSB region are considered domestic waste water and industrial waste water. The former accounts for a major part, as industries in the region are not yet well-developed and there are few significant industrial waste water sources. It is, however, also anticipated that industrial waste water will cause more water quality deterioration as the industrial sector continues to grow.

Few domestic waste water treatment systems are currently operational in the WSB region. With the likelihood of an increase in population, it is anticipated that household waste water arises as a consequence of development. Poor provision of domestic waste water facilities is primarily due to a lack of technical expertise, institutional weakness, and financial vulnerability. Two domestic water treatment systems in the WSB region, in

[1] These classifications are reproduced and attached in Tables 9.1.2 and 9.1.3.

Petchaburi and Hua Hin municipalities, are currently operational but no such system is available in the other WSB municipalities. Setting up treatment systems in other major municipalities should be considered in line with the national policy of water quality improvement in provincial areas.

At present, the Office of Environmental Policy and Planning (OEPP) and the Pollution Control Department (PCD) under the Ministry of Science, Technology and Environment (MOSTE) have been engaging provincial environmental quality improvements. OEPP and PCD have been promoting Provincial Environmental Action Plans to improve environmental quality with the focus on domestic waste water treatment and solid waste management.

The majority of medium- and small-sized industrial establishments in the WSB region are not equipped with appropriate waste water treatment systems. Waste water discharged from these industrial establishments flows into nearby water bodies and eventually reaches the coastal areas. Although the volume of industrial waste water or magnitude of water pollution is considered still within the capacity of the natural purification process (no significant toxic substances were detected in the major water bodies), an indiscriminate increase in waste water discharged into the water bodies would significantly worsen the water quality and cause problems for water use. The potential risk of hazardous industrial wastes, typically in the form of waste water containing heavy metals, would also need to be considered.[1]

(3) Forest Resources (including Mangrove Forest)

The WSB region, particularly near the Thai-Myanmar border, still possesses pristine forests. The GIS analysis has revealed that forest cover in the WSB region accounts for 42.7 per cent of the study area. Major tree types include hill evergreen (28.3 per cent) and mixed deciduous (7.4 per cent). Disturbed forests have also been observed in 5.9 per cent of the total land area.

Illegal logging and traditional shifting cultivation are major constraints on appropriate forest management. Illegal logging is particularly prominent in Kanchanaburi province. The degradation of mangrove forests, which accounts for 0.47 per cent of the total WSB land area, is also a concern in coastal areas. It was observed that a large area of

[1] It should be noted that quite low lead (Pb) concentrations in waters of the Petchaburi, Pranburi, and Lang Suan rivers, were detected. Although the concentration levels are well below the set standard of 0.05 ppm, considerations should be made for preventing further heavy metal substances concentration in the rivers.

mangrove forests in Samut Songkhram and Prachuap Khirikhan provinces were cleared for the use of shrimp farming or damaged by industrial waste water discharged mainly from food processing factories in the nearby provinces. It was reported there were 83,000 rai of mangrove forests in Samut Songkhram province in 1957 but only 500 rai at present. Similar massive deforestation has resulted in only 437 rai of mangrove forests surviving in Prachuap Khirikhan province.

(4) Solid Waste Management

Solid waste disposal problems have reached the critical level in major municipalities throughout the Kingdom. This problem is expected to be a bottleneck harming the life of WSB residents. The disposal of solid waste generated from households, commercial, and industrial establishments into open dumps is a standard practice for municipalities in the WSB region, and the sanitary conditions of the dumping sites are poor. It is anticipated that continuous use of open dumps will result in public health hazards such as vector breeding, disease transmission, foul odors, and surface and underground water contamination. The introduction of sanitary landfill systems to substitute for existing open dumps would be a viable solution to avoid the unnecessary sanitary risks associated with poor solid waste management.

The volume of solid waste generated has also been increasing and the availability of land for treatment will become additional constraints for many WSB municipalities in the near future. Coupled with improving sanitary condition of dumping sites, remedial measures to reduce solid waste volumes should be considered. Among various potential waste volume reduction methods, composting will be one of the most viable options to be applied in the municipalities of the WSB region.

(5) Environmental Advocacy

Although local inhabitants have been paying more attention to the environment, their understanding of specific environmental issues is generally weak, and such limited public understanding hinders the adoption of appropriate natural resources management and environmental quality improvements. Environmental advocacy may therefore play a vital role to address the issue in the long run.

1.2 *Alternative Frameworks for Environmental Improvements*

(1) General

Sustainable environmental improvements in the WSB region should be considered in line with appropriate land zoning classifying land/forest as (i) protected area, (ii) conservation area, and (iii) development area.

Protected areas have the role and functions of preserving valuable flora and fauna, fostering water resources, and preventing natural disasters including soil erosion. The areas categorized as protected areas include national parks, wildlife sanctuaries, and watershed Class 1. These areas are completely protected by law and neither industrial and agricultural activities nor human settlement is allowed, unless cabinet approval is obtained; obtaining this kind of approval is considered quite difficult. In the WSB region, there are seven national parks and four wildlife sanctuaries that have been designated as protected areas since 1966.

Conservation areas can be defined as areas having development potential with environmental sensitivity. Major concerns in this area include soil conservation, water pollution prevention, and conservation of areas having high tourism development potential. Conservation areas typically include forested land not designated as a protected area,[1] watershed Class 2 and coastal areas of Samut Songkhram, Petchaburi, Prachuap Khirikhan, and Chumphon provinces.

Other areas, designated as development areas, may serve as sites for development projects. Development areas can be divided into two types based on the purpose of development: (i) agricultural development areas and (ii) urban and industrial areas to be equipped with comprehensive infrastructure and waste treatment systems.

Alternative frameworks of natural resources conservation and environmental quality improvements in line with the WSB regional development objectives are proposed in the following subsections.

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[1] These lands are also called economic/commercial forests in which development activities are allowed.

(2) Land Resources

Alternative frameworks for land resource improvements are focused on the prevention of further soil degradation and improvement of soil fertility to increase agricultural yield through the continued transfer of currently unused land or low-productive agricultural land to higher value uses, including tree crops and livestock, and even use for other purposes. The following alternatives have been formulated to preserve/improve soil resources:

(i) To avoid any earth-moving activities in vulnerable land areas, particularly watershed Class 1, to prevent possible soil erosion.

(ii) To utilize currently abandoned lands through the application of appropriate soil quality improvement measures (e.g., drip/trickle irrigation) in the lower part of Petchaburi and the upper part of Prachuap Khirikhan. A combination with an agroforestry application should be considered for successful land transformation to the central amenity zone concept.

(iii) To promote organic farming practices in order to prevent a decrease in soil productivity and to reduce the potential risk of accumulating toxic substances in agricultural crops and direct health effects on farmers.

(3) Water Resources

Improvement of water quality in the major water bodies and the prevention of further water quality deterioration caused by domestic and industrial waste water is a major alternative for water resources. These alternatives associated with water resources are set as follows:

(i) To maintain water quality to set surface water quality standards; periodical monitoring of water quality should be conducted.

(ii) To construct domestic waste water treatment systems in the major riverine municipalities; high priority should be given to the municipalities closest to the major rivers with low water quality.

(iii) To relocate small- and medium-sized industrial establishments into industrial estates/parks equipped with waste water treatment systems.

(iv) To locate newly constructed industrial establishments into industrial estates/parks for the collective waste water and solid waste treatment.

(4) Forest Resources

The following alternatives should be considered for preserving forest resources:

(i) To preserve forests in protected areas, measures to prevent illegal logging should be considered. Preservation of existing forests in the areas having high eco-tourism development potential in Kanchanaburi and Petchaburi provinces should be considered as high-priority areas.

(ii) To preserve existing mangrove forests in coastal areas.

(iii) To replant mangrove forests in coastal areas, particularly in Samut Songkhram and Prachuap Khirikhan provinces.

(5) Solid Waste Management

To improve the sanitary conditions of open dump sites by shifting to sanitary landfill systems, the construction of sanitary landfill solid waste management systems in certain municipalities is required Also, composting should be introduced to reduce solid waste volume and thereafter the beneficial use of wastes through soil productivity improvements should be undertaken.

(6) Environmental Advocacy

Environmental advocacy may enhance public environmental awareness of problems through promotional measures that are practical in local communities. The establishment of an institute with comprehensive environmental monitoring, research, and education functions is recommended in the WSB region.

1.3 *Strategy for Improving the Environment*

1.3.1 Soil Management

Soil degradation problems, including declining soil fertility, soil compaction, soil erosion, and salinization, threaten to become more prominent in the WSB region. Attention should be paid to soil conservation since past programs have rarely been successful. The limited success of past soil conservation projects has been largely due to (i) a lack of support from the government agencies, (ii) immaturity of the social and economic conditions of the farmers, and (iii) difficulty in using conservation techniques or the lack of an expectation of immediate return to the farmers.

Soil improvement measures should be: (i) simple enough for local farmers to apply, (ii) low costs, (iii) used for farm-based projects, and (iv) easily replicable. An introduction of drip irrigation in combination with agroforestry practices would be one promising remedial measure to vitalize once-abandoned problematic land. With the establishment of the drip irrigation system[1], perennial trees having a nitrogen fixing effect would be planted. Vegetable and/or fodder crops would be successfully cultivated when the perennial trees become mature and function as a soil fixer. Appropriate tree species and vegetable and/or fodder crops should be investigated at local research institutes with support from the responsible central agencies. When an application method is established, sufficient explanation should be given to local users so that the system is employed most effectively

Comprehensive land reform projects first commenced more than three decades ago have been successfully implemented in Kanchanaburi, Ratchaburi, Petchaburi, and Prachuap Khirikhan provinces. The projects consist of: (i) investigating appropriate crop cultivation and animal husbandry methods in low fertility lands with limited water supply; (ii) disseminating agricultural techniques to farmers; (iii) providing land plots to landless farmers; (iv) providing financial assistance to farmers; and (v) setting up production-marketing systems. Successful projects have served as dissemination centers for farmers and the public who benefit from the practices.

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[1] A drip irrigation system consists of a network of pipes delivering filtered water containing soluble fertilizers directly to the soil around the crops. The drip irrigation system which can provide a continuous supply of water under relatively low pressure, has the advantage of using 50- 70 per cent less water than the other watering methods (e.g., sprinkler irrigation system). Other advantages of drip irrigation include easy weed control and flexibility in the timing of fertilizer applications in relation to crop growth. Successfully- practiced drip irrigation systems for fruit tree growing on poor soil in northern and southern Thailand have proven to be a promising irrigation method in the WSB region.

It is desirable that additional sites for comprehensive land reform be designated in the WSB region. A target location would be in lower Petchaburi and/or upper Prachuap Khirikhan provinces. Successful application of drip irrigation and agroforestry practices will also help enhance environmental aesthetics in the WSB region.

Another remedial measure worth considering to restore low soil productivity is the introduction of organic farming in unhealthy soils. The organic components of healthy soil, called humus, can be maintained if manure, straw, or other plant wastes are regularly added to the soil. In a field fertilized only with synthetic chemicals, the humus will run off more quickly, carrying away valuable fertilizers. It might be true, if only short-term factors are considered, agriculture based on inorganic fertilizers coupled with herbicides and pesticides is the most productive method available. However, this method does not promote long-term stability, which is more important in order to achieve a sustainable agriculture system for local farmers. It is worth noting that organic farming will reduce the burden on farmers to continuously purchase chemical fertilizers.

Organic farming will also help reduce the potential risk of accumulation of the residues of toxic substances in soils and agricultural produce and eventually the human body. A study conducted by the Thailand Development Research Institute Foundation revealed that farmers using chemical fertilizers have been suffering health risk although the risk was mainly caused by inappropriate use of chemical fertilizers. Composting proposed for a solid waste management system will help produce organic materials to be used in organic farming.

The Ministry of Agriculture and Co-operatives has recently announced its support to farmers for converting from the currently practiced cultivation system that is highly reliant on chemical fertilizers and pesticides in organic systems. Meanwhile, nongovernment organizations (NGOs) working on organic farming have also been promoting organic farming practices. Organic agriculture deals not only with natural and economic aspects but with sociocultural aspects in such a way that natural means to cultivate crops will enhance a positive view of "Mother Nature" as farmers respect the intricate relationship between man and nature that was conceived long ago through traditional values and cultures of indigenous communities in the Kingdom.

Efforts to revamp the agricultural production system from a chemical-dependent system to an organic one will also help boost exports of farm products to developed countries (e.g., European Union) which are indicating that the quality of farm products is the main consideration in their decision to purchase from overseas. Even though the prices of chemical-free organic products would be higher than those of their chemically raised counterparts, the increasing demand for safe and environment-friendly agricultural products would sufficiently offset the higher prices.

1.3.2 Water Quality Improvement

Water quality improvement should be considered for both domestic and industrial waste water treatment. Local initiative for domestic water quality improvement and collective industrial waste water treatment should be considered for the implementation of treatment system operation.

For domestic waste water treatment, the construction of waste water treatment systems in major municipalities is recommended. The first priority for constructing domestic waste water treatment systems should be given to the municipalities of Kanchanaburi, Ratchaburi, and Samut Songkhram as these municipalities are located along the Mae Klong river and waste water discharged from these municipalities is a major source of the deterioration in the river water quality. The central agencies responsible for municipal sewage treatment have completed various stages of studies (e.g., feasibility study, detailed design) for constructing domestic waste water treatment systems in Ban Pong and Potharam in Ratchaburi province, and in Prachuap Khirikhan and Chumphon municipalities; construction of the treatment systems in these municipalities is expected to commence soon. In addition to these completed studies of system construction, the agencies have also been conducting studies of the introduction of domestic waste water treatment systems in Kanchanaburi and Ratchaburi. These positive actions towards water quality improvements should be praised and continuous efforts should be highly encouraged.

