7 / Potential Water Resources Development in the Salween River Basin

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INTRODUCTION

The Salween river basin lies in a mountainous and relatively remote region of south-western China, eastern Myanmar and north-western Thailand, approximately between latitudes 16°15′ and 33°15′ north and longitudes 91°00′ and 100°00′ east (Figure 7.1). The Salween river is an international river originating from the Tibetan plateau and flowing southward through the Yunnan province of China, Shan and Kayah states of Myanmar, along the Thai-Myanmar border, and then through the Kayin state of Myanmar before draining into the Gulf of Martaban of the Andaman Sea. Due to its remote location and the political climate within the riparian countries (China, Myanmar and Thailand), the Salween river basin has not been as prominent as some other international basins in the Asian region (e.g. Mekong, Ganges-Brahmaputra). Excluding a few water resources development works on some of its tributaries, it is only in the last decade or so that serious thoughts, both positive and negative, have been expressed on the potential development of the Salween river itself. The ever-growing water and energy demands in the fast developing economy of Thailand, and severe water shortages for various uses especially during the last few years in Thailand, including the capital city of Bangkok and its vicinity, appear to be the main driving force for these initiatives.

In Thailand, the National Economic and Social Development Board (NESDB) in 1993–94 commissioned planning studies on 25 major river basins in order to address the growing water problems throughout the country. These studies were conducted under the coordination of three main agencies involved in the water sector, namely the Royal Irrigation Department (RID), the Electricity Generating Authority of Thailand (EGAT) and the Department of Energy Development and Promotion

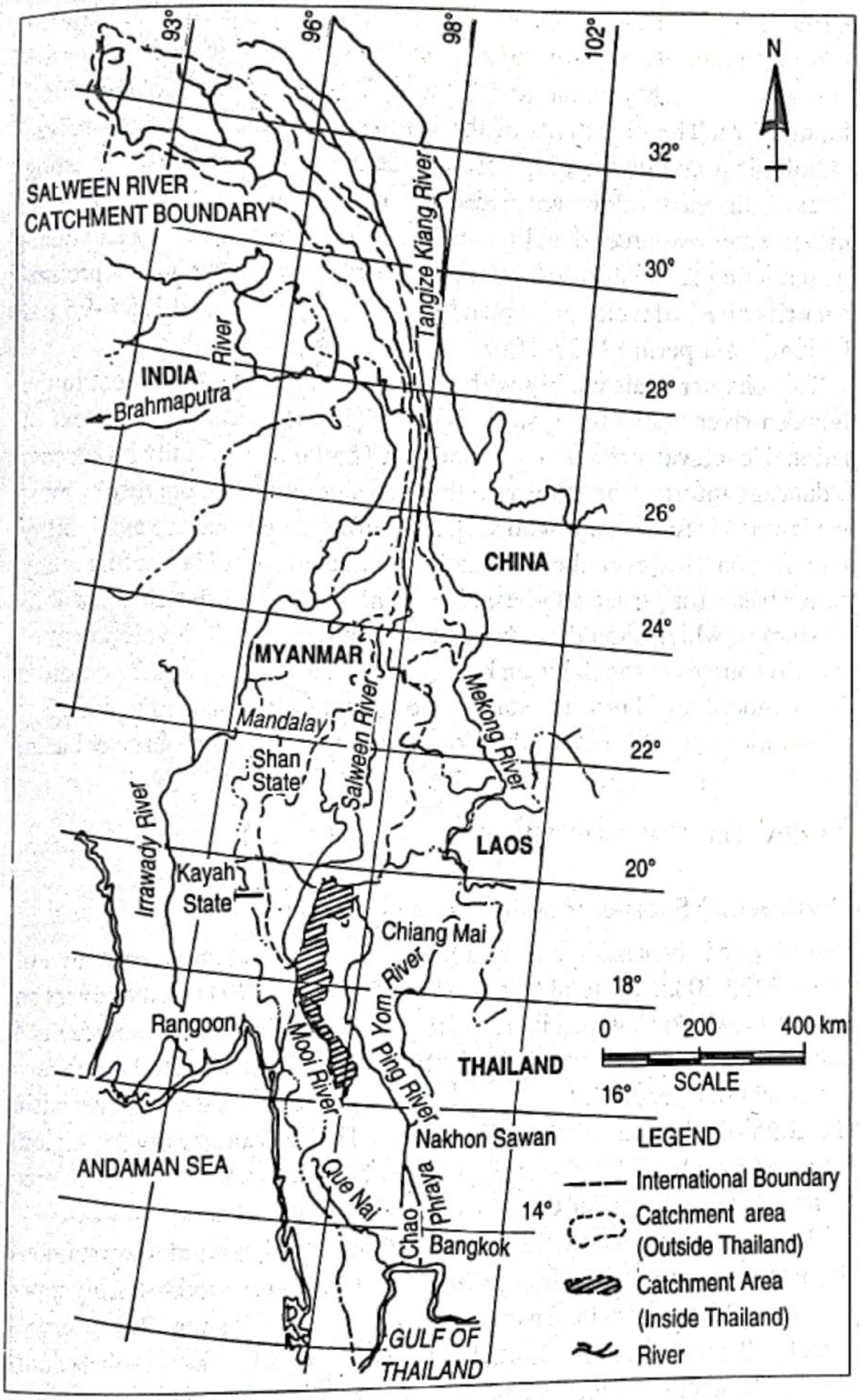

Figure 7.1. Watershed of Salween and Moei river basins for the study area.

(DEDP). One of these studies by AIT (1994) included part of the Salween river basin (and its major tributary, the Moei river, which also forms the border between Myanmar and Thailand) lying within Thai territory (Figure 7.2). The objectives of the studies were to collect and analyse hydrological and meteorological data, details and plans of the existing water resources development projects in order to estimate the potential for further water resources development, both in terms of quantity and quality, including the analysis of water use, in order to come up with a preliminary river basin development plan for the short-term period 1994–96 and the long-term period 1997–2006.

This chapter deals mainly with the water resources assessment in the Salween river (sub-) basin study by AIT (1994), within the context of national level water resources planning in Thailand. The study had access to data and information mainly on the Thai side. As such, the results must be viewed as preliminary, with scope for refinement upon the availability of more data. However, the information generated would be useful for any future basin (or larger sub-basin) level planning and detailed feasibility studies, which should be the next step in the overall development of water resources in the Salween basin. The intention is to briefly describe the methodological process, state some important results and make a few observations on the potential development of this international river basin.

CHARACTERISTICS OF THE SALWEEN RIVER BASIN

Physical and Socio-economic Features

The Salween river basin covers a long and elongated catchment area of about 320,000 km^2 in total (Figure 7.1). The AIT (1994) study covers an area of 17,920 km^2, which includes the whole of Mae Hong Son province and some parts of Tak and Chiang Mai (Figure 7.2). The study area thus covers about 6 per cent of the total drainage area of the Salween river basin (i.e. 2,95,000 km^2) at Ban Mae Pua in the Thai-Myanmar border region. The area may be divided into eighteen sub-basins, which are considered as the planning units for the study.

The study area is characterized by steeply dissected mountainous topography, of relatively fragile watershed and is covered by many types of forests. The present land use consists of forests and range land (approximately 90 per cent), agricultural land (9 per cent) and others such as built-up areas, etc. (1 per cent). As in many other parts of Thailand, agricultural land has increased at the expense of forests over the last couple of years.

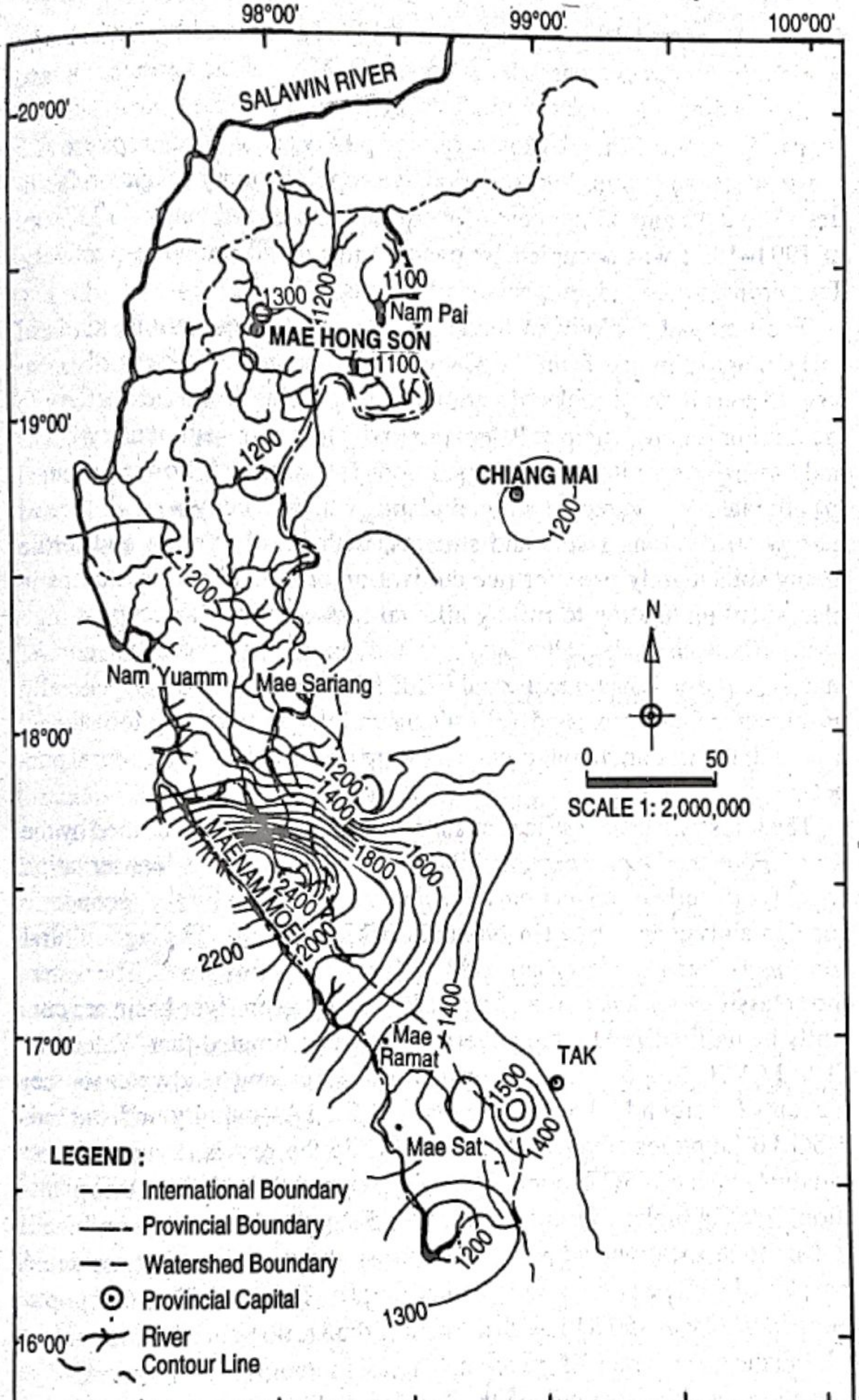

Figure 7.2. Isohyetal map of Mean annual rainfall (mm).

