HELSINKI UNIVERSITY OF TECHNOLOGY
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Water Resources, Large Dams and Hydropower in Asia

A Master of Science Thesis submitted for inspection in Espoo, 28 June 2001

Supervisor: Professor Pertti Vakkilainen

Instructor: D.Sc. Olli Varis

HELSINKI UNIVERSITY OF TECHNOLOGY **ABSTRACT OF MASTER´S THESIS**

Author:	Tommi Kajander
Name of the Thesis:	Water Resources, Large Dams and Hydropower in Asia
Date:	28.6.2001
Number of Pages:	86
Department:	Civil and Environmental Engineering
Professorship:	Water Resources Engineering
Supervisor:	Professor Pertti Vakkilainen
Instructor:	D.Sc. Olli Varis

This Master´s thesis was written at Helsinki University of Technology during the academic year 2000-2001. The thesis is a part of a research project *Global Changes and Water Resources,* which studies population growth, urbanisation, food production, and their interconnections to water resources. The project investigates five critical regions: the Nile basin, West Africa, South Asia, Southeast Asia and China out of which the Asian regions were selected for this thesis.

The goal was to examine the water resources and find out what has been done and what is going on in the sector of dam building in South Asia, Southeast Asia, and China. The focus is given to hydropower. The other aim was to bring out both perspectives, for and against the large dams, and to review the impacts of large dams.

Asia is the most active region for dam development in the world. The water resources of Southeast Asia have remained relatively undeveloped. The Lower Mekong is still untapped although plans for harnessing the river have been prepared since the 1950s. Opposition to the proposed dams is strong. China has a long history in the construction of dams. Nearly half of the world´s large dams are located in China. The dams are mainly constructed for hydropower and flood control like the Three Gorges Project, the world´s largest dam project under construction. The Upper Mekong in China is actively developed without co-operation with the lower riparians. In South Asia, India develops its water resources intensively. Many of the dam projects are very controversial such as the Narmada Valley Development Program. The Farakka Dam on the Ganges River in India has created serious environmental and social problems in Bangladesh. Nepal has a huge hydropower potential but lack of financial resources to develop it. Co-operation with India would be profitable for both nations but is difficult.

As concluding remarks this thesis presents some crucial points that should be taken into account when realizing large dam schemes. These include among other things equal sharing of benefits, application of the participatory approach, and efficient monitoring. Alternatives for large dams should be studied more in depth, especially the water demand aspect where considerable savings in water consumption can be made. Mitigation of negative impacts is essential and includes inter alia watershed management as a whole, considering the ecological water demand and sufficient flow variation by operational rules.

Keywords: water, dam, hydropower, impact, Asia

TEKNILLINEN KORKEAKOULU

DIPLOMITYÖN TIIVISTELMÄ

Tekijä:	Tommi Kajander
Diplomityön nimi:	Vesivarat, suuret padot ja vesivoima Aasiassa
Päivämäärä:	28.6.2001
Sivumäärä:	86
Osasto:	Rakennus- ja ympäristötekniikan osasto
Professuuri:	Vesitalous ja vesirakennus
Työn valvoja:	Professori Pertti Vakkilainen
Työn ohjaaja:	Dosentti Olli Varis

Tämä diplomityö on tehty Teknillisessä korkeakoulussa lukuvuonna 2000-2001 osana *Globaalit muutokset ja vesivarat*-tutkimusta, joka tutkii väestönkasvua, kaupungistumista, ruoantuotantoa ja niiden yhteyttä veteen. Tutkimukseen on valittu viisi kohdealuetta: Niilin valuma-alue, Länsi-Afrikka, Etelä-Aasia, Kaakkois-Aasia ja Kiina. Tässä diplomityössä tarkastellaan Aasian alueita.

Työn tavoitteena oli tarkastella vesivaroja Etelä- ja Kaakkois-Aasiassa sekä Kiinassa ja selvittää suurten patojen rakentamista ja suunnitelmia alueilla, pääpainon ollessa vesivoimassa. Tarkoituksena oli myös tuoda esiin kaksi näkökulmaa: suurten patojen puolesta ja niitä vastaan; hyötyineen ja haittoineen.

Maailmanlaajuisesti tarkastellen suurten patojen rakentaminen on tällä hetkellä vilkkainta Aasiassa. Kaakkois-Aasiassa vesivarat ovat melko rakentamattomia. Mekong on säilynyt valjastamattomana, vaikka joen patoamissuunnitelmia on valmisteltu jo 50-luvulta lähtien. Patojen rakentamista vastustetaan voimakkaasti. Kiinassa patojen rakentamisella on pitkä historia. Lähes puolet maailman suurista padoista sijaitsee Kiinassa. Rakentamisen päätarkoitus on useimmiten tulvasuojelu ja vesivoima, kuten työssä esitellyllä, maailman suurimmalla rakenteilla olevalla, kolmen solan padolla. Mekongin yläjuoksu Kiinassa on valjastettu ja suunnitelmia . Etelä-Aasiassa patojen rakentaminen on intensiivisintä Intiassa. Lukuisat patohankkeet ovat kiistanalaisia, kuten Narmadan laakson kehittämisohjelma. Farakkan pato Ganges-joella Intiassa on aiheuttanut vakavia ympäristöhaittoja ja sosiaalisia ongelmia Bangladeshissa. Nepalilla on huomattava vesivoimapotentiaali, mutta vähän taloudellisia resursseja vesivoiman hyödyntämiseksi. Yhteistyö Intian kanssa olisi kannattavaa, mutta on käytännössä vaikeaa.