In addition to the studies of these two major municipalities along the Mae Klong river, a similar study should be conducted for Samut Songkhram municipality. As the water quality monitoring results indicate, the water near Samut Songkhram municipality is most polluted; immediate action to introduce a treatment system in this municipality is therefore recommended.

Suitable types of waste water treatment systems depend on the availability of land and construction and operation costs. Typical domestic waste water treatment systems suitable for local municipalities in the Kingdom include: (i) oxidation ponds, (ii) aerated lagoons, (iii) extended aeration (including oxidation ditches), and (iv) activated sludge.

Oxidation pond and aerated lagoon systems are land-based treatment methods, generally requiring large areas for the storage and treatment of waste water, for the disposal of effluent when no suitable outlet is available, and for isolation of the site from neighboring land use. The hydraulic and organic loading rates of these systems are commonly based on land area requirements, an approach which provides a convenient way for comparing the various processes. Their advantages over waste water treatment plants (e.g., extended aeration and activated sludge) are their simplicity and, in most cases, their lower capital and operating costs. Because treatment proceeds at a slow rate in land-based systems, applications are restricted to installations where small flows are generated or large land areas are available. Relatively small municipalities in the WSB region are considered to have such conditions. Therefore, municipalities having sufficient land for a treatment system use either the oxidation pond or aerated lagoon system due to their low construction and operation costs.

Extended aeration (i.e., oxidation ditch) or activated sludge systems would be a recommendable alternative for municipalities having limited land but adequate financial sources for system construction and operation; however very few municipalities in the WSB region fall in this category. The major cause of incurred operational costs is the required continuous use of electrical power for rotating paddles or brushes.

Economic and financial viability should also be considered for making domestic waste water systems operational. The financial situations of municipalities in the WSB region are inadequate to construct and operate the treatment systems, necessitating the collection of user charges from potential beneficiaries, households, and commercial establishments. With the recent application of the Polluter Payment Principle (PPP) to local inhabitants, it is now possible to obtain the understanding of the public to pay affordable user charges for the operation of domestic waste water treatment systems. The willingness to pay for the improvement of the environment in some major cities (i.e., parts of Bangkok, Pattaya, and Phuket) has proven that the PPP concept is accepted at least to some extent.

For industrial waste water treatment, installation and operation of a treatment system in industrial establishments should be strictly enforced. Medium- and small-sized industrial establishments that are unable to operate their own treatment systems should consider relocation to industrial estates/parks equipped with central treatment systems accommodating waste water discharged. From the environmental point of view, it is strongly recommended that all newly constructed industrial establishments be located in industrial estates/parks.

1.3.3 Forest Resources Management and Reforestation

Proper management of natural forests controls erosion, stabilizes slopes, moderates streamflows, protects aquatic environments, maintains soil fertility, and preserves wildlife habitats. Poor forest management will cause adverse impacts on soil erosion and siltation, disrupt hydrology resulting in flooding, cause water shortages, degrade aquatic ecosystems, and diminish genetic resources.

Logging in mangrove swamps is particularly destructive both to the forest itself as well as to adjacent areas protected by the mangrove swamps. Mangroves are finely balanced ecosystems quite sensitive to change and also highly productive coastal ecosystems that offer physical protection to the land from the sea (i.e., mangroves stabilize and protect the coast against erosion). These beneficial functions also support the important coastal fisheries in such a way that mangrove forests export a considerable portion of their production to the surrounding waters, largely as a form of leaf fall and other detrital materials that become the base of a detrital food web supporting an array of important commercial finfish and shellfish. These fish typically include mullet, sea trout, crab, and shrimp.

Mitigation measures to conserve forest resources would include: (i) avoiding logging in the rainy season and establishing criteria for logging on slopes and near water and also marking areas that should not be harvested; (ii) supervising logging to reduce damage and encourage rapid regeneration; (iii) restoring land by grading and reseeding disturbed areas; and (iv) observing the established protected forest areas (e.g., national parks and wildlife sanctuaries), ensuring that areas are well-protected by laws and that no illegal encroachment occurs.

Reforestation on degraded land provides a range of environmental benefits and services. Reestablishing forest cover can enrich soil fertility by improving moisture retention, soil structure, and nutrient contents. Establishing forest cover on bare or degraded lands helps reduce runoff of rainwater, regulate stream flow, and improve water quality by reducing sediment inputs into surface waters. Tree replanting can take various forms, including village or community woodlots, and planting on government-owned land or along rights of way. There are few negative environmental impacts associated with such plantings. In fact, the trees provide useful products, as well as environmental and aesthetic benefits. It was observed from the field survey that tree replanting has been widely practiced in the WSB region, particularly in Petchaburi province. Continuous efforts in tree planting are strongly recommended.

Mangrove planting is another issue to be considered. It is recommended that mangrove trees in coastal areas in Prachuap Khirikhan and Samut Songkhram be planted in order to restore the previously rich ecosystem.

Mangrove forest reforestation has been observed in Samut Songkhram and Prachuap Khirikhan provinces. Coastal mangrove forests in Samut Songkhram were replaced with fast-cash-earning shrimp cultivation, but the shrimp fields were eventually abandoned due to a crash in shrimp prices, known as the Ban Khkong Khon disaster in the early 1990s. The degraded area near the shrimp fields in Ban Khkong Khon was chosen for a mangrove reforestation experiment and the devastated areas were soon rejuvenated. As a result of the planting of number of mangrove trees, fish resources are increasing and siltation and erosion have been improved. This mangrove reforestation project has been supported by about 500 local families who wish to restore the ecological balance in the area. The planting has been successfully completed on about 1,000 rai of planned total planting area of 1,200 rai.[1] Financial and technical support for this mangrove reforestation project and possible expansion of the reforestation area are urged. Recommended reforestation areas would be chosen based on a careful field investigation to be jointly conducted by local research institutes and central supervising agencies.

Some mangrove reforestation programs are also ongoing in Prachuap Khirikhan province, mostly in the inner coastline in order to protect juvenile mangrove trees from seasonal storms and/or tidal contamination mainly originated in the upper provinces. On the condition of countermeasures for contaminated water, planting mangrove trees in the coastal areas is recommended. Site selection for planting should consider that mangroves can be most effectively established in areas where a lack of wave action allows fine sediment or mud to accumulate.

A mangrove forest reforestation plan was put forward by the Royal Forestry Department (RFD) in 1994 and the plan aims to plant a total area of 1,248 hectares in Petchaburi, Prachuap Khirikhan, and Chumphon provinces. No reforestation plan was included for Samut Songkhram province at the time, while experimental activities in the province are underway, as mentioned.

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[1] 1 rai = 1,600 m^2

1.3.4 Solid Waste Management

Municipal dumps are located in low-lying areas near watercourses in the WSB region. The unsanitary condition of dumping sites and unavailability of future land for the sites are major constraints on solid waste management. Remedial measures addressing the solid waste problems are two-fold: improvement of sanitary conditions and waste volume reduction.

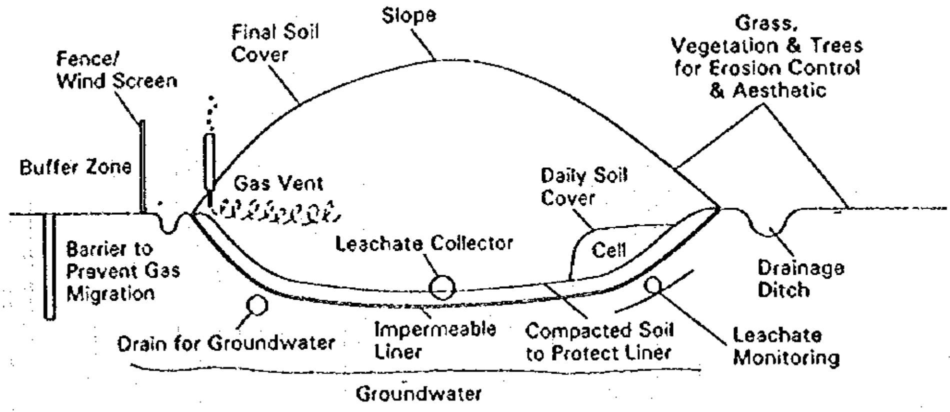
Visual results of unsanitary open dumps are fire, water contamination, offensive odors, rats, flies, and blowing paper. Burial of the waste would reduce these problems, but the greatest improvement can be obtained by compacting the waste in layers and covering it with earth. This treatment method, called sanitary landfill, has been practiced in some municipalities (e.g., Phuket) in the Kingdom. A gradual shift from the currently practiced open dump method to sanitary landfill should be considered and undertaken.

The central supervising agencies (e.g., OEPP and PCD) initiate the improvement of solid waste management systems, and feasibility studies of sanitary landfill for some municipalities in the WSB region will be commenced shortly. It is recommended that densely populated municipalities in the WSB region be equipped with sanitary landfill systems in order to avoid the unnecessary sanitary risks associated with poor solid waste management. Provision of sanitary landfill systems will ensure a great reduction in the problems mentioned.

Some recommendations are presented on ideal sanitary landfill site selection. In general, the site should be inexpensive within economical hauling distance, have year-round access, and be located at least 2,000 m downwind of residential and commercial neighbors. The area should be reasonably clear, level, and well drained, with capacity for not less than about three-year's use until its future role as "open" space is realized. Soil of low permeability, well above the groundwater table, is also desirable for protection of underground water suppliers and as cover material. Final choice of the site should not be made without a detailed hydrogeological investigation.

It is recommended that during Phase I (1997-2001) a sanitary landfill system with its capacity of about 50 tons/day be established in six major WSB municipalities (i.e., Samut Songkhram, Kanchanaburi, Petchaburi, Ratchaburi, Prachuap Khirikhan, and Chumphon). An immediate action plan should be drafted in consultation with NESDB, OEPP, and PCD.

A schematic drawing of a recommendable sanitary landfill system is shown below.



To address the scarcity of land on which to put solid waste, chemical processes (e.g., fluidized bed incineration, pyrolysis, and wet oxidation) and biological processes (e.g., composting and anaerobic digestion) are potential methods for reducing municipal waste volumes and/or converting the waste to useful products. Among these potential waste volume reduction methods, composting would be the most viable option to be applied in the municipalities of the WSB region. The objective of composting is to convert easily degraded organics into humus and produce a nutrient-rich, stable product useful for reclaiming land or improving soil. Through the composting process, organic waste may be partially decomposed by bacteria, worms, and other living organisms, and valuable fertilizers and soil conditioners can be produced. Almost any plant or animal matter, such as food scraps, old newspaper, straw, sawdust, leaves, and grass clippings, will form a satisfactory base for a composting operation. Composed sewage sludge represents a valuable soil conditioner that can be used to increase the humus content of soils, as well as produce fodder for livestock raising. As composting is a waste-recycling technique with many beneficial functions, introduction of composting is highly recommended.

Composting may take place naturally under controlled conditions or in mechanized composting plants. In natural systems, ground garbage, preferably with glass and metals removed, is mixed with a nutrient source (e.g., animal manure, night soil, and sewage sludge) and a filler (e.g., wood chips, ground corn cobs) that permits air to enter the pile. The mixture is placed in wind rows, typically 2-3 meters wide, and turned over once or twice a week. In four to six weeks, depending on atmospheric temperature, when the color darkens, the temperature drops, and a musty odor develops, the process is complete. After the completion of the process, the filler may then be removed and the remaining humus used as soil conditioner. With mechanical plants, continual aeration and mixing enable composting time to be reduced by about 50 per cent. A short period usually follows the mechanical process to allow the composting material to mature.

The study has revealed that solid waste generated in the central amenity zone municipalities/sanitary districts ranged from 2 to 41 tons per day in 1996, having the largest volume of 41 tons per day in Hua Hin municipality. To cope with the increasing concern of clearing up beach resorts (Cha Am and Hua Hin) and the proposed Science City Development project, it is recommended that a composting plant be established in Cha Am/Hua Hin and the Science City. It can be reasonably estimated that dairy solid waste generated in Cha Am/Hua and the Science City is about 50 tons. It can be, therefore, recommended that a composting plant with its capacity of 50 tons per day be established in the area. A feasibility study determining the appropriate capacity and investment cost should be conducted during Phase I, and plant construction should be started in Phase II (2002-06). An action plan of setting up the composting plants should be drafted and consulted with concerned agencies (i.e., OEPP and PCD).