During the period 1986–91, agricultural land increased by 2.3 per cent while forest areas decreased by 3.1 per cent. Most of the agricultural land is observed near Mae Sot in the Tak province. The land system suitable for paddy is quite limited. Mostly rainfed paddy and upland crops prevail; however, some favourable areas do have supplementary irrigation facilities. About 42 and 45 per cent of the total agricultural land of 1727 km^2 in 1991–1992 was occupied by paddy and upland crops, respectively. Tree crops, grassland, etc. occupied the rest.

The regional geology of the study area comprises various kinds of rocks ranging in age from the Cambrian to the present. It mainly consists of consolidated rocks of various types ranging from the Tertiary to the Carboniferous, mainly Paleozoic and Mesozoic sedimentary rocks and Mesozoic granite. The soil conditions fall into the following groups: (a) alluvial soils on recent alluvial plains, which occupy a small area as narrow strips along rivers and streams, with mostly young and fertile loamy soils mainly used for rice cultivation or upland and tree crops in places; (b) undulating to rolling alluvial terraces, which occupy a high position between recent alluvial plains and mountainous areas and consist mainly of red-yellow podzolic and reddish brown lateritic soils, generally unsuited for field crops; and, (c) soils on undulating to rolling footslopes/ hills and steep mountainous areas which are not suited for agricultural purposes.

The forestry land classification map of the study area as outlined by the Royal Forestry Department, Thailand, indicates that the 'conservation zone' (undisturbed) covers most of the area, followed by the 'economic zone', mainly concentrated in the southern Mae Sot area. The 'agricultural zone' and other areas (such as residential) are negligibly small. The watershed classification systems and maps for the Salween river basin are currently being finalized by the government. It is estimated that Watershed Class 1 (WSC 1—protection or conservation forest and headwater source) accounts for around 70 per cent (mostly WSC 1A—wholly undisturbed, WSC 1B being less than 10 per cent), while the rest is divided almost equally between WSC 2 (commercial forest), and WSC 3 (fruit tree plantation), WSC 4 (upland farming) and WSC 5 (lowland farming) combined.

Due to its location and physical features, the study area is considered to be less developed compared to other parts of Thailand. The total population in 1992 was 450,815, with the rural/urban ratio being approximately 4.2 and the growth rate 1.5 per cent. The socio-economic conditions (e.g. education, health, earning) of the local population are poor compared to Thailand's national average. About 45–50 per cent of the population depend on agriculture, 15–20 per cent on trades, services and industry, while 30–40 per cent have no occupation. Less than 10 per cent earn more than the national average and the annual income from employment is less than US $200 for almost half of the population. Although there is a lack of good support services and infrastructure in rural areas, public utility systems such as transport and communications are fairly well developed in the provincial and district headquarters. Many rural areas also have access to fairly good roads and electricity.

From the viewpoint of tourism, the study area is endowed with natural beauties such as waterfalls and caves, in addition to many historical and cultural attractions such as ancient palaces, wats, hill tribes, etc. There are a number of national parks (e.g. Mae Surin, Ka Bak Yai and Lansang) and wildlife sanctuaries (e.g. Mae Pai, Mae Salween, and Mae Yuam) which lie partly or wholly within the area. Mae Hong Son, Mae Sot and Mae Sariang are becoming destinations for increasing numbers of tourists every year.

Hydrologic Characteristics

The general climate of the area is characterized by the winter (November–February), summer (February–mid-May) and rainy (mid-May until October) seasons, influenced by the northeast and south-west monsoons. Altogether, 52 rainfall stations in and around the study area were used for the analysis. Only three index stations recording most of the meteorological variables fall inside the study area but their locations at Mae Hong Son, Mae Sariang and Mae Sot are fairly well-distributed. In general, the number and distribution of these stations appear to be adequate so that the hydrological conditions representative of the study area may be determined. The distribution of mean annual rainfall isohyets (Figure 7.2) shows that rainfall in the Nam Moei sub-basin, particularly in its lower part, is higher than in other sub-basins. It is observed that there is a very wide variation in the annual rainfall values in the study area, ranging from about 900 mm on Om Koi to about 3242 mm in Tha Song Yang. Mean annual rainfall at the representative station at Mae Sariang is about 1180 mm. It is generally observed that of the total annual rainfall, more than 90 per cent occurs during the six-month period from May to October and more than two-thirds falls during the period June–September. July and August are normally the months of heaviest rainfall. The variation of monthly rainfall is much higher than that of annual values.

Although rainfall distribution in the study area was found to vary considerably, other meteorological variables were not. Data from the representative station at Mae Sariang show that the mean monthly temperature is quite uniform throughout the year ranging from about 21° to 30°C.

Extreme maximum and minimum temperatures of 43°C and 3.3°C are observed in April and December, respectively. The annual mean, mean maximum and mean minimum values of relative humidity are 76, 94 and 53 per cent respectively. The mean monthly pan evaporation values at the Mae Sariang index station shows that the maximum value of 192.7 mm occurs in April and the minimum value of 84.9 mm occurs in December. The mean annual evaporation at the station is 1413.0 mm. The net rainfall that is potentially available for run-off occurs only during the period from May to October.

The complex and mountainous topography of the Salween river basin has given rise to a similarly complex river system network. The study area was divided into 18 different sub-basins and 4 independent main sub-basins as planning units for analysis. There are altogether 35 stream gauging stations including the one on the main Salween river, out of which 14, 12 and 8 lie in the Nam Mae Pai, Nam Mae Yuam and Mae Nam Moei sub-basins, respectively. Sediment volume records are available in 23 stations whereas annual extreme value records of flood flows and low flows are available for 24 stations. For planning purposes, monthly streamflow records should have at least 25–30 years' data up to the latest possible date. Since many stations had data problems, the HEC-4 Monthly Streamflow Simulation Model developed by the Hydrologic Engineering Center, US Army Corps of Engineers, was adopted to fill up the missing values and reconstitute the flows at all the sites for the common period 1965–91. For HEC-4 application, only 31 stations with more than 7 years of data were considered. The model results were found to be satisfactory and consistent with the correlation coefficients of raw data. The model also preserved the basic statistics of the original data series very well.

The average specific yields of the streams in the basin are of similar order of magnitude and range from 6.1 to 47.2 sec/km^2. For the Salween river, the yield as 12.3 sec/km^2, whereas for the Moei river it is 26.5 sec/km^2. It is generally observed that August and September are the months of largest flows. More than two-thirds of the annual flow occurs during the period from July to November. For the Salween and Moei rivers, flow during June–November is more than 75 per cent of the annual values. Figure 7.3 shows the monthly streamflows of the Salween river at Ban Mae Pua (drainage area = 295,000 km^2). The variability of flows during rainy months is higher than that during dry months. Coefficients of variation of annual flows of the Salween and Moei rivers are respectively 0.15 and 0.25. The total mean annual run-off from the study area is 8570.7 million m^3 (MCM) which is about 7.6 per cent of total run-off at the Ban Mae Pua gauging station on the Salween river. The average annual sediment

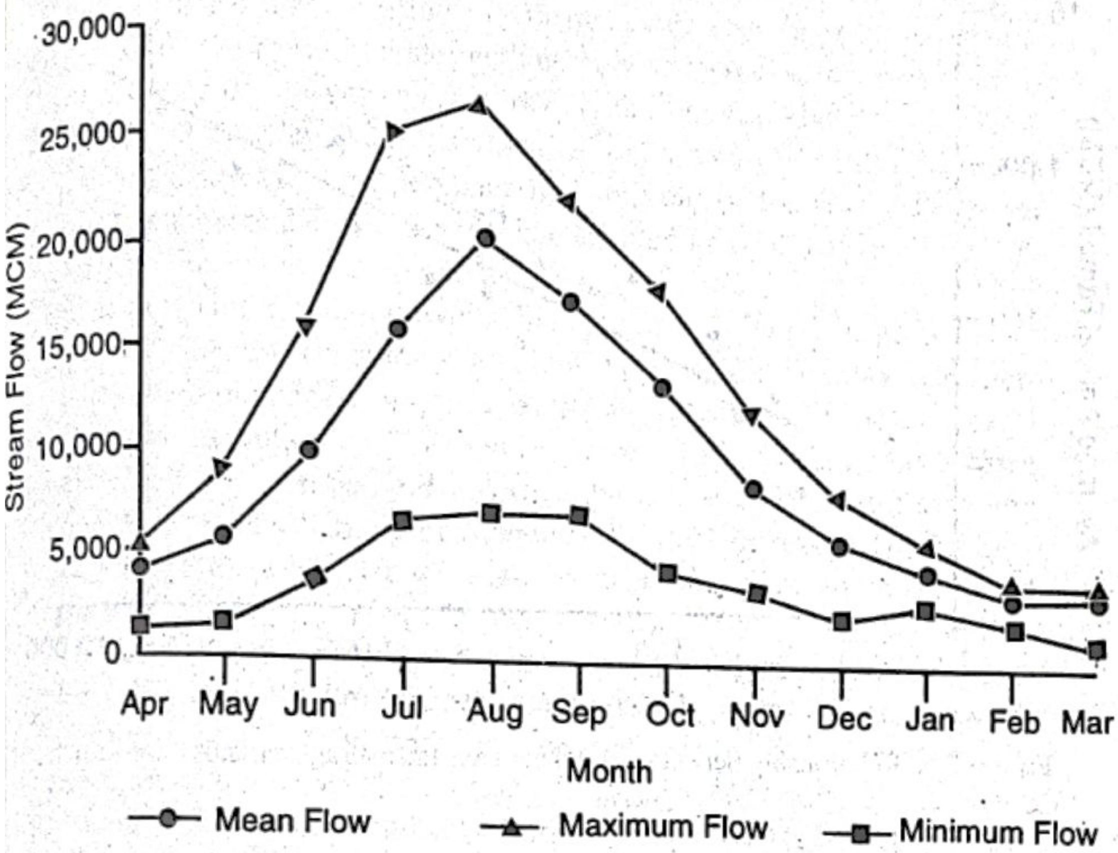

Figure 7.3. Maximum, minimum and average monthly streamflow of Salween river at Ban Mae Pua (years of record: 1970–90).

yield varies from 22.1 to 460.18 tons/km^2 and more than 75 per cent of the annual sediment load occurs between July and October. The sediment yield of the Moei river is 196.5 tons/km^2, while that of the Salween river at 0.25 tons/km^2 is significantly lower. This indicates relatively good upstream watershed conditions in the Salween river basin.

Two sets of relationships, the first between catchment area and average annual run-off, and the second between catchment area and average annual sediment volume, for the sub-basins in the region were developed using regression analysis. These regional relationships, shown in Figure 7.4 and Figure 7.5, may be used for any ungauged location in the basin with catchment area between 33.5 and 8360.0 km^2. Due to its distinctly different specific discharge and sediment yield characteristics, the Salween river itself was not considered.

Information on hydrogeology and groundwater wells in the study area is limited. The geological formations in the area are made up of consolidated and unconsolidated rocks. The consolidated rocks consist of many rock types with widely different lithology, age and structural history. The

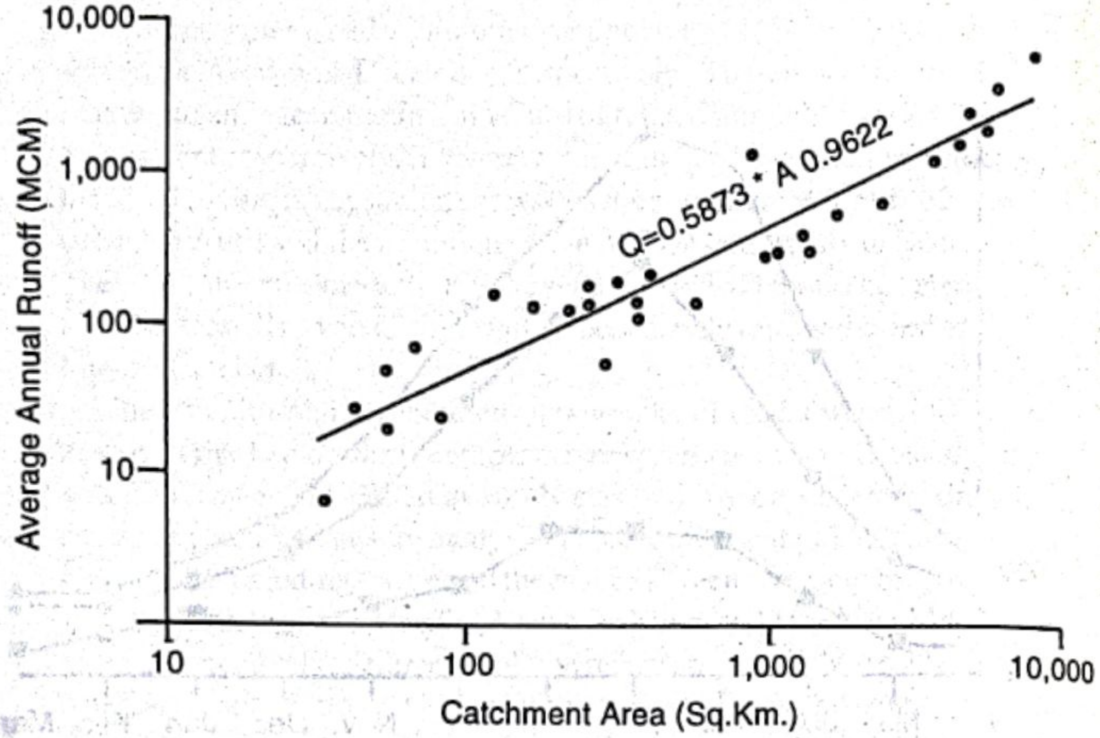

Figure 7.4. Relationship between catchment area and average annual run-off for Salween river basin.

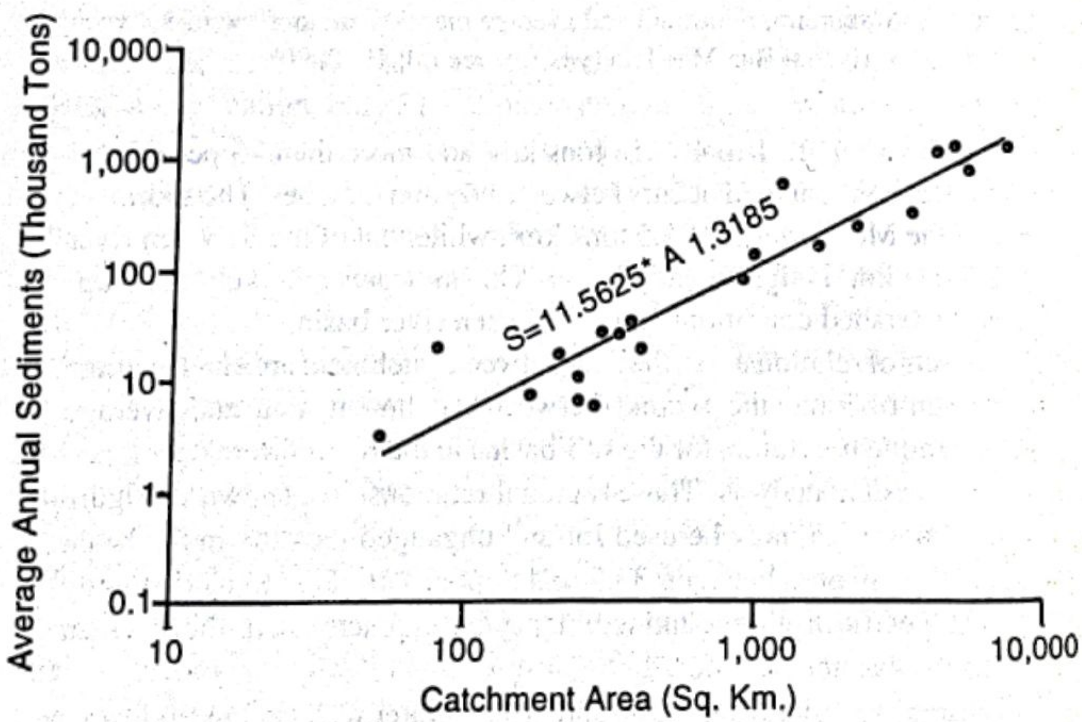

Figure 7.5. Relationship between catchment area and average annual sediment load for Salween river basin.

consolidated rocks are not suitable because groundwater is limited in quantity and is stored in joints, fractures, cavities, bedding planes, decomposed zones, or contact zones with neighbouring rocks. In the study area, important groundwater aquifers are only the unconsolidated sediments of alluvial and terrace deposits which occur as a narrow strip in the Mae Sariang district, where jetted and dug wells can be found. The thickness of the unconsolidated sediments is estimated as 30–50 m. Well yield is 5–10 m^3/hr.

Limited information is available about the quality of surface water as well as groundwater in the study area. Surface water quality characteristics were obtained from field water supply offices of the Provincial Waterworks Authority (PWA) in Mae Hong Son, Mae Sot, Mae Sariang and Phop Phra. Some field investigation and analysis of surface water quality in the Mae Sariang area conducted in 1991 are reported by Technology Ace et al. (1992). However, they indicate that physical, chemical and bacteriological properties of water are mostly well within the National Drinking Water Quality Standards for surface and groundwater in Thailand (NEB, 1989). Only in few cases, turbidity (in case of surface water during the rainy season) and manganese content (in case of groundwater) were found to be over the maximum allowable concentration. Thus, the existing natural conditions and human impacts appear to be environmentally sound.

WATER PROJECTS AND DEMAND ASSESSMENT

Irrigation

Though there are no large-scale irrigation projects within the basin, irrigation is and will continue to be the principal use for water in the study area. There are several existing and potential medium-scale, small-scale diversion and pumping irrigation projects. Although RID is the main responsible government agency for the irrigation sector, many other agencies are also involved in small-scale projects. Operation and maintenance of these small schemes are usually carried out by farmers themselves. In 1993, about 30,234 ha and 9111 ha were irrigated during wet season and dry season, respectively. Medium-scale irrigation projects covered only about 19 and 38 per cent in wet and dry season respectively, while the rest came under small-scale and pumped projects. Total potential irrigation areas in 1996 and 2006 are 34,149 and 57,107 ha respectively. The proportion of medium-scale, small-scale and pumping schemes are respectively 19.9, 72.9 and 7.2 per cent for 1996, and 41.4, 53.3 and

5.3 per cent for 2006. Most of the potential medium projects lie in the Moei sub-basin.

Irrigation water demand was calculated for existing conditions as well as for short-term (1994–96) and long-term (1997–2006) periods. Irrigation water requirements were estimated based on the reference crop evapo-transpiration computed from the FAO Modified Penman method. In order to properly reflect the system type and agro-meteorological characteristics of the study area, six models were considered for calculating net irrigation water requirements for an unit area. Two system types (i.e. medium-scale or pumping schemes with 160 per cent cropping intensity and small-scale schemes with 120 per cent cropping intensity) and three main sub-basins (i.e. Pai, Yuam, and Moei) were considered. Different irrigation efficiencies were considered for wet and dry seasons, and for existing (15 per cent, 30 per cent), short-term (15 per cent, 30 percent) and long-term (30 per cent, 50 per cent) planning periods. These guideline values are quite conservative and the long-term values assume improvement in efficiencies.

Annual gross water demands were estimated to be 616.927, 696.741 and 635.03 MCM respectively for existing (1993), short-term (1996) and long-term (2006) conditions. The long-term irrigation demand is less than the short-term demand due to high irrigation efficiencies. With existing efficiencies (i.e. considering no improvement), however, it is found that the annual gross water demand of 1223.38 MCM is much higher. About 85 and 15 per cent of the annual demand occur, respectively, in the wet season paddy crop during June–October and dry season upland crops (mainly soybean) during November–February for both existing and short-term conditions, whereas the corresponding figures for long-term conditions are 78 and 12 per cent.

Domestic and Other Uses

In the urban and semi-urban areas served by Provincial Waterworks Authority (PWA), people are provided with treated and piped water supply systems. In rural areas, people directly utilize various natural sources of water such as rainwater, springs, groundwater and surface water. Based on the available information and estimates, the consumption rates for domestic purpose in the study area were considered as 50 and 175 litres per capita per day respectively in rural and urban areas. Gross domestic water demands in 1993, 1996 and 2006 were estimated to be 11.77, 12.32 and 14.29 MCM respectively. As a considerable proportion of the existing population has access to drinking and domestic water supply facilities, net water demand for additional population in the future is significantly reduced. Similarly, based on certain criteria for water consumption rates and the growth rates assumed for other water use sectors, water demands were estimated for various time periods. The water demands in 1993, 1996 and 2006 are respectively 1.98, 3.421 and 21.184 MCM for industry; 0.525, 0.552 and 0.650 MCM for tourism; and, 1.953, 2.026 and 2.447 MCM for livestock. Thus, water demands for these purposes within the study area are very small.

Hydropower

Only mini- and micro-hydropower projects currently exist in the area. The total installed capacity of existing mini-hydropower projects (normally greater than 200 KW) is 7.8 MW generating an annual energy of about 46.3 GWh. The total installed capacity of existing micro-hydro projects (normally smaller than 200 KW) is 128.2 KW. Seven mini-hydropower projects with total installed capacity of 14.7 MW and annual energy generation of 72.4 GWh are included in DEDP's master plan. An additional nine projects, with total installed capacity and annual energy of 18.2 MW and 79.5 GWh respectively, are identified. Several micro-hydropower projects are also identified by DEDP. These potential projects add up 860 KW, providing an annual energy of about 7.5 GWh. Nine micro-hydropower projects with total installed capacity of 190 KW and annual energy of 1.7 GWh, are additionally identified.

Due to the ever-increasing energy demand of the rapidly developing economy of the country, Thailand has long been actively involved and interested in the development of hydroelectric power projects, including those on international rivers. In the study area, several large- and medium-scale potential hydropower development projects have been identified and studied at different levels by various previous investigations co-ordinated by EGAT and DEDP (NEA). As shown in Table 7.1, there are altogether 13 potential projects of different sizes whose total installed capacity is 6650 MW and annual energy generation is 37,660 GWh. Out of these, only eight projects lie within the Thai territory while the other five which lie on the international rivers Salween and Moei have a combined installed capacity of 5961 MW and annual energy generation of 36,091 GWh. Locations of the projects are shown in Figure 7.6. The salient features of these international river projects are based upon the preliminary study by EPDC (1992), which also considered all the previous project proposals on Salween and Moei rivers by EGAT and DEDP (NEA).