Industrial hazardous waste disposal generated from industrial establishments has become a subject of considerable concern in the WSB region as the number of industrial establishments using hazardous materials is growing. The hazardous wastes causing greatest concern are heavy metals dissolved in waste water. Although there is no clear evidence of problems associated with heavy metals, their concentrations should be carefully monitored, particularly groundwater underlying major industrial plants. Industrial plants potentially generating these type of wastes should be located in industrial estates/parks and a treatment system should be installed in the estates/parks in order to prevent unnecessary environmental problems. To deal with an increasing volume of industrial hazardous waste, the Department of Industrial Works (DIW) of the Ministry of Industry has established a waste treatment plant in Ratchaburi province that has been operational since the early 1990s. An increase in its treatment capacity or the setting up additional plants to facilitate future increases in hazardous wastes in the WSB region will be required. The Bang Saphan Industrial Estate Study proposed establishment of an industrial hazardous waste treatment system in the Bang Saphan area.[1]

To deal with the considerable volume of coal fly ash to be produced by IPPs in the Lower WSB, fly ash reuse/recycling is a matter of concern. As evidenced in lignite fly ash dumping site at Mae Moh, Lamphan province, the accumulated volume of coal fly ash will be another kind of solid waste problem. One possible solution is to utilize coal fly ash

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[1] Reference is made to the Feasibility Study on the Bang Saphan Industrial Estate by IEAT/JICA, January 1997.

as a component of construction materials (e.g., cement) or other beneficial uses. One possibility is to produce "environment-friendly cement" by using fly ash. Although careful examination of the chemical composition of fly ash is required, it is likely that fly ash could be used for the cement material. The produced cement could also be used for the composition of concrete blocks as a form of artificial reefs for the rehabilitation of coastal fisheries. It is recommended to carry out a study examining the possibility of applying fly ash for the above mentioned purposes.

1.3.5 Environmental Advocacy

Enhancement of public environmental awareness may play a significant role in improving living conditions. Achievement of effective environmental improvements will only be made with the understanding and support of local inhabitants.

Promotional activities would most likely be conducted through (i) educational institutions at various levels, (ii) mass media (e.g., participatory radio and television and newsletters), and (iii) public gathering places (e.g., the posting of promotional materials and the organizing of advocacy meetings).

Through formal education systems, various levels of educational institutions could be involved in enhancing natural resources conservation and environmental quality improvements. Up to the upper secondary level, emphasis on environmental benefits enhanced by personal hygiene is encouraged. At the university level, in environmental sciences, environmental engineering, environmental management, and teacher education for environmental education is recommended. As the country's three largest universities (Chulalongkorn, Mahidol, and Kasersart) all are located in Bangkok and have large faculties and research outputs, it is recommended the results of this research be transferred to local research institutes through the exchange of faculty in order to strengthen academic research in local institutes in the field of environmental studies. This kind of interuniversity exchange can also be enhanced through the Internet system.

Through nonformal educational systems, active use of mass-media and public gathering places can be an effective means of environmental advocacy. Close coordination with NGOs is recommended for the effective use of the nonformal educational systems.

Another effective means of enhancing environmental awareness is to establish an region-based environmental monitoring, research and training center. The center would have the functions of (i) environmental monitoring supported by measurement instruments; (ii) research base for challenging new approaches to drip irrigation; agroforestry, and organic farming that would be applicable to the WSB region; and (iii) the provision of environmental education in the fields of waste management, natural resources conservation, and environmental aesthetics for local government officials, tourism-engaged staff, national park rangers, and NGO staff. The center would be located in the Science City within the proposed central amenity zone of the WSB region.

Some examples of environmental advocacy through the nonformal education systems include (i) to organize nature exploration tours for local people in order to enhance their understanding of importance of natural forests and associated environment, (ii) to organize waste water treatment plants and reforestation (including mangrove forests) sites visiting tours for better understanding of ongoing environmental improvement activities, and (iii) to set up nature exhibition centers at appropriate locations (e.g., near dam sites and reservoirs). As proposed in tourism sector recommended measures, the third example would help local people understand the importance of water management for efficient water use, natural disaster prevention, and even power generation.

These environmental advocacy activities would be achieved by close cooperation among NGOs, local educational institutes, and supervising agencies. In addition, proposed Environmental Monitoring, Research and Training Center would also be of great assistance for enhancing region-based environmental advocacy.

1.3.6 Environmental Monitoring

An environmental monitoring system suitable for the WSB region should be established. An effective monitoring system carefully watching the environment will be realized by a combination of the direct involvement of local people and supervision of the central agencies. Learning/training of actual environmental monitoring will be attained through the Environmental Monitoring, Research and Training Center proposed to be setup at the Science City. Prototype of the center is attributed to the JICA-assisted Environmental Research and Training Center (ERTC) in Pathumthani province. Since its establishment in 1991, ERTC has been providing high quality training in various environmental monitoring fields (e.g., water quality, air quality, noise and vibration, and soil quality). It is recommended that environmental monitoring know-how accumulated at ERTC be utilized for the region-based monitoring system establishment in the WSB region. It is also recommended that forest and wildlife management be added for more suitable monitoring system in the region. In order to make the environmental monitoring successful, it is essential that central agencies supervise the monitoring system and provide necessary advice. The supervising agencies will include DA for soil quality, OEPP, PCD and DIW for water quality, OEPP and PCD for air quality, OEPP and PCD for solid waste management, RFD and OEPP for forest resource conservation, and OEPP for noise level monitoring. In addition, DEQP is also expected to provide any necessary advice through its supervising ERTC to proposed region-based Environmental Monitoring, Research and Training Center.

1.4 Environmental Sector Projects

The following environmental sector projects have been identified through a series of field investigations and close communication with central and provincial government agencies, research institutes, private and nongovernmental organizations.

(1) Organic Farming for Environment-Friendly Agriculture

To improve soil productivity of unhealthy soil and to reduce the potential risk associated with excessive use of chemical substances, it is proposed to promote organic farming practices in the WSB region. The promotion program could be combined with the rehabilitation of problematic land, the program for promoting livestock raising, and the program for setting up a composting plant for solid waste disposal if it is evaluated to be viable.

(2) Promotion of Mangrove Reforestation

The current mangrove reforestation plan of RFD in Petchaburi, Prachuap Khirikhan, and Chumphon provinces has encouraged expansion of reforestation areas. Furthermore, it is proposed to take up reforestation preparation in Samut Songkram province, where a vast mangrove forests were cut for shrimp farming. Currently ongoing mangrove planting in coastal area near Samut Songkram municipality should be praised and an expansion of the planting area should be implemented.

Beneficial use of destroyed mangrove forest areas currently abandoned after use of shrimp farming in Prachuap Khirikhan and Samut Songkram provinces will also be proposed (e.g., use for aquaculture development projects, and for an environment-friendly free trade zone and recreational areas).

(3) Promotion of Domestic Waste Water Treatment

The program proposes to install domestic waste water treatment plants in major municipalities located on the banks of the principal river systems in the WSB region. The priority of plant installation will be accorded to the municipalities of Kanchanaburi, Petchaburi, and Samut Songkhram as these municipalities are located along the Mae Klong river and untreated waste water are discharged into the river. Oxidation ponds or aerated lagoons would be a recommendable treatment method due to its low construction and operation costs.

(4) Promotion of Solid Waste and Hazardous Waste Management

The proposed approach to solid waste disposal management will consist of two principal programs: (i) to promote sanitary landfill instead of unsanitary open dumps currently practiced, and (ii) to demonstrate and promote a composting plant for waste-recycling (reusing organic wastes for soil improvements and/or animal fodder). The composting plant is proposed to be established in the central amenity zone where existing resort areas (i.e., Cha Am and Hua Hin) are located and a newly proposed Science City will be developed.

(5) Environmental Monitoring, Research, and Training Center

To enhance environmental awareness, the establishment of an environmental monitoring, research, and training center in the Science City within the central amenity zone is proposed. The center would have the functions of (i) environmental monitoring supported by measurement instruments, (ii) research base for land rehabilitation, agroforestry, and organic farming, and (iii) environmental education in the fields of water and solid waste management, natural resources conservation, and environmental aesthetics.

Table 9.1.1 Water Quality at Selected Sampling Stations

Name of River	Sampling Location	DO	BOD	Faecal Coliform
Mae Klong	Kanchanaburi (1)	6.5	1.2	900
Mae Klong	Kanchanaburi (2)	6.6	1.2	4,800
Mae Klong	Kanchanaburi (3)	6.4	1.5	3,500
Mae Klong	Kanchanaburi (4)	6.0	1.0	800
Mae Klong	Ratchaburi (1)	5.6	1.2	10,000
Mae Klong	Ratchaburi (2)	5.4	1 2	32,000
Mae Klong	Ratchaburi (3)	5.4	1.1	15,000
Mae Klong	Ratchaburi (4)	5.4	1.1	15,000
Mae Klong	Samut Songkhram (1)	5.3	1.2	23,000
Mae Klong	Samut Songkhram (2)	5.1	1.3	15,000
Mae Klong	Samut Songkhram (3)	4.9	1.4	4,600
Petchaburi	Petchaburi	n/a	1.2	n/a
Pranburi	Pranburi	n/a	1.3	n/a
Lang Suan	Lang Suan	n/a	1.3	n/a

Unit: DO (mg/l),BOD (mg/l), Faecal Coliform (MPN/100ml)
Source: The Department of Public Health (1995)

Table 9.1.2 Surface Water Quality Standards

Parameters	Units	Standards for class***				
		1	2	3	4	5
Temperature	C	n	n'	n'	n'	-
pH		n	5 - 9	5 - 9	5 - 9	-
Dissolved Oxygen	mg/l	n	6	4	2	-
BOD (5 days, 20C)	mg/l	n	1.5	2.0	4.0	-
Coliform bacteria						
-Total coliform	MPN/100ml	-	5,000	20,000	20,000	-
-Fecal coliform	MPN/100ml	-	1,000	4,000	4,000	-
NO_3-N	mg/l	n	5.0	5.0	5.0	-
NH_3-N	mg/l	n	0.5	0.5	0.5	-
Phenol	mg/l	n	0.005	0.005	0.005	-
Cu	mg/l	n	0.1	0.1	0.1	-
Ni	mg/l	n	0.1	0.1	0.1	-
Mn	mg/l	n	1.0	1.0	1.0	-
An	mg/l	n	1.0	1.0	1.0	-
Cd	mg/l	n	0.005*	0.05**	0.05**	-
Cr (hexavalent)	mg/l	n	0.05	0.05	0.05	-
Pb	mg/l	n	0.05	0.05	0.05	-
Hg (total)	mg/l	n	0.002	0.002	0.002	-
As	mg/l	n	0.01	0.01	0.01	-
CN	mg/l	n	0.005	0.005	0.005	-
Radioactivity						
-Gross alpha	Becquerel/l	n	0.1	0.1	0.1	-
-Gross beta	Becquerel/l	n	1.0	1.0	1.0	-
Pesticides (total)	mg/l	n	0.05	0.05	0.05	-
-DDT	micro.g/l	n	1.0	1.0	1.0	-
-Alpha BHC	micro.g/l	n	0.02	0.02	0.02	-
-Dieldrin	micro.g/l	n	0.1	0.1	0.1	-
-Aldrin	micro.g/l	n	0.1	0.1	0.1	-
-Heptachlor	micro.g/l	n	0.2	0.2	0.2	-
-Endrin	micro.g/l	n	None	None	None	-

Note: n = natural condition
n' = natural condition but changing not more than 3 C
* = water hardness not more than 100 mg/l as $CaCo_3$
* = water hardness more than 100 mg/l as $CaCO_3$
*** = Water Classification

Source: The Water Quality Control Division, The Department of Pollution Control, The Ministry of Science, Technology and Environment, 1986.

Table 9.1.3 Classification of Water Conditions

Classifications	Water Conditions	Objectives
Class 1	Extra clean	(1) Drinking water (require only ordinary sterilizing process) (2) Ecosystem conservation which basic living organisms can spread breeding naturally
Class 2	Very clean	(1) Drinking water (require the ordinary water treatment process) (2) Aquatic organism conservation for living and assisting for fishery (3) Fishery (4) Recreation
Class 3	Medium clean	(1) Drinking water (the ordinary water treatment process is mandatory) (2) Agriculture
Class 4	Fairly clean	(1) Drinking water (the special water treatment process is mandatory) (2) Industry (3) Other activities
Class 5	Other than above	(1) Navigation

Source: The Water Quality Management Division, The Pollution Control Department, The Ministry of Science, Technology and Environment, 1986.

APPENDIX I To Chapter 1

PROFILES OF PROPOSED PROJECTS/PROGRAMS

Project No. EV1

1. PROJECT TITLE: Organic Farming for Environment-Friendly Agriculture

2. LOCATION: WSB Areawide

3. AGENCY: Department of Agriculture, Department of Agriculture, Department of Agricultural Land Reform

4. OBJECTIVE:

(1) To improve low soil productivity

(2) To reduce the potential risk of accumulation of residues of toxic substances in agricultural crops

(3) To protect farmers' health from excessive use of chemical fertilizers and pesticides

(4) To promote organically grown produce for domestic consumption and experts

5. PHASING: Pilot site selection, organic farming application, and promotion of organic products will be carried out during Phase I (1997-2001) and Phase II (2002-2006).

6. PROJECT DESCRIPTION:

Excessive use of chemical fertilizers and pesticides has reduced soil productivity and also increased the potential risk of accumulation of residues of toxic substances in agricultural crops and direct health effects on farmers.

To improve the soil productivity of degraded land and to reduce the potential risks associated with the use of chemical substances, it is proposed to promote organically grown products especially on land with low soil productivity in the WSB region. The promotion program will be combined with the rehabilitation of problematic land, the program for promotion of livestock raising, and with the program for setting up a composting plant for solid waste volume reduction and recycling.

7. RELATION WITH OTHER PROJECTS: EV5 (Environmental Monitoring, Research, and Training Center)

8. COST (APPROX.): Phase I: US$ 6 Million
Phase II: US$10 Million

Project No. EV2

1. PROJECT TITLE: Promotion of Mangrove Reforestation

2. LOCATION: Coastal Areas of Samut Songkram and Prachuap Khirikhan provinces

3. AGENCY: Royal Forest Department

4. OBJECTIVES: (1) To support currently ongoing mangrove reforestation projects

(2) To newly plant mangrove forests near coastal areas

5. PHASING: Phase I: Study of identification of currently ongoing mangrove reforestation projects and finding a possibility of the area expansion and new planting site selection

Phase II: Mangrove planting in new sites

6. PROJECT DESCRIPTION:

It is proposed to take up mangrove reforestation programs in Samut Songkhram province where a vast area of land previously used for shrimp cultivation has been abandoned. The mangrove reforestation program will target the coastal area in Samut Songkhram, while the abandoned shrimp fields will be utilized for establishment of an environment-friendly free trade area or recreational area. Mangrove reforestation will also be implemented in the coastal area in Prachuap Khirikhan, together with aquaculture development projects having appropriate waste treatment facilities.

7. RELATION WITH OTHER PROJECTS: Not Applicable

8. COST (APPROX.): Phase I: US$ 3 Million
Phase II: US$ 32 Million

Project No. EV3

1. PROJECT TITLE: Domestic Waste Water Treatment

2. LOCATION: Major Municipalities in the WSB region

3. AGENCY: Office of Environmental Policy and Planning, Pollution Control Department

4. OBJECTIVES:

(1) To manage and control domestic waste water discharged from households and commercial establishments

(2) To improve water quality of major rivers for the betterment of inhabitants' water use

(3) To improve sanitary conditions of the municipalities

5. PHASING:

Phase I: Based on feasibility study and detailed design, domestic waste water treatment facility construction and operation in the three high priority municipalities (i.e., Samut Songkhram, Kanchanaburi, and Ratchaburi)

Phase II: Facility construction and operation in the other major WSB municipalities

6. PROJECT DESCRIPTION:

It is proposed to install domestic waste water treatment plants in the major municipalities that are located on the banks of the principal river systems in the WSB region. Priority for installation should be accorded to the municipalities of Kanchanaburi, Ratchaburi, and Samut Songkhram as these municipalities are located along the Mae Klong river and waste water is discharged into the river without treatment.

Oxidation pond or aerated lagoon would be a recommendable system for WSB municipalities due to its low construction and operation costs.

It is assumed that an aerated lagoon system with its daily treatment capacity of about 10,000 m^3 be established in Kanchanaburi, Ratchaburi, and Samut Songkhram municipalities during Phase I, and in the other five municipalities during Phase II.

7. RELATION WITH OTHER PROJECTS: Not Applicable

8. COST (APPROX.):

Phase I: US$ 96 Million
Phase II: US$ 160 Million

Project No. EV4

1. PROJECT TITLE: Solid Waste and Hazardous Waste Management

2. LOCATION: Major Municipalities and Industrial Estates

3. AGENCY: Office of Environmental Policy and Planning, Pollution Control Department, Department of Industrial Works, and IEAT

4. OBJECTIVES:

(1) To improve sanitary conditions of municipalities

(2) To prevent possible toxic/hazardous waste intrusion into nearby waters

(3) To reduce waste volume and utilize waste for soil improvement and animal fodder.

5. PHASING:

Phase I: Improvement from open dumps to sanitary landfill

Phase II: Establishment of composting plants

6. PROJECT DESCRIPTION:

The proposal for solid waste management consists of two principal programs; one is to promote sanitary landfill instead of open dumps, while the other is to demonstrate and promote a composting plant for waste-recycling and production of organic materials for soil improvement and animal fodder. The composting plant is proposed first to be set up in the central amenity zone where resort areas (Cha Am and Hua Hin) are located and development of a Science City is newly proposed.

It is assumed that during Phase I a sanitary landfill system with a capacity of about 50 tons/day be established in six major WSB municipalities (i.e., Samut Songkhram, Kanchanaburi, Phetchaburi, Ratchaburi, Prachuap Khirikhan, and Chumphon), and during Phase II a composting plant with a capacity of about 50 tons/day be constructed in the Central WSB.

In addition to solid waste, industrial hazardous wastes will be managed by the panned hazardous waste treatment system in the Bang Saphan Industrial Estate.

7. RELATION WITH OTHER PROJECTS: Not Applicable

8. COST (APPROX.):

Phase I: US$ 96 Million
Phase II: US$ 35 Million

Project No. EV5

1. PROJECT TITLE:	Environmental Monitoring, Research and Training Center
2. LOCATION:	Science City in the Central Amenity Zone
3. AGENCY:	Department of Environmental Quality Promotion, Pollution Control Department
4. OBJECTIVES:	(1) To set up region-based environmental monitoring system with analysis equipment (2) To collect and update environmental information for research and other beneficial purposes (3) To provide environmental training and education in the various fields
5. PHASING:	Phase I: Basic study and plan formulation Phase II: Center construction and operation

6. PROJECT DESCRIPTION:

In parallel with the environmental advocacy programs to be promoted in the WSB region, it is proposed to set up an environmental monitoring, research, and training center in the science city proposed in the central amenity zone. The center would have the functions of (i) environmental monitoring supported by measurement instruments, (ii) research base for challenging new approaches to drip irrigation, agroforestry, and organic farming that would be applicable to the WSB region, and (iii) the provision of environmental education in the fields of waste management, natural resource conservation, and environmental aesthetics.

7. RELATION WITH OTHER PROJECTS:	EV1	(Organic Farming for Environment-Friendly Agriculture)
	EP1	(Cooking Stove Dissemination)
	EP2	(Energy Substitution)

8. COST (APPROX.):	Phase I: US$ 3 Million Phase II: US$ 80 Million

Chapter 2 WATER RESOURCES

2.1 *Background*

2.1.1 National Water Resource Development Policy

Water resources development and management in Thailand is entering into an advanced stage characterized by demand-side management as well as supply-side expansion. Although the planning, development, and management of various water related facilities is still conducted largely by sector such as irrigation, hydropower, and water supply, the allocation of limited water resources reflects increasingly a viewpoint of river basins for overall efficiency and as an eco-system for environmental soundness. The establishment of the National Water Resources Board under NESDB in 1983 represents an early action taken along this line.

The 8th Plan has re-defined the emphasis of national development to account explicitly for human-centered and socially-oriented development. One of the central ideas is to pursue holistic development on the balance among different sectors, regions, and segments of the society to ensure improved quality of life for individuals, and sustainable development and international competitiveness for the Kingdom. A holistic or comprehensive river basin approach is naturally an important part of this strategy.

Specifically, the 8th Plan proposes that water resources development "establish systematic management of water resources, especially at the river basin level, including the provision of clean drinking water and supervision of water quality, pollution control and drainage." This will be supported by (i) establishment of supervisory and coordinating mechanisms for water resources development at national and river basin levels, (ii) wide participation by agencies, local governments and people for water allocation, (iii) user charges for water supply and wastewater treatment, (iv) improvement of water delivery systems, and (v) a public information campaign to promote more effective water use and water saving.

The 8th Plan aims at establishment of international competitiveness of the Thai economy and proposes broad measures for infrastructure development to improve quality of life and efficiency in production. Measures related to water are (i) development of water resources consistent with basin potentials and eco-system preservation, (ii) public-private coordination for management and maintenance of existing water resources for full utilization, (iii) support for private sector investment in waterworks for regional urban areas, (iv) reduction of the average water loss ratio through efficient management, (v) differential water pricing, (vi) public awareness campaign together with incentive measures for water-saving, and (vii) establishment of a central agency for water resources development.

The 8th Plan also sets specific targets to protect water quality as part of quality of life of individuals and communities. It prescribes to "ensure that water quality does not fall below 1996 standards in rivers, seas, coastal areas and all natural water resources, with particular emphasis on the lower Chao Phraya River, the Tha Chin River, pollution control zones and major tourist destinations." The Plan also dictates to "formulate pollution control plans for 25 major river basins around the country."

2.1.2 Water Related Agencies

For many years, government efforts for water resources development and management have been undertaken a large number of agencies in charge of different aspects. At present, a total of 35 agencies under eight ministries are involved in water resources development and management. Of these agencies, 16 have been implementing water-related projects. Major agencies involved in different subsectors are the Royal Irrigation Department (RID) for irrigation, the Electricity Generating Authority of Thailand (EGAT), the National Energy Administration (NEA), and the Provincial Electricity Authority (PEA) for hydropower generation and delivery, the Department of Mineral Resources for groundwater exploration, and the Metropolitan Waterworks Authority (MWA) and the Provincial Waterworks Authority (PWA) for domestic water supply.

Implementing arrangements differ for large, medium, and small-scale water resources development projects. Definitions of and involvement of main entities in projects of different scale are outlined in the following subsection:

(1) Large-Scale Projects

Large-scale water resource development projects have been implemented by two responsible agencies, the Royal Irrigation Department (RID) under the Ministry of Agriculture and Co-operatives (MOAC) and the Electricity Generating Authority of Thailand (EGAT) under the Office of Prime Minister (OPM). RID has been directly involved in project planning, design, implementation, and maintenance services to meet water requirements for irrigation of agricultural land and other water demand sectors, including expansion of urban and industrial areas. The definition of large-scale projects is as follows:

- Construction costs, over Baht 200 million;
- Storage volume, over 100 million m^3 (MCM);
- Water surface area, over 15 km^2;
- Irrigable area, over 90,000 rai; and
- Construction period, over five years

(2) Medium-Scale Projects

Medium-scale projects are defined as follows:

- Construction cost, from Baht 4 to 200 million;
- Storage volume, from 10 to 100 million m^3 and;
- Construction period, from one to five years.

RID is responsible for irrigation canal system implementation from water intake (at dams, diversion work, and pumping stations on river banks) to water distribution offtake. Planning and implementation of medium-scale projects involve three agencies: RID, the Office of Accelerated Rural Development (ARD) under the Ministry of Interior (MOI), and the Department of Energy Development and Promotion (DEDP) under the Ministry of Science, Technology and the Environment (MSTE).

(3) Small-Scale Projects

Small-scale projects are those with construction costs smaller than 4 million Baht and construction periods shorter than one year. These schemes involve water harvesting management in small valleys and community areas for domestic and supplemental irrigation purposes; they are initiated typically by village peoples through consensus, supported by technical and financial assistance from the 16 agencies involved in water resource development projects, including groundwater exploitation.

2.1.3 Basin System and Main Rivers

The WSB is divided into four main river basins: (i) the Mae Klong river basin, which includes part of Kanchanaburi, Ratchaburi, and Samut Songkhram provinces; (ii) the Petchaburi river basin largely coinciding with the boundaries of Petchaburi province; (iii) the Western coast river basin in Prachuap Khirikhan province; and (iv) the Southeastern coast river basin, covering most part of Chumphon province (Refer to Figure 9.2.1).

Of the entire Mae Klong river basin covering 30,800 km^2 with 14 sub-basins, about a half or 15,500 km^2 falls in the Study Area. The lower Mae Klong river basin within the Study Area consists of five sub-basins: (i) the lower part of Mae Nam Khwae Yai (4,100 km^2), (ii) the lower part of Mae Nam Khwae Noi (2,000 km^2), (iii) Huai Taphpen (2,600 km^2), (iv) Lam Pa Chi (2,500 km^2), and (v) the Mae Nam Mae Klong Plain Area (4,300 km^2).

The Petchaburi river basin, located just south of the lower Mae Klong river basin, has an area of 5,603 km^2, consisting of four sub-basins: (i) the Upper Petchaburi (2,210 m^2), (ii) the Middle Petchaburi (1,328 km^2), (iii) the Lower Petchaburi (1,027 km^2), and (iv) the Petchaburi Coast (1,042 km^2). The area of this river basin coincides largely with Petchaburi province. The western area of the river basin features a mountain range about 1,000 to 1,500 m above sea level along the international border with Myanmar.

The Western coast river basin, located just south of the Petchaburi river basin, covers 7,100 km^2 and encompasses four basins: (i) the Pranburi (2,900 km^2); (ii) the upper part of the Prachuap Khirikhan coast (1,400 km^2); (iii) the middle part of the Prachuap Khirikhan coast (1,600 km^2); and (iv) the lower part of the Prachuap Khirikhan coast (1,200 km^2). The Western coast river basin extends 200 km north to south and 15-70 km west to east.

The Southeastern coast river basin, located in the southern part of the WSB region, covers about 6,700 km^2 and include three sub-basins: (i) Khlong Ta Taphrao basin (2,230 km^2), (ii) the upper part of the Southeastern coast basin (2,840 km^2), and (iii) Khlong Lang Suan basin (1,650 km^2), all within Chumphon province. This narrow basin extends 150 km from north to south and 60 km from west to east. The western part of the basin is mountainous, 500 to 1000 m above sea level.

2.1.4 Rainfall and Runoffs

(1) Rainfall

Annual precipitation is high in the mountainous areas in the north and also the southern-most part of the WSB, exceeding 2,000 mm, and low in the central part, especially along the coast, around 1,000 mm or even lower. The mean annual rainfall varies within each of the main river basins. In the Mae Klong river basin, it varies from 1,100 mm in the lower basin to 2,200 mm in the upper basin (Refer to Figure 9.2.2). The annual rainfall in the Petchaburi river basin (Refer to Figure 9.2.3) and the upper part of the Western coast basin ranges from 1,200 mm along the border with Myanmar to less than 1,000 mm in the coastal area. In the lower part of the Western coast basin, the annual rainfall increases toward the south up to 1,400 mm (refer to Figure 9.2.4) The annual rainfall in the Southeastern coast basin ranges from 1,500 mm in the north to 2,400 mm along the mountain range in the south.