According to EPDC (1992), from an economic viewpoint (benefit/cost

Table 7.1. Potential large- and medium-scale hydropower projects

No.	Project	Province	Index map	Sub-basin no./project code	Catchment area (sq. km)	Annual flow (MCM)
1	Upper Nam Pai	Mae Hong Son	4647 II	2/02H1	1,142	447
2	Huai Mae Sa	Mae Hong Son	4647 II	3/03H1	477	186
3	Nam Pai No. 1	Mae Hong Son	4647 II	5/05H1	1,817	728
4	Nam Pai No. 6	Mae Hong Son	4647 IV	5/05H2	3,725	1,578
5	Nam Mae Samat	Mae Hong Son	4647 III	6/06H1	1,540	523
6	Nam Mae La Luang	Mae Hong Son	4646 III	9/09H1	248	77
7	Mae La Ma Luang (Nam Yuam)	Mae Hong Son	4544 I	10/10H1	6,030	2,948
8	Nam Nago	Mae Hong Son	4544 I	13/13H1	835	1,366
9	Upper Salween	Mae Hong Son	4545 IV	–/14H1	2,93,100	1,18,627
10	Lower Salween	Mae Hong Son	4545 III	–/14H2	2,94,500	1,18,627
11	Moei No. 1	Tak	4741 IV	–/16H1	1,810	1,360
12	Moei No. 2	Tak	4643 II	–/18H1	6,420	4,810
13	Moei No. 3	Tak	4544 I	–/18H2	8,710	8,590

Table 7. 1 (*contd.*)

No.	Full supply level (msl)	Installed capacity (MW)	Annual energy (GWh)	Construction cost (1993) (million Baht)	Cost/KW Baht/KW	Agency	Watershed class	Forest class
1	495.0	17.5	38.3	1,075	61475.12	EGAT	4	WS* & C
2	515.0	10.2	22.2	823	80,675.24	EGAT	3	C & E
3	475	48.9	112.4	2,458	50258.58	DEDP	1A	WS & C
4	400.0	291	620	10,138	34837.06	DEDP	1A, 1B	NP*, WS, C
5	415.0	39.9	87.5	2619	65639.60	EGAT	1A	NP & C
6	650.0	9.2	20.1	657	71454.08	EGAT	1A	C
7	155.0	160	411	6303	39393.47	EGAT	1B	C & E
8	270.0	140	318	4975	35536.95	EGAT	2	C
9	220.0	4540	29,271	82,742	18225.11	DEDP	1A	C
10	86.0	792	5422	23648	29858.59	DEDP	4	C
11	300.0	110	244	4161	37827.27	DEDP	2	C
12	180.0	231	523	6091	26367.97	DEDP	1B	C
13	120.0	288	631	8985	31197.92	DEDP	2	C
Total		6,650.0	37,660.0	152,776.8				

*NP—National Park; WS—Wildlife Sanctuary; C—Conservation Forest; E—Economic Forest

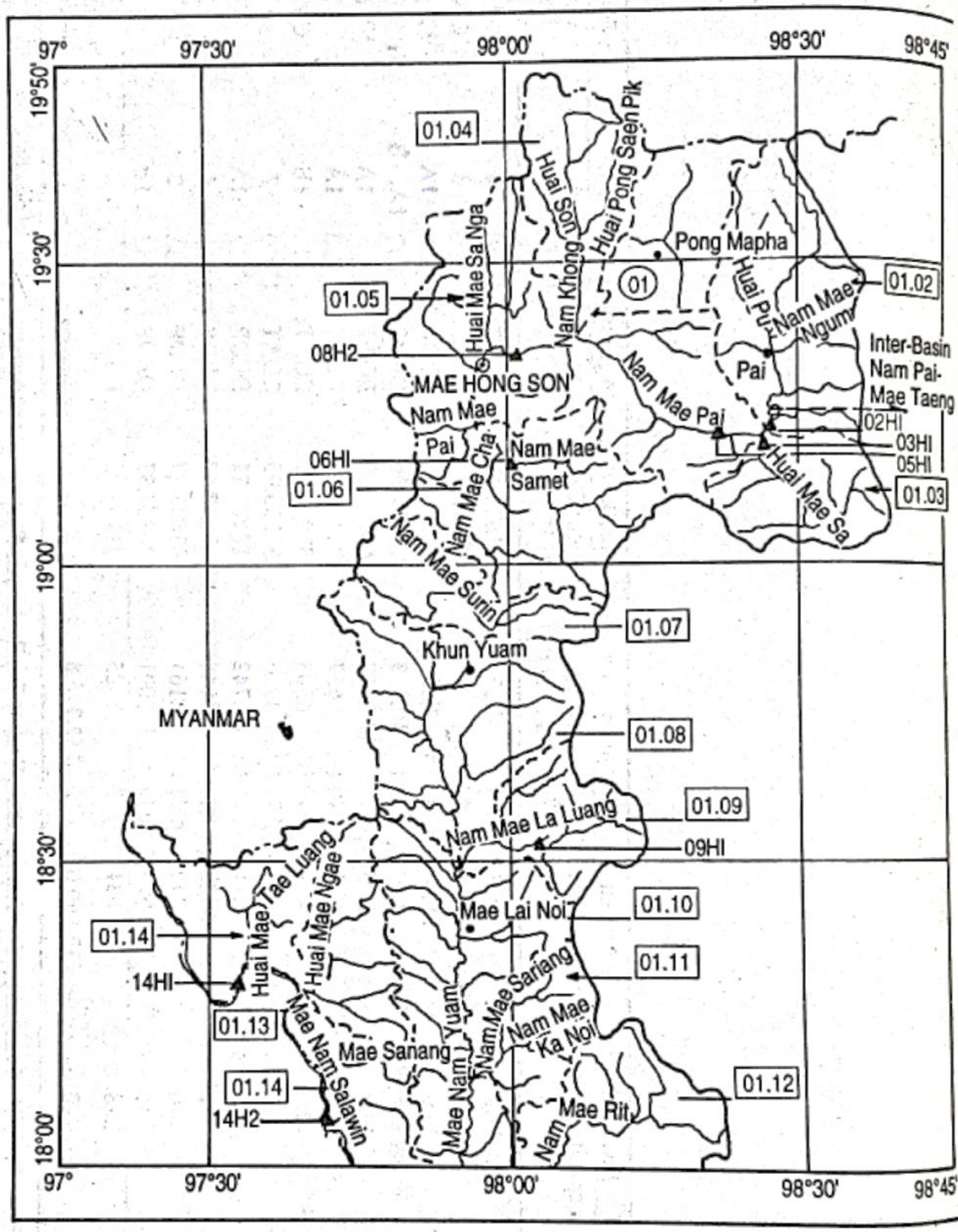

Figure 7.6. Potential hydropower projects.

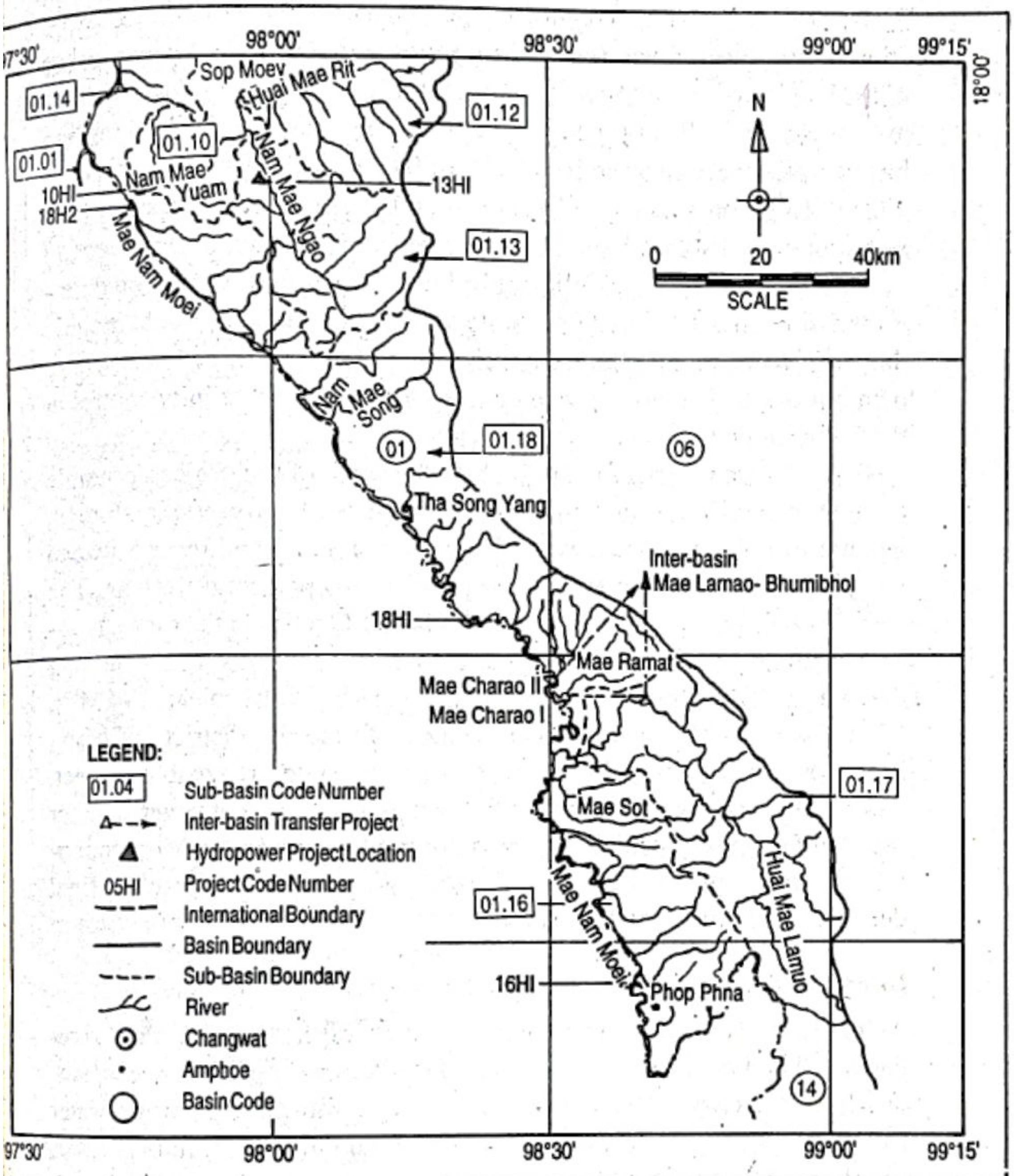

Figure 7.6. (*Cont.*)

ratio at 10 per cent discount rate), the Upper Salween project had the highest B/C ratio of 4.92 followed by the Lower Salween project (3.25). These projects are actually multi-purpose in nature. Major benefits will be from hydropower generation and irrigation, mainly on the lower reaches of the Salween river in Myanmar outside the Salween basin. Irrigation area at the reservoir full supply level of 220 m is estimated to be 1.20 million ha during the wet season and 0.48 million ha during the dry season (EGAT, 1981). Irrigation area as well as social and environmental impacts, such as population displaced, and farmland or forest land inundated, depend upon the specification of full supply level, which will have to be determined following a detailed feasibility study. Other benefits might include domestic water supply, flood control (on the Myanmar side), fishery, augmentation of low flow, improvement in navigation and salinity control in the Salween delta.