Seasonal variation of rainfall is significant throughout the WSB. In the Upper WSB, 90 per cent or more of the annual rainfall occurs during the rainy season between May and November, with the peak usually in September. The peak of rainfall tends to come later toward the south: usually October in the Central WSB and November in the Lower WSB. The seasonal variation is less pronounced in the Lower WSB, and about 60 per cent of the annual rainfall occurs in May-November.

(2) Runoff

Runoff patterns are affected not only by rainfall patterns but also by other factors such as topography, vegetation, soil types, and land use. The runoff coefficient is extremely low in the Petchaburi river basin and the Western coast river basin due mainly to low precipitation, short and steep river morphology, and soil conditions. A typical runoff coefficient is 25 per cent in the Petchaburi river basin and 20 per cent in the Western coast river basin. The runoff coefficient in the Mae Klong river basin and the Southeastern coast river basin is in the range of 30-60 per cent.

Seasonal variation of unregulated runoff is the largest in the Southeastern coast river basin and the smallest in the Western coast river basin. For instance, the 80 per cent dependable monthly flow is less than 20 per cent of the average monthly flow in the Southeastern coast river-basin, in the range of 20-25 per cent in the Mae Klong river basin, and about 25 per cent in the Western coast river basin.

2.1.5 Issues for Water Resources Development and Management

The WSB region is about 450 km long from north to south and has an international border with Myanmar at the watershed. Prachuap Khirikhan province is particularly narrow, only about 20 km wide at its narrowest part. The river basin system of the WSB, therefore, is characterized by comparatively small basins except for that of the Mae Klong river. The longitudinal profile of the small rivers is characterized by the steep gradient and short distance from the upper watershed in the west to the seacoast in the east.

The WSB region receives 900-2,400 mm of annual rainfall on an average. However, 80-90 per cent of this annual rainfall generally occurs from May to October during the rainy season. Due to this extreme concentration of rainfall in six months, soil erosion and other flooding, and other problems occur during the rainy season, while some areas face water shortages in the dry season.

Considering the region's natural hydrological cycle and the local topography and soil conditions, the strategy for regional water resource development focuses on conservation utilizing modern scientific technology and engineering methods in combination with sound agro-ecological practices following the national policy. Water resources in the WSB are limited and development costs are increasing, particularly since project costs must now cover not only direct costs, but also land acquisition costs and compensation for property damage in the project area, as well as costs required for resource protection and conservation, as identified through environmental impact assessments (EIAs).

Water requirements for agricultural crop production, including irrigated paddy and upland crops, vary seasonally as well as with various climatic conditions such as temperature, sunshine duration, and evapotranspiration. From the viewpoint of water resource conservation, irrigation water use should be minimized through water saving efforts; alternative irrigation practices, such as the use of sprinkler and drip systems for cash crops during the dry season may offer viable options. Particular attention should be paid to land degradation caused by an increase in soil salinity as a result of water logging caused by irrigation of upland crops during the dry season. It is reported that an area of about 182 million rai has acid soil and soil salinity problem, and about 107 million rai is affected by soil erosion in the Kingdom.

Water pollution is related to discharges from domestic sewerage and industrial plants, as well as to pesticide contamination to river water and also groundwater. Increased use of fertilizer to enhance agricultural productivity is another source of non-point pollution.

2.2 *Existing Conditions and Plan by River Basin*

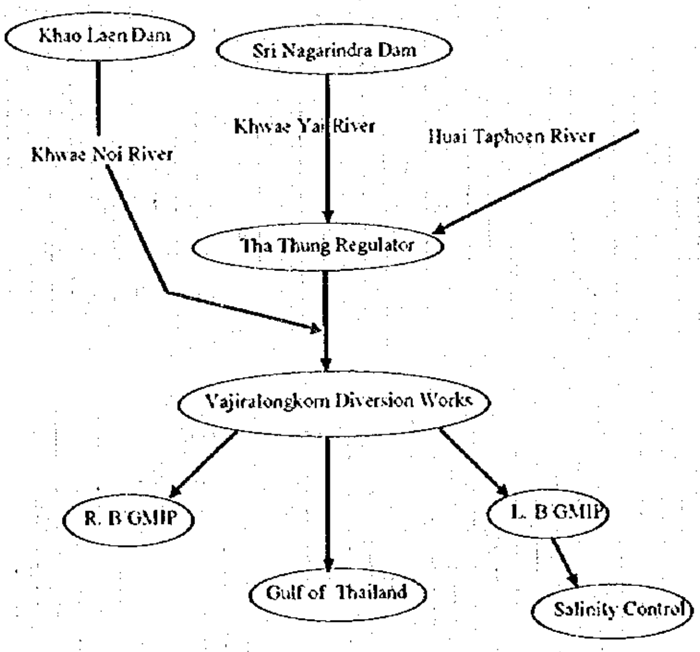
2.2.1 Mae Klong River Basin

(1) General Characteristics of the River Basin

<u>River system and reservoirs</u>

The lower Mae Klong river basin in Kanchanaburi has two existing reservoirs, the Khao Laen dam in the Khwae Noi river and the Sri Nagarindra dam in the Khwae Yai river. The Tha Thung Na regulation works have been built about 50 km downstream from the Sri Nagarindra dam for regulation of discharge from the dam and runoff from the Huai Taphoen river. About 20 km downstream from the Tha Thung Na regulation works, the Vajiralongkorn diversion works were built for water supply; in association with the two upper dams and the Tha Thung regulator, the works function to divert water to both banks for agricultural crop production and to urban and industrial areas. The river system and reservoirs in the lower Mae Klong river basin are shown in the figure below.

River System and Reservoir Location in Lower Mae Klong River Basin



Notes:
GMIP : Greater Mae Klong Irrigation Project
R.B. : Right bank
L.B. : Left Bank

Hydrometeorology

The Mae Klong river basin is the second largest river basin in Thailand, after the Chao Phraya. The analysis of rainfall records at key gauging stations in the Mae Klong river basin indicates that annual rainfall varies from 1,100 mm at the lower part of the basin to 2,200 mm in the upper part of the basin, with most rain produced by the southwest or summer monsoon (Refer to Figure 9.2.2). Rainfall usually begins in May and increases in intensity until it reaches its peak usually in September, after which it decreases toward November; about 90 per cent of annual rainfall occurs in this May-November period. Evaporation throughout the Mae Klong river basin is normally highest in March and April. The annual evaporation depth is 1,330 mm to 1,860 mm on average, which is significant from the viewpoint of water losses at the surface of reservoirs and evapotranspiration in agricultural croplands. Annual average temperature in Kanchanaburi is 28 degrees Celsius and relative humidity is 87 per cent.

Soil Characteristics

Agricultural lands in the lower Mae Klong river basin are mostly irrigated areas located on both banks of the river from the Vajralongkorn diversion works to the point 120 km downstream of the works. The dominant soil type in the area is Land Unit 14 in the standard classification system of Thailand. In the irrigated area about 99 per cent of the soil is alluvial, non-calcic brown, and humic gray. Most of the soil shows a weak acid to neutral reaction (except acid sulphate soils) and has a high cation exchange capacity and high saturation as well as a relatively high moisture retention capacity owing to the topographic conditions and soil texture. The acidity of Mae Klong soil is distributed in the lower areas.

In the land classification study, the area slope was found to be 2-5 per cent with suitable soil drainage conditions. The surface soil is about 30 cm deep and of a sandy loose texture with a pH of 5.0-7.0. More than 30 cm deep, a fertile clay soil with a texture that is sandy loose to loose is found. The lower Mae Klong river basin includes a large area of high agricultural crop productivity, particularly for paddy cultivation and tropical upland crops.

Groundwater

The Hydro-geological Map of Thailand indicates that extensive and productive Chao Phraya aquifers are found in the lowland between the Mae Klong and Tachin rivers. In the highland area in the Khwae Noi and the Khwae Yai valleys, aquifers generally overlay older sediments that form multiple productive aquifers at relatively shallow depths. The profile is moderate to well sorted sands and gravels, with intercalated clay or silty sand beds, as thick as 10-40 m. Yield is generally 180-800 l/min depending on the type of aquifers. Water quality varies usually from place to place, but is slightly salty in the coastal areas along the Gulf of Thailand where salt intrusion in the groundwater is common.

Groundwater use in the lower Mae Klong river basin involves 1,423 wells (823 in Kanchanaburi, 408 in Ratchaburi, and 96 in Samut Songkhram, as well as 96 in Nakhon Pathom). These wells have a yield capacity of 100 to 200 m^3/hour and water quality of 310 to 1,120 mg/l of suspended solids (SS), 8 to 310 g/ml of chlorine (Cl), and 0.03 to 1.56 g/ml of iron (Fe), based on records obtained from selected public supply wells in the basin. These groundwater sources have been providing about 125,000 m^3/day of water to domestic users in city, town, and rural areas as well as to industry in Kanchanaburi province.

(2) Water Utilization

Utilization of river water in the Mae Klong river system has been operated through the main dams and reservoirs, diversion works, and water supply canal networks, as described below.

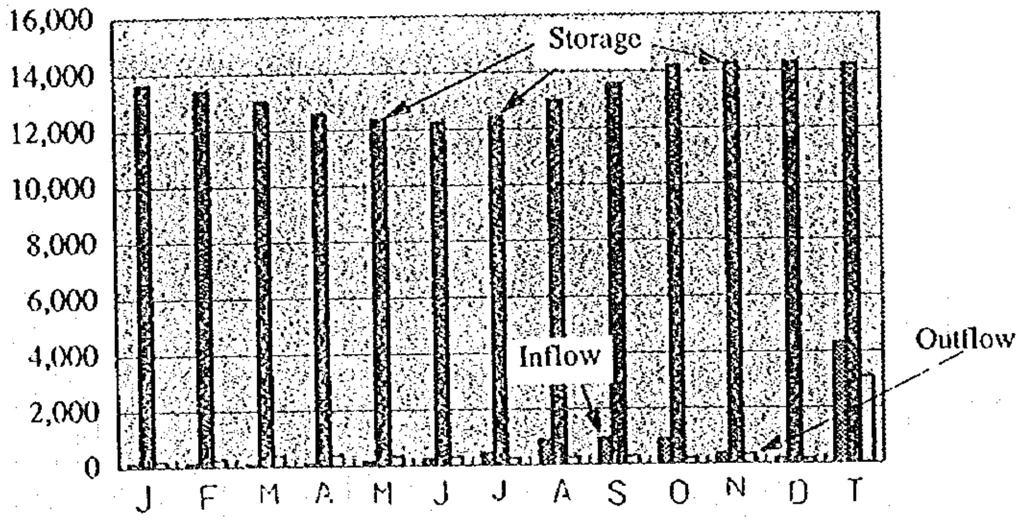
Sri Nagarindra reservoir and Tha Thung Na regulator

The Sri Nagarindra reservoir was constructed in the Khwae Yai river in 1978 and has been operated by EGAT. The reservoir has multiple functions, including hydropower generation, water supply for irrigation, domestic use, and industrial use, as well as salinity control in the estuary through the Tha Thung Na regulation works and the Vajiralongkorn diversion works. The Sri Nagarindra reservoir is characterized as follows:

- Catchment area, 10,880 km^2;
- Annual mean inflow, 4,280 MCM (the average from 1978 to 1995);
- Gross storage capacity, 17,745 MCM; and
- Effective storage capacity, 7,470 MCM.

The volume of water stored in the Sri Nagarindra reservoir was 12,500 MCM to 14,500 MCM per annum during the past 17 years of operation (1978-1995), representing 70 to 82 per cent of the reservoir's gross storage capacity (17,745 MCM). An average outflow of 3,080 MCM was released from the reservoir per year, i.e., 21 to 25 per cent of the annual storage volume, while the average annual inflow was 4,280 MCM. The difference between inflow and outflow (1,200 MCM) largely represents losses due to evaporation from the reservoir surface and seepage in the reservoir body. Monthly inflow, outflow, and storage of the Sri Nagarindra reservoir is shown in Table 9.2.1.

Monthly Sri Nagarindra Reservoir Operation (Unit : MCM)
(Monthly Average in 1978-1995)



The Tha Thung Na regulator is located about 50 km downstream from the Sri Nagarindra reservoir; the function of this regulator is mainly to control discharge to downstream areas, which involve water released from the Sri Nagarindra dam on the main Khwae Yai river and runoff in the Taphoen river (one of the tributaries of the Khwae Yai), which is upstream of this regulator. The Tha Thung Na regulator has a regulation capacity of 55 MCM. Annual mean outflow is 3,770 MCM at Tha Thung Na. Pump irrigation projects have been developed on both banks along this 30 km section of the Khwae Yai river.

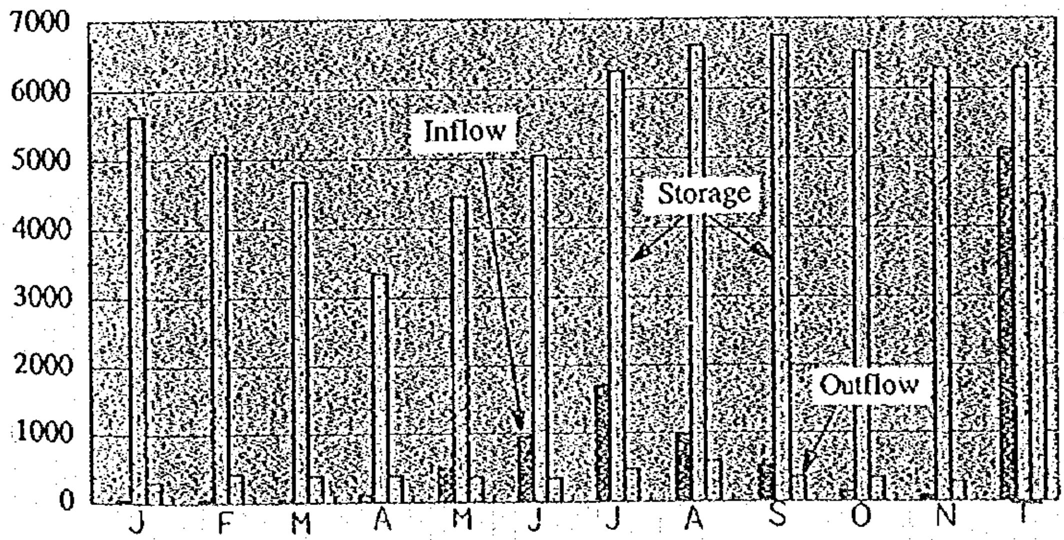
<u>Khao Laen reservoir and Vajiralongkorn diversion works</u>

The Khao Laen reservoir in the Khwae Noi river has been operated by EGAT since 1984, with multiple functions as those of the Sri Nagarindra reservoir. It is characterized as follows:

- Catchment area, 3,720 km^2;
- Annual mean inflow, 5,120 MCM (the average from 1984 to 1995);
- Gross storage capacity, 9,500 MCM; and
- Effective storage capacity, 5,800 MCM.

Operation of the Khao Laen reservoir from 1985 to 1995 indicates that the reservoir volume varied from 3,300 to 6,700 MCM, which accounted for 35 to 71 per cent of the gross storage capacity of 9,500 MCM. Annual average outflow of the reservoir was about 2,520 MCM, i.e., 38 to 76 per cent of the average reservoir volume, while the average inflow was 5,120 MCM over the period. The difference between inflow and outflow (2,600 MCM) largely represents losses due to evaporation and seepage. Monthly inflow, outflow, and storage of the Khao Laen reservoir is shown in Table 9.2.2.

Monthly Khao Laen Reservoir Operation (Unit: MCM)



The water released at the Khao Laen dam will reach the Vajiralongkorn diversion works located about 150 km downstream. Along this distance, several irrigation projects have been developed using the Khwae Noi river water, which is fed by water released from the Khao Laen dam and several tributaries that flow into the Khwae Noi.

The Vajiralongkorn diversion works, located about 100 km upstream of the estuary of the Mae Klong river, play a key role in diverting water of the Khwae Noi and the Khwae Yai rivers to the agricultural land, residential areas, and industrial areas, as well as water for salinity control in the Mae Klong river estuary, where saltwater intrusion occurs in the dry season. According to inflow records from May 1972 to January 1996 (refer to Table 9.2.3), the operation involved an annual mean inflow of 6,750 MCM and outflow of 2,520 MCM. The balance of 4,230 MCM was diverted to main canals on both banks of the Mae Klong river.

Greater Mae Klong Irrigation Project (GMIP)

The GMIP is a particularly large-scale irrigation scheme introducing water from the Vajiralongkorn diversion works to the development of the area along both banks of the Mae Klong river. The irrigated area is about 3 million rai (480,000 ha), located in the lower Mae Klong river basin and the surrounding areas in Suphan Buri, Nakhon Pathom, Samut Sakhon, and Petchaburi provinces. The irrigation canal network includes 190 km of main canals and 1,200 km of lateral canals (80 km of main canals and 770 km of lateral canals on the left bank, and 110 km of main canals and 430 km of lateral canals on the right bank). In the irrigated area of 3 million rai (480,000 ha), the cropped area has increased from 2.3 million rai in 1979 (representing crop intensity of 76 per cent) to 5.4 million rai in 1990 (crop intensity of 180 per cent) as shown below.

Cropped Area under Different Crops (Unit: rai)

Crop	1979	(%)	1990	(%)
Paddy	830,000	(36)	2,600,000	(48)
Sugar cane	1,000,000	(44)	1,400,000	(26)
Perennial crops	300,000	(13)	900,000	(17)
Field crops	160,000	(7)	500,000	(9)
Total	2,290,000	(100)	5,400,000	(100)

Although updated data are not available, it has been learned in the field that the crop intensity has decreased substantially in recent years.

Annual water supply from the Vajiralongkorn diversion works in a recent year (1992) is summarized below.

Annual Water Supply from GMIP in 1992

Units: MCM

	Water Requirements*				Water	
Season	Rice	Upland Crop	Fishpond	Total	Supply	Percentage
Dry	1,113	1,444	47	2,604	2,030	45%
Wet	1,328	716	20	2,063	2,461	55%
Total	2,440	2,160	67	4,667	4,491	100%

Note: * Calculated for net field water requirement (MCM)
Source: NESDB

On-farm development in the GMIP has been delayed, and as of 1996 areas covered by land consolidation and ditch-and-dike (on-farm) development are limited as summarized below.

* Extensive land consolidation area — 439,500 rai (15 per cent)
* Old type of ditch-and-dike — 1,200,000 rai (40 per cent)
* New type of ditch-and-dike — 100,000 rai (3 per cent)

Further, the Mae Klong river water is released for salinity control in Samut Songkhram province; this water is also used for orchard and shrimp farming. For these purposes, the river maintenance flow from the Vajiralongkorn diversion works should be at least 50 m^3/sec in the dry season (about 1,577 MCM per annum) so that the salinity level is controlled at less than 2.0 gm/l.

Small and medium reservoirs

Medium-scale reservoirs in the lower Mae Klong river basin have a storage capacity of 0.2 to 4.3 million m^3, including seven projects in Kanchanaburi province and six in Ratchaburi province, mainly for irrigation and a few for domestic water supply that have been under RID management since 1950. The small-scale reservoirs, which include about 43 in Kanchanaburi and 33 in Ratchaburi under RID, are mainly for water storage through the harvesting of rain water, typically in a small basin in the valley. The project scale is below 1.0 MCM storage capacity for irrigation, domestic use, and also inland fish culture projects, implemented since 1982. The small- and medium-scale projects in Kanchanaburi and Ratchaburi provinces are summarized in the table below.

Summary of Small- and Medium- Scale Projects

		Kanchanaburi		Ratchaburi		
	Unit	Medium	Small	Medium	Small	Total
Project	No.	7	43	6	33	89
Capacity	MCM	3.0	11.4	7.0	7.9	29.3
Beneficial Area	Rai	12,100	37,000	4,800	37,200	91,100

Note: Additional small-scale projects are under construction, nine in Kanchanaburi and seven in Ratchaburi
Source: RID

Pumping irrigation projects have been implemented from 1982 to 1992 by the Department of Energy Development and Promotion (DEDP), with no recent projects implemented in the lower Mae Klong river basin. The projects implemented to date have involved 36 pumping stations and a combined beneficial area of 97,100 rai, including 32 stations and 86,600 rai in Kanchanaburi and four stations and 10,500 rai in Petchaburi. The small-scale projects have been implemented by the Office for Accelerated Rural Development, which has provided water supply to rural areas. Projects now operating include 138 small reservoirs and 339 wells in total.

(3) Future Plans

In the Mae Klong river basin, the following medium-scale projects have been included in the 8th Five-Year Plan, for implementation by RID.

Planned Reservoir works

Project	Location	Capacity	Beneficial Area
Puta Kean	Kanchanaburi	N/A	N/A
Huai Lum Sai	Kanchanaburi	13.9	24,000 rai

Source: Royal Irrigation Department

Also, another medium-scale project, the Huai Tha Koey storage dam (13.8 MCM), is planned for multipurpose use in the sub-basin of Lam Pachi in Suan Phung district, Ratchaburi; RID plans to complete this project by the end of 2001.

(4) Flood Control

Floods in the middle and lower reaches of the Mae Klong river are mainly due to discharges from tributaries other than the Khwae Yai and the Khwae Noi, which are regulated respectively by the Sri Nagarindra reservoir and the Khao Laen reservoir. One of the major tributaries without any regulation work at the moment is the Lam Pa Chi river, having a catchment area of about 2,500 km^2. The Lam Pa Chi river drains water in the mountain ranges of 1,000-1,200 m above sea level in Kanchanaburi and Ratchaburi provinces, where annual rainfall averages around 1,100 mm. The Lam Pa Chi river joins the Khwae Noi river in the vicinity of Ban Lam Pachi, located upstream of the Vajiralongkorn diversion works.

A severe flood was experienced in September-October 1996, and it was reported that about 6,100 houses were damaged and 452,000 rai (72,300 ha) of agricultural land were affected by the flood. The flood discharge of the Lam Pa Chi river at that time was unavailable.

One of the alternative solutions to control water of the Lam Pa Chi river is to construct a reservoir on the mainstream. The Metropolitan Waterworks Authority conducted a master plan for water supply and distribution of Metropolitan Bangkok in 1990, in which a plan for the construction of the Lam Pa Chi dam was involved. Since water resources development in the Lam Pa Chi river basin has not been thoroughly studied, it is suggested that such a study be conducted from the viewpoints of flood control, water supply, and irrigation in the medium and long term.

(5) Salinity Control

Salinization is in progress in the lower basin of the Mae Klong river, due mainly to: (i) direct seawater intrusion from the coast, (ii) saltwater intrusion into river estuaries as a result of tidal fluctuation, and (iii) lack of adequate drainage. For seawater intrusion along the coast, RID completed construction of a 36 km long coastal protection dike on the right bank, and planned to construct a 52 km long like on the left bank.

The Vajiralongkorn diversion works have been designed to secure 50 m^3/s of maintenance flow in the dry season. This water is equivalent to 1,577 MCM per annum. However, according to the operation records of the Vajiralongkorn diversion works, the monthly discharge from the diversion works has fallen short of this requirement in December-January in most years.

Operation of the water works in the Mae Klong river should be further reviewed taking into account the following aspects:

(i) Whether the maintenance flow of 50 m^3/s in the downstream from the Vajiralongkorn diversion works can be guaranteed through modification of reservoir operations at the Sri Nagarindra and Khao Laen reservoirs;

(ii) How large the water requirement is in the coastal lands to be protected by the coastal dike constructed by RID, and how drainage works can be improved in these lands;

(iii) Whether water supply from the Mae Klong river basin to the BMA is indispensable; and

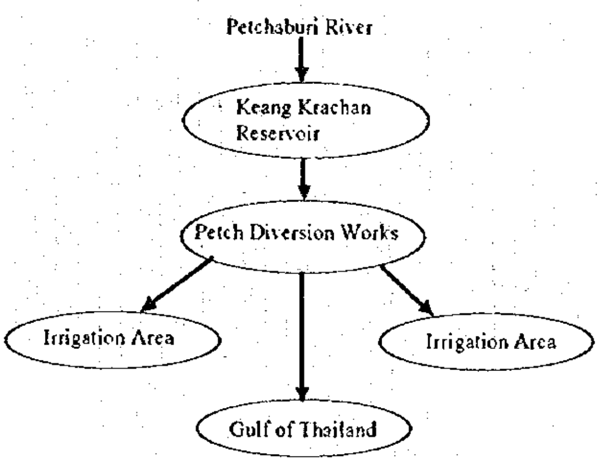
(iv) Whether the construction of a structure on the Mae Klong river estuary is required to prevent salt water intrusion, and if it is economically feasible and environmentally acceptable.

2.2.2 Petchaburi River Basin

(1) General characteristics of the River Basin

The Petchaburi river is joined by three tributaries before it debouches into the Gulf of Thailand. Water resource development projects in the basin consist of the large-scale Keang Krachan reservoir and two small ones, as well as the Petch diversion works. The water is distributed from the diversion works to an irrigation area that covers 462,500 rai (74,000 ha). The Keang Krachan reservoir (710 MCM), with a catchment area of 2,200 km^2, has been regulating the water flow in the basin since 1955. A diagram of the Petchaburi river system is illustrated below.

Petchaburi River System and Reservoir Location



The main Petchaburi basin, which covers 4,570 km^2 or 81 per cent of the total Petchaburi basin of 5,600 km^2, is divided into three subbasins based on the extent of runoff control by the Keang Krachan reservoir and the Petch diversion works. The irrigation area covers 340 villages and 20,850 families. The Keang Krachan reservoir serves multiple functions, including hydropower generation, the priority for reservoir operation being irrigation. The operation of the Keang Krachan reservoir and the Petch diversion works is summarized below. (Refer to Table 9.2.4).