Considering various factors such as the scale of the project, possible inundation and environmental impacts due to dam/reservoir storage, amount of funds required, ease of negotiation, etc., the Lower Salween project appears to be an attractive option at this preliminary stage. The smaller-scale projects on the Moei river had B/C ratios in the range 1.02–1/27, with the Moei 2 Project appearing to be the most favourable among the three. EPDC (1992) also indicated that the Mae Kok Project (294 MW, 637 million KWh), located at Ban Tha Don of Mae Eye district of Chiang Mai province was most likely to be an appropriate or sizeable project, among all the six projects on Thai-Myanmar border. However, further detailed feasibility studies, within a comprehensive basin-wide economic-environmental analytical framework, are necessary before the final decision for implementation is made.

Inter-basin Water Transfer

As the water supply versus demand scenario of the adjacent Ping river basin in Thailand is unfavourable and is increasingly getting worse, studies have been conducted to investigate the possibility of diverting water from various sub-basins of the Salween to the Ping basin. In particular, supplying the important Bhumibol reservoir with water from the Salween river basin is envisaged to be one of the methods which could be employed to alleviate the water shortage problems in other regions (upper and lower Chao Phraya or central plains including the capital Bangkok and its vicinity) and to provide benefits related to hydroelectricity, irrigation, industrial and domestic water supply, low flow augmentation and salinity control in the Chao Phraya delta. The economy of the rapidly developing

Thailand is heavily dependent on the central region as most of the industrial and agricultural activities are concentrated there. Accordingly, a major proportion of Thailand's existing as well as future water demand is required in this region.

ESCAP (1991) has estimated that about 38,500 million m^3 will be required annually for irrigation in Thailand by the year 2000 and 68.5 per cent (26,400 MCM) of this amount will be required in the central region. This corresponds to an estimated annual irrigated area of 3.4 million ha for the whole country and 2.25 million ha for the central region in the year 2000. Since these estimates are based on past trends and do not consider the likely irrigation water requirements of potential irrigation areas (especially during the dry season and under lower irrigation efficiencies), these are possibly underestimates. Similarly, the domestic (urban and rural) and industrial water demand in the central region of Thailand by the year 2000 will be 1800 (1639 for urban and 161 for rural) and 2099 MCM per year. Furthermore, demands for low flow augmentation and environmental control in the central region continue to rise. The same study has also estimated that only 10,900 million m^3 of water resources are available annually in the central region, thus accounting for at least 19,399 MCM of water shortage in the year 2000. Although various strategies such as demand management, improvement of irrigation efficiencies, improved water allocation policies, use of groundwater, etc. have their critical roles in improving the situation, the magnitude of shortage clearly indicates the importance of any inter-basin water transfer that is feasible.

Newjec et al. (1993a, b) have studied various water diversion schemes for the augmentation of the Bhumibol reservoir:

(1) Mae Lamao-Bhumibol transfer project (feasibility study)
(2) Nam Pai-Mae Taeng transfer project (preliminary study)
(3) Mae Charao 1 transfer project (feasibility study)
(4) Mae Charao 2 transfer project (feasibility study)

The details of these inter-basin water transfer projects are summarized in Table 7.2 and their locations shown in Figure 7.6. Based on a comparative study of various schemes from Nam Pai and Mae Charao (except Mae Lamao), Newjec et el. (1993a) recommended the alternative Mae Charao 2 for further investigation considering factors such as diversion amount, tunnel length, location of outlet and benefit cost ratio. In this scheme, water from the Nam Moei river is pumped up to the proposed Khanaeng Khi Thoe reservoir and then conveyed to the Mae Tun river. Newjec et al. (1993b) note, following a comparative study by EGAT in

Table 7.2. Proposed interbasin diversion projects

No.	Project	Province	Transferred from/to	Catchment area (km^2)	Annual inflow (MCM)	Full supply level (msl)	Annual diverted water (MCM)	Lifting head (m)	Conveyance canal capacity (m^3/s)	Construction cost in 1993 (million Baht)	Remarks
1	Mae Lamao–Bhumibol	Tak	Salween/ Ping	1395	457.4	250.0	356.1	80.0	25.0	5342	Cost excludes D/S irrigation
2	Nam Pai–Mae Taeng	Mae Hong Son/ Chiang Mai	Salween/ Ping	1660	530.0	480.0	455.0	75.0	40.0	7952	B/C = 1.74
3*	Mae Charao 1	Tak	Salween/ Ping	5808	4074.5	170.0	599.7	123.0	40.0	9348	Diversion through Mae—Lamao dam
4*	Mae Charao 2	Tak	Salween/ Ping	6261	4371.0	140.0	629.0	169.0	40.0	6538	Independent scheme B/C = 1.99

*Water is diverted from the international river Moei; however, diversion is less than the contribution from the Thai territory.

1987 on various water diversion schemes from the Pai, Ngao, Moei and Mae Lamao rivers for Bhumibol reservoir, that the Mae Lamao-Bhumibol diversion would be the most promising one. Both Mae Charao schemes originate from the Thai side of the international river Moei. AIT (1994) examined only the Mae Lamao-Bhumibol and Nam Pai-Mae Taeng interbasin transfer schemes. Whereas the Mae Lamao-Bhumibol scheme proposes to divert 356 MCM of water annually by means of a tunnel capacity of 25 m^3/s, the Nam Pai-Mae Taeng scheme intends to divert 455 MCM annually through a 40 m^3/s capacity tunnel. Mae Charao intends to divert even more water. Furthermore, it seems possible to divert much larger quantities of water from the main stream of the Salween river. This should be investigated further.

Watershed Management

There are many types of small-scale watershed and environment management projects, including several Royal projects, existing and planned in the study area. Due to the lack of data and because these projects usually have broad objectives and socio-economic impacts, it is difficult to assess their status at this stage. However, it is necessary to seek or coordinate the management of all the natural resources within a catchment area in order to conserve and enhance the natural environment and the yield of water sources. Hence, these small projects should also be considered in the development programme for the future and could be implemented by concerned agencies at appropriate levels, normally at the village levels. As suggested by the NESDB guidelines, the minimum water necessary to maintain low flow conditions and environmental quality at various control points have been estimated based on the average annual low flows, which is a conservative assumption. Since the available information on water quality conditions indicates sound natural conditions and negligible human impacts, water demands for environmental quality control are not expected to be great.

ANALYSIS OF POTENTIAL WATER RESOURCES DEVELOPMENT

In order to study the water supply and water demand relationship for existing as well as future conditions, and to determine the maximum potential for water resources development in the basin, the HEC-3 'Reservoir System Analysis for Conservation' developed by the Hydrologic Engineering Center of the US Army Crops of Engineers in 1981 was used

(HEC, 1981). The model simulates the behaviour of a water resources system for such conservation purposes as water supply, navigation, recreation, low flow augmentation and hydroelectric power. HEC-3 consists of five basic system components: system hydrology, reservoirs, control points, power plants and diversions. The HEC-3 model is popular in Thailand at present.

For analytical purposes, the whole basin in the study area was divided into three independent main sub-basins (namely Nam Mae Pai, Nam Mae Yuam and Mae Nam Moei) and a combined sub-basin consisting of two smaller independent sub-basins (namely Huai Mae Tae Luang and Nam Mae Ngae). HEC-3 was used to run each model configuration/scenario for the three water demand scenarios (i.e. existing case—1993; short-term case—1996; and long-term case—2006) and 27 years of streamflow data reconstituted using the HEC-4 model. The simulation model also considered such details as the minimum flow constraints, local flows, return flow components, proposed project characteristics, reservoir operating criteria and diversion requirements at various specified locations. The sub-models were conceptualized and run individually so that, when combined, they yielded the water balance for the whole study area. Figure 7.7 presents a flowchart showing the main steps of the analysis by the HEC-3 model.

Present and Future Scenarios

The analysis of the situation in 1993 indicates that, except in sub-basins 5, 10 and 16, all types of water demands in all the sub-basins are satisfied without any significant shortages. Shortages of about 8.8, 10.2 and 3.8 per cent in meeting irrigation demands and about 8.8, 11.2 and 17.5 per cent in meeting the required minimum flows at control points occur respectively in sub-basins 5, 10 and 16. For the whole basin, the model results show that out of the average annual inflow of 8565.67 MCM, about 7.2 per cent is diverted for irrigation and other uses, 6.3 per cent is actually consumed, and 93.8 per cent (including return flow) flows downstream.

Analysis of the short-term situation in 1996 represents the condition at the end of the current Seventh National Economic and Social Development Plan (1992–96). Most of the projects and water demands in this case correspond to those already planned in the study area by several government agencies. For the whole basin in 1996, about 8.0 per cent of the average annual inflow of 856.67 MCM is diverted for irrigation and other uses whereas the consumptive use and outflow from the basin account for about 7.1 and 92.9 per cent respectively.