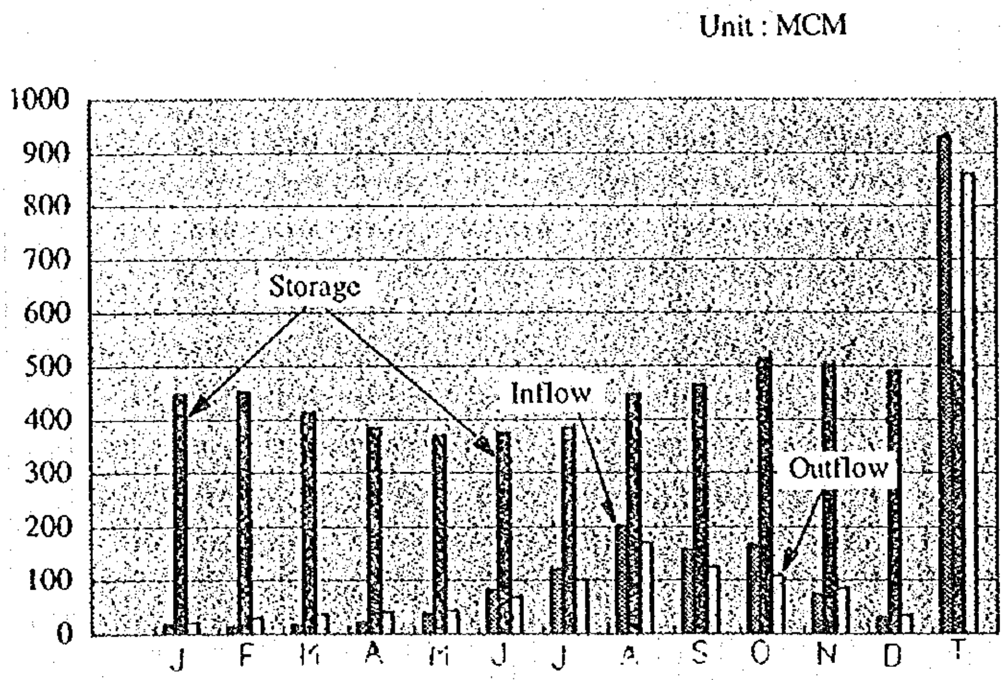
Keang Krachan Reservoir and Petch Diversion Work Operation

Units: MCM

	Keang Krachan Reservoir		Petch Diversion Works	
	Inflow	Outflow	Inflow	Outflow
Mean	930	860	710	480
Maximum	1,590	1,580	960	1,440
Minimum	410	480	490	110

Note: Averages from 1967 to 1995
Source: Royal Irrigation Department

Monthly Operation of Keang Krachan Reservoir



(2) Water Utilization

Large-scale project

The Petchaburi project irrigates 462,500 rai (74,000 ha) of agricultural land. The average annual rainfall is 900 mm and mean air temperature is 27.8 degrees Celsius in the irrigation command area; the wet season in the basin is from May to December. Water for irrigation is diverted by the Petch diversion works, located at Tha Yang about 55 km downstream of the Keang Krachan reservoir. The water supply canal network consists of 87 km of main canals and 41 lateral canals on both banks of the Petchaburi river. The reservoir storage and irrigation water supply are regulated as follows:

- Dry season (February to May):
  * Over 380 MCM, rice cultivation has no restriction;
  * 300-380 MCM, rice and other crops can be cultivated partly in irrigable areas; and
  * Below 300 MCM, cultivation of rice and other crops is impossible.
- Wet season (June to December):
  * Over 300 MCM, water is supplied for rice cultivation on 1st June;
  * 250-300 MCM, water is supplied for rice cultivation on 1st July; and
  * Below 250 MCM, water is supplied for rice cultivation on 15th July.

A review of the Keang Krachan reservoir operation from 1967 to 1995 indicates that only 57 per cent of outflow of the reservoir (860 MCM) or 68 per cent of the inflow at the Petch diversion works (710 MCM) have been used for irrigation over 462,500 rai (74,000 ha). About 17 per cent (150 MCM) of the outflow from the reservoir have been used in the area located between the reservoir and the diversion works. This implies that about a quarter of the release from the reservoir is not effectively used.

Out of the gross irrigable area, about 439,000 rai (70,240 ha) is currently used for agriculture. Cultivation of paddy accounts for 93 per cent of the irrigated agricultural land, while the remaining 7 per cent for upland crops and orchards. According to the Land Consolidation Office, extensive land consolidation works have been completed only for 9.6 per cent or 42,100 rai (6,740 ha) of the irrigated land.

Small- and medium-scale projects

While there are no medium-scale projects in the Petchaburi basin, RID and ARD have developed small projects harvesting rainwater in small reservoirs since 1977. The small-scale projects are limited to an maximum irrigable area of 4,500 rai for surface water schemes. There are 227 small-scale reservoirs and 114 groundwater wells in the Petchaburi river basin.

Domestic water sources are available from reservoirs and wells mainly operated by ARD and PWA. Domestic water users consist of five types:

- Water supply authority, 9 units;
- Public activities, 260 units;
- Industry, 5 units;
- Tourist industry, 6 units; and
- Water user, 20 cities, 850 households.

In the coastal areas, irrigated agricultural land is influenced by the tidal fluctuations of the Gulf of Thailand, and two 91 km-long dikes were constructed to prevent seawater intrusion in the areas of Cha Am, Tha Yang, Petchaburi, Ban and Khao Yoi districts. These dikes not only prevent salt water intrusion but also play an important role in coastline conservation.

(3) Future Plan

In the Petchaburi basin, RID has planned the following two (medium-scale) reservoirs in the 8th Five-Year Plan.

Future Plan in Petchaburi River basin

Name of Project	Location	Capacity	Beneficial Area	Remarks
Huai Mae Pra Chan	Petchaburi	41.5 MCM	22,000 rai	Medium-Scale
Huai Pak	Petchaburi	27.5 MCM	4,100 rai	Medium-Scale

(4) Flood Control

In its lower reaches, the Petchaburi river meanders on the flat land, causing flooding during the seasons of heavy rain. Flood damage is caused on bridges, roads, and a number of houses along the river course, as experienced during the flood in September-October 1996. Since appropriate measures have not been taken for flood control in this area, it is suggested that studies be conducted further with respect to the following aspects:

(i) Operation of the Keang Krachan reservoir and two other reservoirs planned in upstream to reduce flood volume and peaks;

(ii) Straightening of extreme meandering segment of the river course and development of inundation ponds; and

(iii) Revetments along the residential areas.

2.2.3 *Western Coast River Basin*

(1) General Characteristics of the River Basins

River morphology

The rivers in the Western coast river basin have a steep gradient from the mountain in the west to the Gulf of Thailand. The profiles of the six rivers in the Western coast basin are tabulated below.

Characteristic River Profile

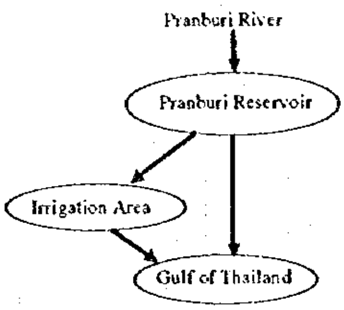
River	Original Elevation	Distance	River Slope
Pranburi	420 m	180 km	1 : 1,200
Kuiburi	580	70	1 : 400
Khlong Bung	530	45	1 : 350
Khlong Thap Sakae	800	25	1 : 150
Khlong Bang Saphan	450	45	1 : 420
Khlong Bag Saphan Noi	80	30	1 : 580

Given the steep longitudinal profiles of the rivers in the Western coast basin, consideration should be given to: (i) effective use of runoff water and flood water as much as possible; (ii) the need not only for the development of reservoirs, but also soil conservation and groundwater "cultivation"; and (iii) the need for water storage works.

River system and reservoir

The existing Pranburi reservoir is the only large-scale project in the Western coast river basin. In addition, six medium-scale projects are in operation as well as a number of small-scale projects. RID has been operating the Pranburi reservoir for 18 years (i.e., since 1978) mainly to supply water for irrigation of 231,000 rai (36,960 ha).

Pranburi River System



Key features of the Pranburi reservoir are summarized as follows:

- Catchment area, 2,030 km^2;
- Annual inflow, 360 MCM (the average from 1978 to 1995);
- Gross storage capacity, 537 MCM; and
- Effective storage capacity, 445 MCM.

Characteristics of the Pranburi reservoir operation are shown below (Refer to Table 9.2.5).

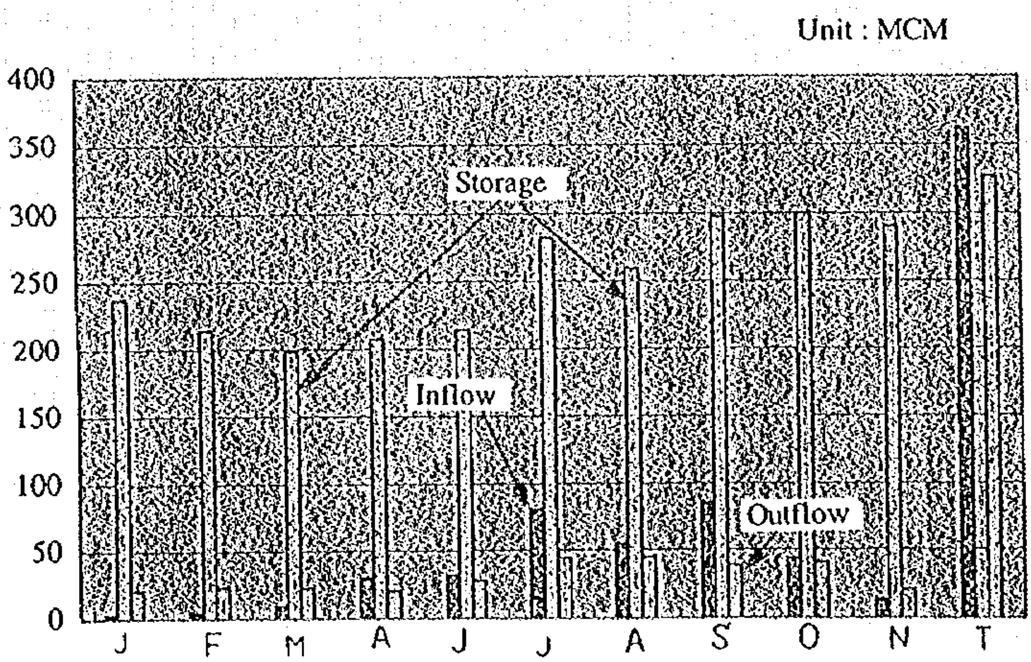
Pranburi Reservoir Operation

Units: MCM

Item	Inflow	Outflow
Mean	360	330
Maximum	1,220	830
Minimum	30	100

Source: Royal Irrigation Department

Monthly Pranburi Reservoir Operation



A review of reservoir operation from 1978 to 1995 shows that this dam and reservoir has released 92 percent (330 MCM) of its inflow (360 MCM) for irrigation of about 231,000 rai (36,960 ha). Over the 17-year period, storage volume varied from 200 MCM to 300 MCM, i.e., 45 to 67 per cent of effective storage capacity (445 MCM). No water has been spilled over the dam.

(2) Water Utilization

There are two medium-scale projects in the Western coast basin, the Yang Chum reservoir (32 MCM) in Amphoe Kuiburi and the Klong Kraja reservoir (10 MCM) in Amphoe Prachuap. In addition, many small-scale projects are operating at several locations in the basin. These projects of small- and medium-scale, are summarized below.

Small- and Medium- Scale Projects in the Western Coast River Basins

Item	Unit	Medium-Scale Projects	Small-Scale Projects	Total
Projects	No.	6	122	128
Capacity	MCM	62	7	68
Beneficial Area	rai	51,000	84,800	135,800

Source: RID and ARD

(3) Future Plan

The following medium-scale reservoir works are planned by RID for the 8th Five-Year Plan.

Planned Reservoirs in the Western Coast

Project	Location	Capacity	Beneficial Area
- Khlong Jakra	P. Khirikhan	10.4 MCM	4,000 rai
- Khlong Tong	P. Khirikhan	9.2 MCM	7,000 rai
- Qan Sai Tong	Bang Saphan	7.8 MCM	4,000 rai
- Huai Pak	P. Khirikhan	27.5 MCM	4,100 rai

Source: Royal Irrigation Department

2.2.4 *Southeastern Coast River Basin*

(1) General Characteristics of the River System

The river system in the Southeastern coastal basin consists mainly of five rivers: the Chumphon river, the Swai river, the Khao Bang river, the Lang Suam river, and the La Mae river. Several varieties of tropical fruits and vegetables are grown in these river basins, including rambutan, durian, mangosteen, coconut, and oil palm as well as beans, tomatoes, and rice. The rainfall pattern in the basin is favorable for these crops, with 36 per cent of rainfall distributed from April to July, 51 per cent from August to November, and 13 per cent from December to March. Rice comprises half of the cropped areas in the rainy season and 25 per cent in the dry season.

(2) Water Utilization

While this basin has no large-scale reservoir at present, it has a medium-scale reservoir and 160 small-scale reservoirs developed by RID and ARD since 1962, with a total irrigation area of 133,000 rai (21,280 ha).

In the upper part of the Southeastern coastal basin, drainage work on the Chumphon plain is under construction to protect against surface inundation of agricultural land. Also, improvement of old regulators in meandering rivers near the estuary is being undertaken to prevent salt intrusion due to tidal fluctuations and also for flood control.

(3) Future Plan

In the three river basins of Chumphon province, RID plans to construct the two reservoirs (one large and one medium) during the 8th Five-Year Plan.

Planned Future Reservoirs

Project	Location	Capacity	Beneficial Area
Tha Sae, Rub Ro*	Chumphon	337 MCM	179,000 rai
Klong Tam Mang	Chumphon	-	10,000 rai

Note :
* Feasibility study was completed in 1995. The project includes two subprojects :
  - Tha Sae subproject: 194 MCM, 87,000 rai
  - Rub Ro subproject: 143 MCM, 92,000 rai

Source: RID

Water stored in the Tha Sae and the Rub Ro reservoirs is planned to be utilized in the following manner.

Water Supply Plan

Units: MCM

Water Demand	Tha Sae Reservoir	Rub Ro Reservoir
Irrigation	134.3	154.8
Amphoe Muang	8.35	8.35
Amphoe Tha Sae	6.24	-
Chumphon	-	37.5
Amphoe Bang Saphan	30.0	-
Salinity Control (cu. m/sec)	0.24	1.03
Total	179.1	201.7

Note: For Tha Sae reservoir operation, about 30 MCM of water annually will be supplied to Amphoe Bang Saphan through a pipeline conveyance system.
Source: RID

(4) Flood and Salinity Control

The lower reaches of the Chumphon river basin (Chumphon river and Tha Taphao river) are subject to periodic floods. Flood damage is particularly notable in the area downstream from the confluence of the Rub Ro and Tha Sae rivers. A study was made to mitigate floods by constructing two floodwater diversion canals (Pak Phraek and Hua Wang-Phanang Tuk canals with a total capacity of 540 m^3/s) and improvement of the upper reaches of Tha Taphao river (increased design discharge of 450 m^3/s). Together with the flood control effect of the Tha Sae and the Rub Ro reservoirs (totaling 360 m^3/s), the flood discharge might be substantially decreased in the lower Tha Taphao river. The economic effects of the proposed flood control scheme should be further examined before its implementation.

Salinization is another constraint in the lower reaches of the Tha Taphao river and the Chumphon river. The need for a salinity control structure in these river estuaries should be further evaluated from economic and environmental points of view.

2.3 *Water Supply-Demand Balance*

Water endowments and availability are widely varied among river basins in the WSB not only due to the variable rainfall pattern but also reflecting topography, soil, vegetation, and land use. To plan for long-term water resources development for balanced and sustainable performance of the WSB socio-economy, a macro water supply-demand balance has been worked out based mainly on past studies by RID.

2.3.1 Water Demand

The existing water demand in 1996 has been estimated by main river-basin for irrigation, urban/industrial use, rural water supply, and other uses. The irrigation water demand estimate is based on RID data for irrigated area. The urban/industrial and rural water demand has been estimated based on urban/rural population and assumed per capita water use. Other uses are added such as the need for maintenance flow for salinity control and other purposes. Results are summarized below.

Estimated Water Demand in 1996

(Unit : MCM/year)

	Main River Basins			
Use	Mae Klong	Petchaburi	Western Coast	Southeastern Coast
Irrigation	7,632	1,126	1,174	521
Urban/industrial	47	9	9	9
Rural	10	2	2	3
Others	388	78	30	39
Total	8,077	1,215	1,215	572

Irrigation water demand in the future has been projected, incorporating the future plan by RID for irrigated agriculture. Domestic and industrial water demand has been projected in line with the socio-economic framework for development of the WSB and corresponding sector plans. Water demand for specific development projects such as the Bang Saphan development is reflected in the projection. Results are summarized below.

Projected Water Demand in 2001 and 2011

(Unit : MCM/year)

Water Demand	Main River Basins			
	Mae Klong	Petchaburi	Western Coast	Southeastern Coast
Existing Water Demand, 1996	8,077	1,215	1,215	572
Projected Water Demand, 2001	8,093	1,391	1,350	1,182
Projected Water Demand, 2011	8,113	1,446	1,566	1,502

2.3.2 Surface Water Resources

Surface water availability has been determined by main river basin based on the rainfall data and rainfall-runoff relationships derived on the basis of data obtained from RID. The long-term average availability of surface water has been calculated and critical flow conditions have also been analyzed. Calculation of the average availability of surface water is given in Table 9.2.6 and summarized below.

Average Availability of Surface Water

Main River Basin	Catchment Area (km^2)	Surface Water Availability (MCM/year)
Mae Klong	15,500	10,721
Petchaburi	5,607	1,540
Western Coast	7,100	1,446
Southeastern Coast	6,720	4,359
Total	34,927	18,066

2.3.3 Water Supply-Demand Balance

The projected water demand and the calculated availability of surface water are summarized in the table below.

Water Supply-Demand Balance by Basin

(Unit : MCM/year)

Main River Basin	Water Demand 1996	2001	2011	Surface Water Availability
Mae Klong	8,077	8,093	8,113	10,721
Petchaburi	1,215	1,391	1,446	1,540
Western Coast	1,215	1,350	1,566	1,446
Southeastern Coast	572	1,182	1,502	4,359

Water demand in the Mae Klong river basin is not projected to increase much although it contains a rapidly developing urban area, since the dominant water demand for irrigation was assumed to stay at the present level. Intensification of the irrigated agriculture for diverse crops is the direction to pursue in this basin. The projected demand also includes a maintenance flow of 50 m^3/sec to control salt water intrusion during the dry season.

The water demand in the Western coast river basin is projected to increase more rapidly than in the Petchaburi river basin due mainly to the Bang Saphan development. As a result, projected demand in 2011 exceeds even the average availability of surface water in the Western coast river basin.

The water demand in the Southeastern coast river basin is also projected to increase rapidly. This is due to the two dams/reservoirs planned to be developed during the 8th Plan period for irrigation and urban water supply, and also much increased fruit production under supplemental irrigation in the WSB master plan. Still, the Southeastern coast river basin will have a large amount of surplus water.

The water availability in the WSB region is and will be more critical than the average availability of surface water indicates. Without further water resources development, unregulated flow in rivers is such that the 80 per cent dependable monthly flow is only 20-25 per cent of the average monthly flow in the Mae Klong river basin, around 25 per cent in the Petchaburi and the Western coast river basins, and less than 20 per cent in the Southeastern coast river basin. This can be increased as indicated below by constructing flow regulating structures such as dams.

Operation records of existing dams/reservoirs indicate the following. The 80 per cent dependable monthly discharge is over 50 per cent of the average monthly flow at the Khao Laen and the Sri Nagarinda dams in the Mae Klong river basin. The Pranburi dam in the Western coast basin has increased the 80 per cent dependable monthly discharge to some 45 per cent of the average unregulated monthly flow. The 80 per cent dependable monthly discharge from the Kaen Krachan dam in the Petchaburi river basin has been about 36 per cent of the average unregulated monthly flow.

Without additional flow regulating structures, both the Petchaburi and the Western coast river basins will face critical water shortages by 2001. The water shortages in the Western coast river basin cannot be resolved by in-basin development alone, as the demand in 2011 would exceed the supply even if the flow were fully regulated. Trans-basin water supply to the Western coast river basin is therefore required.

The serious water shortages expected in the Western coast river basin are due in part to the Bang Saphan development. The water demand-supply balance has been separately worked out for the Bang Saphan area. Results are shown below.

Water Demand and Supply in Bang Saphan

Units: MCM

		2001	2006	2011
Demand:	Irrigation	15	15	15
	Domestic use	1	2	3
	Steel Complex	12	16	36
	Industrial Estate	1	9	24
	Others	0.2	1	1
	(Total)	(30)	(43)	(79)
Supply:	Bang Saphan river			
	- Diversion for irrigation	15	15	15
	- Pump for industry	15	15	15
	- New reservoirs	-	-	20
	- Tha Sae pipeline	-	15	30
	(Total)	(30)	(45)	(80)

Source: JICA study on Bang Saphan Industrial Estate

As indicated in the above table, water requirements in the Bang Saphan area have to be met by the Tha Sae dam and reservoir to be constructed in Chumphon province by 2006 by means of a trans-basin water supply scheme. A supply of 30 MCM planned for and reserved in the Tha Sae reservoir will be required by 2011.

Additionally, new reservoirs will have to be planned in the Bang Saphan river basin to secure a total supply of 20 MCM by 2011. A set of small reservoirs in the Bang Saphan river system should be studied in time for the scheduled demand by the steel complex and the industrial estate.

2.4 WSB Water Resources Development Plan

2.4.1 Objectives

Objectives for water resources development in the WSB region have been defined in view of the potentials and constraints in each river basin analyzed above, as well as the overall WSB regional development objectives and the government policy outlined in Section 2.1. They are defined as follows, covering social, economic, and environmental aspects:

(i) To ensure a sufficient supply of domestic water of reasonable quality to satisfy basic human needs and enhance quality of life ;

(ii) To expand the urban water supply to support high economic growth with accelerated industrialization ; and

(iii) To manage watershed and irrigated land as an essential part of integrated land and water ecosystems.

2.4.2 Strategy

The 8th Plan represents a major departure from growth and economic efficiency-oriented development to more socially-oriented and human-centered as well as environmentally sustainable development. It is reflected in the national policy and strategy for the management of environment and natural resources. Related specifically to water resources, holistic development and management of river basin level and control of water quality are taken as the basic strategy for water resources development and management in the WSB. More specific strategy components are described.

(1) Holistic River Basin Approach

In line with the renewed national policy, a holistic river basin approach is to be taken for water resources development and management in the WSB. This approach takes an entire river basin from its uppermost watershed all the way to the coastal area as a totality to realize environmentally sustainable development in the balance between various water uses. The following would be particularly important in the WSB river basins:

Watershed management

Existing forests in the upper catchment areas including virgin forests should be protected as an essential condition for watershed management. Catchment areas should be improved with reforestation, if necessary, associated with additional flow regulating structures for cultivation of both surface water and groundwater. Reservoir operations should take account of the need to reduce salt water intrusion. Irrigation should be taken as the means to increase and retain soil moisture during the dry season, and crop selection should reflect residual soil moisture to be determined by soil type, topography, and other local conditions.

Multi-purpose development and management

To make effective use of limited water resources, existing and additional water facilities should be used for multiple purposes. Operation of existing dam/reservoirs and other hydraulic structures should be improved to make irrigation for diverse crops more effective and to allow better control of water quality. New dams should be constructed based on economic and environmental viability for flood control, irrigation, domestic water supply and other purposes. New dams in the Petchaburi and the Western coast river basins should take account of their effects on groundwater cultivation and retention of soil moisture during the dry season.

Demand-side management

Demand-side management is an important part of the holistic approach to water resources management. More important for this would be the intensification of irrigated agriculture especially in the Mae Klong river basin, and rationalization of water charges for various uses. The latter may include increased user charges for irrigation concomitant with larger responsibilities given to farmers for management of on-farm development and water use.

Trans-basin diversion

The water balance analysis in the previous section has clarified that the Western coast river basin will face serious water shortages, even if its in-basin potential is fully developed. The only option to realize the planned development based on locational advantages and the deep sea port is to introduce additional water by trans-basin diversion. The most viable source of additional water is the Southeastern coast river basin, where there will be a large amount of surplus water even under critical conditions of the dry season after its in-basin development by 2011.

(2) Water Quality Control

Control of water quality will increasingly be more important for development of the WSB. Poor water quality would become a critical constraint to sustainable economic development through increased water treatment costs and reduced land productivity as well as exhaustion of assimilative capacity of the environment. The following are important components of the water quality control strategy for the WSB.

Groundwater use and drainage

Groundwater in most coastal areas of the WSB has been affected by salinization due in part to over extraction. To reduce groundwater use, availability of surface water should be increased by additional flow regulating structures. Such structures in the Petchaburi and the Western coast river basins should be seen also as the means to cultivate groundwater.

Groundwater tables may be raised as a result of groundwater control and cultivation. This may aggravate drainage conditions in some coastal areas, causing more serious soil salinization problems in the dry season. Drainage by artificial means (e.g., by pumping), however, should be avoided especially in areas of acid sulphate soil. Drainage should be planned carefully in association with irrigation development.

Reservoir operation

Operation of existing dams/reservoirs needs to be improved based on a thorough review, to ensure sufficient discharges during the dry season to minimize salt water intrusion into river estuaries. As clarified in Sub-section 2.2.1, the maintenance flow requirement in the Mae Klong river has not been met during December-January in most years.

Sewage treatment

Water quality in rivers and coastal waters has been degrading along with urbanization/industrialization. Even in the Southeastern coast river basin, water quality in the Chumphon, Park Paung, Au Tapan, and Saiburi rivers have been designated as Class 3 and Class 5 in the five rank classification. Poor water quality involves serious social costs in term of reduced value of land and water for economic activities and higher health risks. Advanced sewage treatment facilities need to be introduced in steps. Priority in the WSB should be given to more rapidly growing urban centers and tourism areas.

2.4.3 Projects

The following five projects have been formulated for inclusion in the WSB master plan.

Project No.	Project Title
WR 1	Irrigated Agriculture Intensification
WR 2	Improvement of Water Management
WR 3	Multipurpose Reservoir Development
WR 4	Salinity Control
WR 5	Flood Control and Drainage Systems Improvement

Each project supports different components of the strategy presented above, and serves collectively the attainment of the objectives.

Irrigated Agriculture Intensification represents the strategy component of demand-side management. Farmers' organizing for the management of on-farm development and water use, and the introduction of revised user charges are important components of the project as well as land consolidation and physical infrastructure.

Improvement of Water Management represents part of the watershed management strategy to be applied in the Mae Klong river basin. Improvement of operation of the existing water works, as suggested in Subsection 2.2.1 is a pre-requisite for the implementation of this project.

Multipurpose Reservoir Development consists of several multipurpose dam projects to be implemented in phases. The Tha Sae dam/reservoir project will be implemented first during Phase I, not only for irrigation and water supply for urban areas in the Southeastern coast river basin but also for water supply for the Bang Saphan development by trans-basin diversion.

Salinity Control addresses a specific issue of the water quality control in the Mae Klong, Tha Taphao and Chumphon rivers. Review of the reservoir operation is important part of the project in view of changing needs for water supply due to more intensive irrigation, diversifying cropping patterns, and increasing urban and industrial uses. In the long run, construction of a salinity control barrage may be required at the estuary, subject to assessment of environmental impact and economic viability.

Flood Control and Drainage Systems Improvement represents another strategy component for water quality control. Drainage systems in major river basins should be planned carefully together with selection of crops and farming systems.