For the long-term development by the year 2006, only one major

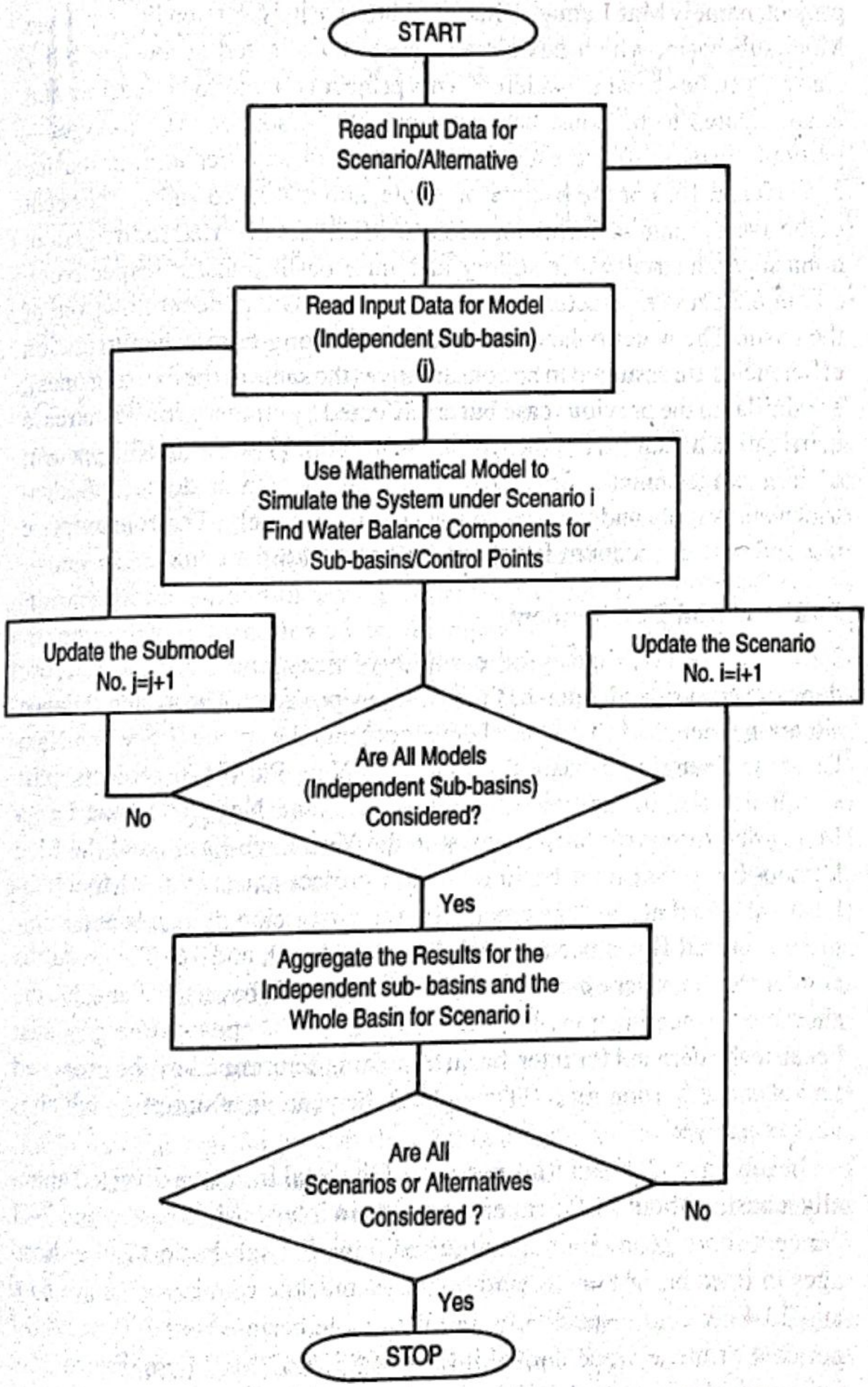

Figure 7.7. Flowchart for HEC-3 model analysis.

project, namely Mae Lamao-Bhumibol Interbasin Diversion Project in the Moei sub-basin, which has already been investigated at the feasibility study level, has been considered. This project is found to be feasible and is anticipated to be constructed during 1998–2002. Some shortages—particularly in meeting the required minimum flows—occur in sub-basins 2, 5, 10 and 16. For the basin as a whole, about 7.2, 0.6 and 4.0 per cent of the average annual inflow of 8565.67 MCM are diverted for irrigation, domestic/industrial water supply and inter-basin transfer respectively. About 6.8 per cent is actually consumed while 89.2 per cent flows out of the basin. The water balance situations in the long-term, when irrigation efficiencies are assumed to be conservative (the same as the existing ones), are similar to the previous case but are affected by almost twofold increase in irrigation demands. For the whole basin, about 12.9, 0.6 and 3.5 per cent of the average annual inflow are rediverted for irrigation, domestic/industrial water supply and inter-basin transfer, respectively. The consumptive use and outflow account for about 11.7 and 84.8 per cent.

Full Potential Development

This condition investigates the feasibility of many potential multi-purpose dams/reservoirs and inter-basin diversion projects. The water balance situation when the full potential development takes place (i.e. when Nam Pai–Mae Taeng inter-basin diversion and Nam Pai No. 6 projects exist simultaneously in the Pai sub-basin, both Nam, Ngao and Mae Lama Luang dam/reservoir projects exist in the Yuam sub-basin, and the Mae Lamao–Bhumibol inter-basin diversion project exists in the Moei sub-basin) shows that shortages in meeting the irrigation demands and minimum required flows occur in sub-basins 2, 5, 10, and 16. This result is similar to the earlier observation. However, in sub-basins 2, 3 and 17, the shortages in meeting trans-basin diversion amount appear to be significant because the demand for inter-basin transfer is determined by the proposed tunnel capacity running full throughout the year, an assumption which is very conservative.

In sub-basin 2, about 91.1 per cent of the total inflow is diverted annually, causing about 71.9 per cent shortage in inter-basin transfer and 74.1 per cent shortage in minimum required flow. For sub-basin 17, the shortages in inter-basin transfer and downstream flow requirements are 57.0 and 20.4 per cent respectively. For the whole basin, about 7, 0.6 and 8.1 per cent of the average annual inflow of 8565.67 MCM are diverted for irrigation, domestic/industrial water supply, and inter-basin transfer purposes, respectively. About 6.6 per cent is actually consumed while only 77.9 per cent flows out of the basin.

Alternative Large Projects

As the actual development of water resources projects is determined by socio-economic, environmental, and institutional factors, in addition to technical and financial ones, there are other possible scenarios which might alternatively exist in the long term (2006) and beyond. Besides, the characteristics and performance of individual projects are useful for planning and policy-making purposes. Hence, various possible alternative scenarios for major projects have been developed and studied using HEC-3 models.

Pai Sub-basin

For the Pai sub-basin, three individual projects identified by previous studies and four possible scenarios or schemes have been considered. The upper Pai reservoir in sub-basin 2 has been proposed as an inter-basin water transfer scheme which will also collect water from sub-basin 3 through a tunnel and divert the collected water together to Mae Taeng river, which, in turn, flows into the important Bhumibol reservoir. Nam Pai No. 1 and Nam Pai No. 6 are the two other projects studied for storage-based hydropower development. Table 7.3 provides a summary of the performance characteristics of the reservoir projects for the four scenarios. Under scenario 1, if the Nam Pai–Mae Taeng inter-basin water diversion (i.e. Upper Pai) project is not implemented, but Nam Pai No. 1 and Nam Pai No. 6 are simultaneously developed, then they can generate 64.2 and 467.9 GWh of annual energy respectively. These figures are very close to those under independent development of Nam Pai No. 1 (i.e. 64.2 GWh for scenario 3) and Nam Pai No. 6 (i.e. 467.6 GWh for scenario 4). This shows that there is no synergistic gain due to the simultaneous development of Nam Pai No. 1 and Nam Pai No. 6. Hence, these projects need not be developed simultaneously.

Comparison of the reservoir performance parameters with and without the Upper Pai transfer project shows that the output of Nam Pai No. 6 is significantly reduced with the development of the Upper Pai. The size of this dam/reservoir hydropower project, as proposed by previous studies appears to have been overestimated in the presence of at an inter-basin transfer project. A detailed re-evaluation of the studied features of this project is, therefore, recommended if the inter-basin diversion project is seriously considered for implementation. Both Nam Pai No. 1 and Nam Pai No. 6 fall under watershed class 1A and conservation forest zone. For the Nam Pai–Mae Taeng inter-basin transfer project, variation of the annual diversion amount with tunnel capacity (Table 7.4) shows that by

Table 7.3. Summary of reservoir parameters in Pai sub-basin

Description	Present Study					JICA 1981	
	Scenario 1						
	Nam Pai #1	Nam Pai #6	Scenario 2 Nam Pai #6	Scenario 3 Nam Pai #1	Scenario 4 Nam Pai #6	Individual river Nam Pai #1	Development Nam Pai #6
Catchment area (km^2)	1817	3725	3725	1817	3725	1817	3725
Inflow (MCM)	488.86	1192.45	855.07	488.86	1194.14	729.07	1578.32
High water level (msl)	475	400	400	475	400	475	400
Low water level (msl)	463	387	387	463	387	463	387
Storage capacity (MCM)	765	2421	2421	765	2421	765	2421
Effective storage (MCM)	290	571	571	290	571	290	571
Normal intake level (msl)	471	395.7	395.7	471	395.7	471	395.7
Tail water level (msl)	402	224	224	402	224	402	224
Normal effective head (m)	67.3	169.2	169.2	67.3	169.2	67.3	169.2
Installed capacity (MW)	48.9	291	291	48.9	291	48.9	291
Annual energy (GWh)	64.2	467.9	331.8	64.2	467.6	112.42	619.95
Annual firm energy (GWh)	42.79	303.86	205.01	43.15	307.61	82.36	495.98
Net evap. (MCM)	9.16	15.7	14.73	9.45	15.4	—	—
Power release (MCM)	429.18	1187.7	852.53	428.73	1188.27	—	—
Spill (MCM)	0	1.23	0	0	2.66	—	—

Notes: Scenario 1: Pai No. 1 and Pai No. 6 only (without Upper Pai).
Scenario 2: Upper Pai and Pai No. 6 (without Pai No. 1) (full potential development).
Scenario 3: Nam Pai No. 1 only.
Scenario 4: Nam Pai No. 6 only.
JICA: Prefeasibility study made by JICA (1981).
Upper Pai indicates Pai–Mae Teng inter-basin diversion.

Table 7.4. Variation of annual diversion amount (MCM) with tunnel capacity for Nam Pai–Mae Taeng inter-basin transfer project (FSL = 480 msl)

Tunnel capacity (cm)	20	30	40	50	60
Diversion (MCM)	274.85	326.89	354.96	367.41	373.12

reducing the capacity of the tunnel from 40 m^3/s to 30 m^3/s (25 per cent reduction), almost 92 per cent of the annual diversion amount is achieved, whereas by enlarging the tunnel capacity to 50 m^3/s (25 per cent enlargement), only about 3.5 per cent increase in diversion amount occurs. The results favour a reduction in the tunnel capacity for optimum development; however, the exact size will have to be determined in a more detailed study. It is also noted that the annual diversion amount is only 355 MCM compared to 455 MCM as quoted by Newjec et al. (1993b).

Yuam Sub-basin

Two storage-based hydropower projects, namely Nam Ngao and Nam Mae Lama Luang, which are also listed in the power development plan (PDP 90–02) of EGAT, are considered in the Yuam sub-basin. Table 7.5 provides the summary of the project performance characteristics for the three scenarios studied. For scenario 1, when the two projects will be developed simultaneously, the amount of annual energy generated from Nam Ngao and Mae Lama Luang projects will be 280.2 and 480.83 GWh respectively. Individual development of Nam Ngao will generate 282.8 GWh (scenario 2) while Mae Lama Luang will yield 460.9 GWh of annual energy (scenario 3). Thus, the total energy output under independent development is slightly less than the total output under simultaneous development of the two projects. The outputs as quoted by JICA (1989) are somewhat higher due to both higher inflows and the large size of the Mae Lama Luang project. This project has been presently scaled down by EGAT.

Moei Sub-basin

The Mae Lamao–Bhumibol inter-basin diversion project is the only individual project of considerable size (in addition to some medium-scale irrigation projects) in the Moei sub-basin. The present study has investigated the possible amount of water that can be diverted for various design alternatives through the HEC-3 model. Annual water diversion as a function of tunnel capacity and reservoir full supply level is given in Table 7.6.

Table 7.5. Summary of reservoir parameters in Yuam basin

Description	Present study scenario				JICA			
	1		2	3	Individual development		Integrated development	
	NN	MLL	NN	MLL	NN	MLL	NN	MLL
Catchment area (km²)	835	6030	835	6030	835	6030	835	6030
Inflow (MCM)	1240.45	2644.89	1240.45	2631.79	1366.09	2948.24	1366.09	2948.24
High water level (msl)	270	155	270	155*	270	165	270	165
Low water level (msl)	255	133	255	133	255	143	255	143
Storage capacity (MCM)	925	345	925	345	925	486	925	486
Effective storage (MCM)	329	185	329	185	329	277	329	277
Normal intake level (msl)	264	147	264	147	264	156	264	157
Tail water level (msl)	162.9	66.3	162.9	66.3	162.9	66.3	162.9	67
Normal effective head (m)	96.1	76.7	96.1	76.7	96.1	84.7	96.1	85
Installed capacity (MW)	140	120	140	120	140	160	140	240
Annual energy (GWh)	280.2	480.83	282.8	460.9	306.8	540.9	300.7	583.4
Annual firm energy (GWh)	188.47	314.38	188.52	295.59	—	—	—	—
Net evap. (MCM)	−6.87	−1.93	−6.8	−3.65	—	—	—	—
Power release (MCM)	1225.11	2523.87	1222.97	2447.35	—	—	—	—
Spill (MCM)	26.11	122.49	26.11	190.79	—	—	—	—

Scenario 1: Nam Ngao (NN) and Mae Lama Luang (MLL) together (full potential development).
Scenario 2: Nam Ngao only.
Scenario 3: Mae Lama Luang only.
JICA: Feasibility study made by JICA (1989).
*– FSL is lowered to 155 m.

Table 7.6. Variation of annual diversion amount (MCM) with tunnel capacity and full supply level for Huai Mae Lamao–Bhumibol Inter-basin Transfer Project

Capacity vs Diversion		Full supply level vs Diversion	
Tunnel Capacity (cm)	Diversion (MCM)	Full supply level (msl)	Diversion* (MCM)
15	292.18	260	361.09
20	320.74	255	351.66
25	339.25	250	339.25
30	349.61	245	322.67
35	356.92	240	317.12
40	361.78		
45	364.62		
50	366.01		

*Under tunnel capacity 25 cm.

Under the proposed canal capacity of 25 m^3/s and the reservoir full supply level of 250.0 m, 339.25 MCM of water can be diverted annually. This is slightly less than the figure of 356.0 MCM quoted by previous studies (Newjec et al., 1993b). It is found that by increasing the tunnel capacity or by raising the full supply level, the diversion amount can be increased. But the increase is not very significant. For example, only about 5 per cent increase in diversion amount can be achieved by enlarging the tunnel capacity by 40 per cent from the proposed capacity of 25 m^3/s. Similarly, by raising the reservoir water level from 250 m to 260 m msl, an increase in diversion amount from 339.25 MCM to 361.09 MCM (6.4 per cent increase) can be achieved. However, other environmental and socio-economic considerations have to be taken into account in deciding about the final figures. Thus, the EGAT proposed salient features of the Mae Lamao–Bhumibol interbasin diversion project appear to be appropriate, except for the diversion amount mentioned previously.

Projects on International Rivers

Four individual projects (two each on the Salween and Moei) have been considered separately for HEC-3 model study. The intention is to verify the previously quoted output figures and predict their performance under the updated hydrologic conditions. Moei 1 is not considered because the site is inferior due to technical and economical factors. For the Salween river projects, two scenarios have been studied. Scenario 1 considers the Upper Salween and Lower Salween as the storage dam and regulating dam respectively, whereas scenario 2 considers both Upper and Lower Salween as run-of-the-river hydropower projects. Model schematic diagrams for the two cases are shown in Figure 7.8.

Table 7.7 provides the summary of the salient features and performance characteristics of the Salween river schemes. The project output values from previous studies (EPDC, 1992) are slightly different from the corresponding figures under scenario 1 of the AIT (1994) study. Annual energy outputs computed by AIT (1994) are 27,554 GWh and 4917 GWh for Upper and Lower Salween schemes respectively, as compared to the corresponding figures of 29,271 GWh and 5422 GWh reported by EPDC (1992). Due to smaller scale in development, scenario 2 appears attractive (though with less output than scenario 1) for the Upper Salween while for the Lower Salween, the output is almost similar under the two scenarios. For 1200 MW installed capacity and 120 m (msl) reservoir full supply

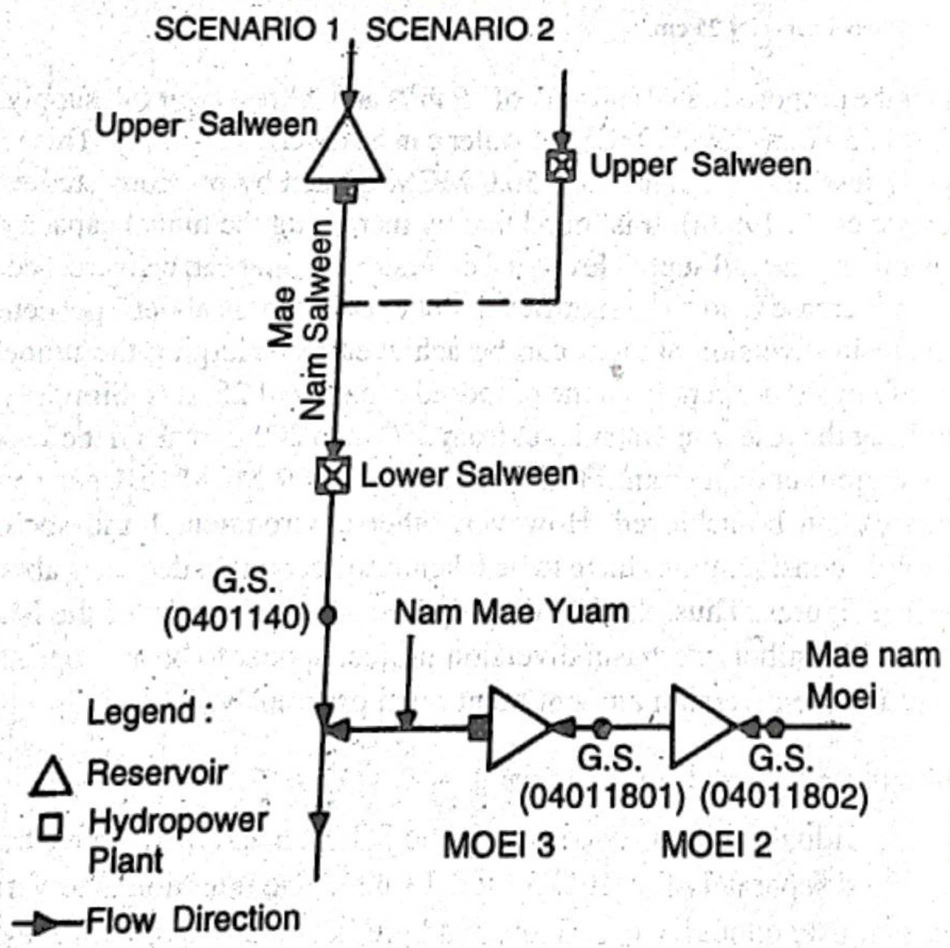

Figure 7.8. HEC-3 model schematic diagrams for Salween and Moei river projects.

Table 7.7. Summary performance of the hydropower plants in international rivers

Description	Unit	Upper Salween			Lower Salween			Moei 2		Moei 3	
		Present study		EPDC	Present study		EPDC	Present study	EDFC	Present study	EDFC
		Scenario 1	Scenario 2		Scenario 1	Scenario 2					
Catchment area	km²	293,100	293,100	293,100	294,500	294,500	294,500	6420	6420	8710	8710
Inflow	MCM	114,800	114,846	118,627	115,400	114,846	118,627	4037.85	4810	7287.43	8590
High water level	m(msl)	220	120	220	86	86	86	180	180	120	120
Low water level	m(msl)	168	110	168	73	73	73	170	170	110	110
Total storage	MCM	21,000	490	25,000	245	245	245	968	968	968	980
Effective storage	MCM	15,800	215	15,800	167	167	167	638	638	505	505
Normal intake water level	km²	202.7	116.7	202.7	81.7	81.7	81.7	176.7	176.7	116.7	116.7
Tail water level	m(msl)	88	85.9	85.9	62	60.8	60.8	131.8	131.8	82.7	82.7
Normal effective head	m	116.8	30.8	116.8	20.9	20.9	20.9	44.9	44.9	34	34
Spill	MCM	30,744.1	28,958.6	—	33,027.9	33,082.7	—	515.79	—	1279.95	—
Installed capacity	MW	4540	1200	4540	792	792	792	120	231	150	288
Annual energy	GWh	27,554	7150.51	29,271	4916.87	4911.55	5422	385.93	523	514.93	631
Firm energy	GWh	16,107	6862.53	18,744	4705.75	4731.73	4175	288.8	110	383.03	91

Scenario 1: Upper Salween as storage dam and Lower Salween as regulating dam.

Scenario 2: Upper Salween and Lower Salween both as run-of-the-river projects.

level, the annual energy output is 7150 GWh for the Upper Salween (scenario 2). For the Moei river schemes, the AIT (1994) study analysed systems with smaller installed capacities being considered by EGAT (personal communication, 1993) than those analysed by EPDC (1992). In spite of the average annual inflow being less, the corresponding average annual energy outputs are higher, probably due to different assumptions inherent in the two studies.

Thus, the model results have indicated that the proposed development projects and planning alternatives are feasible from the water balance point of view, and no significant additional measures are required to overcome the shortage of water supply for the estimated water demand conditions within the basin. The water supply and demand situation in the Salween river basin appears to be favourable in the foreseeable future, until the year 2006 and beyond. The proposals to divert water from the Pai and Moei sub-basins to the adjoining basins in Thailand, where there is an acute water shortage, appear to be well justified provided necessary attention is paid to the socio-economic and environmental impacts of such inter-basin transfer projects.

DEVELOPMENT PLANS AND ENVIRONMENTAL IMPACTS

The AIT (1994) study presents preliminary water resources development plans/programmes and associated investment schedules for implementation of the plans within the study area (part of the Salween basin). The proposed programmes for the development and implementation of water resources plans/projects are based on the following strategies;

(1) development of small- and medium-scale water resources projects in every sub-basin to meet the requirements of domestic and industrial water supply, supplementary as well as dry-season irrigation, and hydroelectricity;
(2) irrigation being the major water sector with severe management problems, emphasis on the improvement of efficiency of the existing irrigation systems (as this requires both structural and non-structural measures, both financial and political support is deemed necessary);
(3) development of feasible inter-basin transfer projects for the economic development of the region as well as to help alleviate the severe water shortage conditions of the adjoining river basins in the country;
(4) integrated watershed management projects for very small areas

not being considered under (1) above, in order to satisfy the water needs as well as to protect the watershed and its natural environment;

(5) development of feasible large-scale hydropower and multi-purpose projects including those on international rivers for the long-term socio-economic development of the riparian countries.

The river basin development plans formulated may be summarized as follows:

(a) *Short Term (1994–96)*

New irrigation development	= 3915 ha
Improvement of existing irrigation	= 6977 ha
Mini-hydropower project	= 3020 KW (1 project)
Micro-hydropower project	= 60 KW (1 project)

(b) *Long Term (1997–2006)*

New irrigation development	= 22,958 ha
Improvement of existing irrigation	= 23,257 ha
Mini-hydropower project	= 7510 KW (4 projects)
Micro-hydropower project	= 180 KW (4 projects)

Locations of water supply and watershed management projects, which are usually of small and distributed nature, are difficult to specify at this stage. Further detailed studies will be required to ascertain these as well as the potential projects under the full development stage of the basin. In addition to the projects and programmes discussed above, many more water resources projects in the Salween river basin have the potential to be developed in the distant future. These include dam/reservoir and inter-basin transfer projects as discussed earlier. The four projects inside Thailand (the Nam Pai–Mae Taeng inter-basin diversion, and three hydropower projects, namely Nam Pai No. 6, Nam Ngao and Mae Lama Luang) may be realized beyond the year 2006. The Mae Lamao–Bhumibol inter-basin diversion scheme is expected to be implemented during the latter part of the planning period. Due to the complex nature of this project, probably two to three years additional to the construction period 1998–2002 proposed by Newjec Inc. et al. (1993b) will be required for the project to become fully operational.

The existing water management situation in the study area, as in many other developing countries, is not up to the expected levels. Particularly in the irrigation sector, efficiency needs to be improved and this should be included in the development programme. Existing rainfall and stream gauging stations in the sub-basins of the study area are generally adequate. No additional sediment and water quality stations are necessary; however, all the existing stations should be properly maintained so that monitoring of related variables may be continued.

The total investment cost for the proposed irrigation, water supply, hydropower, trans-basin and integrated watershed management projects in the study area over the entire planning period 1994–2006 is 10,874.06 million Baht (approx. 435 million US$). Almost 49.1 per cent (i.e. 5342 million Baht) of this amount is for the Mae Lamao-Bhumibol inter-basin transfer project, while irrigation, water supply, hydropower and watershed management account for about 35.0, 9.1, 5.0 and 1.8 per cent respectively. Thus, the scale of investment for the proposed projects looks reasonable.

The existing environmental condition of the Salween river basin was briefly described earlier. The primary environmental impacts of the proposed projects are those related to water quality and forestry. Due to relatively less economic and human activities in the study area, water quality is not expected to be adversely affected in the future. Although many proposed projects lie in the conservation forest zone, they are outside the strictly prohibited areas such as wildlife sanctuaries and national parks. Although there will be some impact due to the projects (particularly those in watershed class 1B), because most of these projects are small in size, no serious environmental impact due to forest land degradation is expected.

The environmental impact of the only major project in the study area (namely the Mae Lamao–Bhumibol Inter-basin Diversion Scheme) has been studied at the feasibility study level (stage I) by Newjec et al. (1993b) and no adverse impact is foreseen. Four mitigating measures have been built into the project (i.e. lowering of water level, provision of downstream release, provision of downstream irrigation development and avoidance of class 1A land), and a full environmental impact assessment of the project has been planned for stage II. Similarly, Technology Ace et al. (1992) have conducted a detailed environmental impact assessment of Nam Yuam River Basin Hydroelectric Development Project in the study area. Their study provides details on the physical resources, ecological resources, human use values and quality of life values affected by the Mae Lama Luang project. An environmental-economic analysis was also conducted. The detailed feasibility study of any large water resource development project to be taken up in the future should include a full social and environmental impact assessment.

INSTITUTIONAL ARRANGEMENTS FOR COOPERATIVE DEVELOPMENT

As described previously, several multi-purpose dam/reservoir and inter-basin transfer projects have been studied on the international rivers Salween and its major tributary Moei bordering Myanmar and Thailand. Due to the unique nature and remote location of these river basins, and because of limited water demand within the basins, they have excess water available that could be beneficially utilized for adjacent water-deficit areas and, indeed, for the overall development and well-being of the riparian countries. Due to a much smaller scale of economic and human activities, the existing environmental condition of the Salween river basin (e.g. sediment yield, water quality, forest conservation) is sound so far. With due consideration to social and environmental aspects of development, there is a good opportunity for the joint development of the Salween river basin by the riparian countries.

In fact, Thailand and Myanmar have already expressed their willingness to cooperate in the joint development of these rivers along their borders and started the arduous process of eventually reaching a mutual agreement. In January 1989, the Royal Thai government approved the Ministry of Science, Technology and Environment to form a national committee for Thai–Myanmar hydropower projects (EGAT, 1993). The committee has the Secretary and another representative of the National Energy Administration (now the Department of Energy Development and Promotion) as the chairman and secretary respectively, while the members are representatives from RID, EGAT, Thai-Burmese Strategy Department (TBSD), Chiang Rai province and Ranong province. Their duties are to (i) coordinate works among concerned units on Thai-Burmese border hydropower projects, (ii) request cooperation from the Burmese side in implementing the Thai-Burmese border hydropower projects according to the TSBD, and (iii) form sub-committees for special purposes as assigned by the committee. In April 1989, the committee discussed the issues with Myanmar Electric Power Enterprise (MEPE) and a joint committee was set up in July 1989, with NEA and MEPE taking up the leading roles in the two countries.

Several meetings of the joint committee are reported to have been held since it was formed. Although the joint committee has agreed on the cooperation in general terms (as an example, asking EPDC to conduct preliminary studies), they still have not reached a formal Memorandum of Understanding (MOU). The main hurdle appears to be on the condition of 'equitable rights to use water', following the project implementation. Yet, the possibility of reaching an agreement, even without the mediation of a third party, looks real. This is because incentives clearly exist for both Thailand and Myanmar in developing the water resources of the Salween river basin. Because of the problems of insurgents in the areas near the Thai-Myanmar border and because it has other options for water resources development near its demand centres, Myanmar appears to have given less priority to Salween river development in the past. However, times are changing and Myanmar is realizing the importance of joint development for its own overall economic development. Myanmar is also slowly but surely, taking active interest in improving its relations not only with Thailand but also with other Southeast Asian, especially ASEAN member, countries. Similarly, the critical need for water in Thailand is clear and this has already generated a supportive political environment. In addition, Thailand has the infrastructure and financial means required for the joint development.

One of the problems with the existing set-up as well as past studies is that they emphasize technical aspects, especially those related to the hydropower sector, and do not give due consideration to issues related to other sectors such as irrigation, industrial and domestic water supply and environmental control. Hardly any attempt has been made so far to collect or exchange data and information for a realistic assessment of water demands for various purposes. Critical issues related to financial, social and environmental aspects of water resources development have not been given the same attention as technical issues. Without integration of multiple issues and multiple sectors, a satisfactory solution may not be found, thus raising the possibility of conflicts in the future. It will not be possible then to achieve sustainable water resources development.

Since the Salween river basin is shared by China, Myanmar and Thailand, any institutional arrangement for cooperative development should consider all the three countries. In terms of approximate geographical contribution to the Salween river flow, China contributes about 50 per cent, Myanmar about 45 per cent and Thailand the rest. With other major rivers like the Mekong and Tangize Kiang located more proximate to the demand centres within China, it appears unlikely that China would be serious about water resources development projects on the Salween for its own use. On the other hand, relations between China and Myanmar are growing healthy, with wide-ranging cooperation being jointly stated at the highest political levels of the two countries. With changing political and economic climates in the region where China is a leading country, it would be beneficial to have an agreement among all the three countries to avoid any conflict whatsoever.

Such an arrangement may be initiated through the establishment of a joint committee, similar to the bilateral Thai-Myanmar joint committee mentioned previously. Within this broad multilateral framework and guidelines for cooperation, Thai-Myanmar cooperation would be more meaningful, even if China is not seriously considering the Salween at present. In fact, China could even play the role of facilitator in resolving some outstanding conflicts between Myanmar and Thailand that are stopping them from signing an MOU, and become a witness to the process. Although the cooperation and negotiation process between Thailand and Myanmar has already started, much more remains to be done. Probably a broader framework would facilitate the extensive process of negotiation and planning for shared water resources to move much more speedily than it has in the past.

An alternative arrangement would be to have a neutral party such as an international organization involved in the water sector and experienced in resolving shared water resource issues (e.g. the United Nations Development Programme the United Nations Environment Programme) acting as facilitator in the negotiation process. Proper attention to complex financial, social and environmental issues under a transparent medium could be better provided under such an arrangement. From the viewpoint of integrating different aspects of the development dilemma during the planning stage, yet another alternative arrangement could be the creation of a Salween River Basin Authority, similar in concept to the Mekong Secretariat for the Mekong river basin. With the present favourable situation, such a comprehensive river basin authority for the Salween river would have an excellent chance of success. From the practical viewpoint, Thailand and Myanmar could initiate the process within the bilateral framework of agreement, with scope for inclusion of China at an appropriate time in the future.

CONCLUDING REMARKS AND RECOMMENDATIONS

The assessment of water resources and water demand conducted by AIT (1994) covering part of the Salween river basin, highlights various aspects of problems and prospects in the potential development of this international river basin. The overall methodology adopted is based on the systems approach utilizing various analytical techniques. Delineation into sub-basins has facilitated consideration of specific conditions, constraints and potential, in terms of both water supply and water demand. Data and information collection from different water-related institutions, and subsequent checking, processing and storage, have made it possible to assess various hydrologic components as well as water uses on an administrative-region as well as sub-basin level. The resulting understanding of the hydrology, data monitoring network systems, water resources and water uses form the basis for planners and policy makers interested in water resources development in the Salween river basin.

Since the process and information are known with some certainty only on the Thai part of the basin, it is necessary to extend the process to include the major part of the basin (which includes Myanmar). Such a comprehensive basinwide framework of analysis will allow an understanding of the total system (especially its financial, social and environmental components) and a complete analysis of various development and management alternatives. Most of the previous studies are project-oriented studies in specific sectors (mainly hydropower). They do not deal with social and environmental issues as much as technical and economic ones, thus ignoring the sustainability of development. They also do not deal with demand assessment of various water use sectors.

Hydrologic relationships (e.g. catchment area and mean annual runoff/sediment load) developed by AIT (1994) may be used in the ungauged basins of the Salween and Moei rivers; however, inclusion of stations in Myanmar and China in deriving these relationships would improve their applicability. Currently, not much is known about the status of the hydrologic monitoring network in these countries. As hydrologic data is a prerequisite for rational and scientific water resources planning, any institutional arrangement for the joint development of water resources in the Salween or Moei river must include the dissemination of data among partner countries. Hydrologic monitoring as well as detailed research and development studies are recommended in the future to improve the information base for planning.

Although the water resources availability and water demands in different sub-basins of the study area vary, the relative situations in all these sub-basins are similar, in that they are favourable. In overall terms, existing as well as planned water resources development in the Thai part of the Salween river basin is presently of a much smaller scale than in many other river basins of Thailand. The favourable situation of the study area and the river basin should be taken into account when considering water resources development alternatives to benefit the regions beyond the sub-basins/

basins. Proper analytical approaches and techniques, which consider multiple development strategies (as shown in the example) and multiple issues, should be used. Good opportunities exist for the joint development of the international rivers Salween and Moei. In addition to the technical considerations, appropriate institutional arrangements must be devised for real progress and cooperation in a spirit of mutual trust and goodwill. Under the prevalent economic and political climates of the riparian countries, there is every reason to be hopeful and optimistic. Indeed, the Salween river has the potential to become one of the few examples of successful international river basin development in the not too distant a future.

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