Lopuksi diplomityössä esitellään tärkeimmät näkökohdat , jotka tulisi ottaa huomioon patohankkeissa. Näitä ovat mm. hyötyjen tasapuolinen jakaminen, osallistuvan lähestymistavan soveltaminen ja hankkeiden tehokas seuranta. Vaihtoehtoja, kuten vedenkäytön tehostamista, suurille padoille tulisi tutkia perusteellisemmin. Patojen haittojen minimointi on välttämätöntä ja sisältää mm. kokonaisvaltaiset valuma-aluetarkastelut, ekologisen vedentarpeen huomioimisen ja riittävän luonnonmukaiset virtaamavaihtelut.

Hakusanat: vesi, pato, vesivoima, hyöty, haitta, Aasia

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ABBREVIATIONS

ADB	Asia Development Bank
BOT	Build-Own-Transfer
CTGPC	China Three Gorges Project Corporation
FAO	Food and Agriculture Organization of the United Nations
GNP	Gross Domestic Product
ICOLD	The International Commission on Large Dams
IRN	International Rivers Network
MRC	Mekong River Commission
MWR	Ministry of Water Resources (China)
NGO	Non-Governmental Organization
PRC	People´s Republic of China
RID	Royal Irrigation Department of Thailand
TGP	The Three Gorges Project
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCD	World Commission on Dams
WRI	World Resources Institute

FOREWORD

This master´s thesis is a part of a research project called *Global Changes and Water Resources.* The project started in 1997 by Dr. Olli Varis at the Laboratory of Water Resources at Helsinki University of Technology (HUT). It studies population growth, urbanisation, food production and their interconnections to water resources and between all of them. The project has a five year funding from the Academy of Finland.

This thesis was written at the Laboratory of Water Resources, Helsinki University of Technology during the academic year 2000-2001. As a part of the thesis, a two week study tour to China was taken place in September 2000 to get acquainted with China´s water resources management and water projects. This thesis work received its funding from the Academy of Finland (project no. 45809) and Ministry of Agriculture and Forestry.

I would like to thank Professor Pertti Vakkilainen and Dr. Olli Varis. Prof. Vakkilainen supervised my thesis while Dr. Varis instructed me by giving advices and ideas. In addition I would like to thank Sven Hallin Foundation which sponsored the study tour to China and Maa- ja Vesitekniikan Tuki ry. which granted me a scholarship for this thesis.

Espoo, June 2001

Tommi Kajander

1 INTRODUCTION

1.1 Background

This thesis relates to the research project, *Global Changes and Water Resources*. The project started in 1997 at Laboratory of Water Resources in Helsinki University of Technology by Dr. Olli Varis.

The following issues are included in the project as major driving forces:

- Population growth
- Urbanization and other patterns of migration
- Changes in climate, environment and nature
- Economy
- Human capital, technology and industrialization

In the beginning of the whole project following criterion were chosen in order to determine the most critical regions in the world (Varis 1997, Vakkilainen & Varis 1999):

- The available water resources are already utilised to a great extent, and the situation is rapidly worsening
- A major part of population lives in these areas
- Population is growing substantially
- Urbanization, especially the growth of megacities is considerable
- Low level of income
- Net imports of crops and/or undernourishment already present, and increasing

According to the criterion five regions were selected as research areas: China, Southeast Asia, South Asia, Nile basin and Sahel in West Africa.

In this thesis China, Southeast Asia and South Asia were chosen for the target areas. Africa was left out to attain more scope for this study.

Online information about the *Global Changes and Water Resources* - Project is available at:
http://www.water.hut.fi/wr/research/glob/glob.html

1.2 Definition of Key Terms

As this thesis is about large dams a definition of such structures is needed and given below.

The International Commission on Large Dams (ICOLD) defines a large dam as a dam with a height exceeding 15 m. If the dam´s height is 5-15 m and the reservoir volume is more than 3 million m^3 the dam is also classified as a large dam.

1.3 Objective and Execution of the Thesis

Objective of this thesis was to find out where and why large dams are constructed and planned. The aim was to examine the already constructed dams and the plans concerning the construction of large dams in the study regions. The focus is given to hydropower. The other aim of this thesis was to find out the impacts of large dams and to bring out the both perspectives, for and against the dams.

The study is done by reviewing literature and searching the internet.

The most useful www-sites used in this thesis are given in Appendix 1.

In addition a two-week study tour to China took place in the beginning of September 2000. During the journey several universities and research centers were visited to get acquainted with the water resources management in China. Several experts were met and discussed with. The travel report (in finnish) of the excursion is available online. http://www.water.hut.fi/wr/kiina2000/index.html.

1.4 Structure of the Work

Chapter 2 discusses water resources management by large dams in general. Trends concerning the construction of large dams and hydropower are presented. The reasons why large dams are constructed are discussed as well. The chapter ends to a section where the report of the World Commission on Dams and the reactions it has gained are slightly discussed.

In chapters 3 to 5 the study regions are taken into examination. Each chapter follows the same structure. First the region and its water resources are presented in general. The largest and most important rivers have their own chapters, where information concerning the river´s watersheds and discharges are presented. After the presentation of the regions and their water resources, the construction of large dams in the area is discussed. The chapters 3-5 end in the country reviews where the water resources and large dams are discussed more in depth on a national level. The country reviews include the case studies, which present several selected dam schemes.

At the end of the thesis the concluding remarks are presented in chapter 6. Appendices 1 and 2 are attached at the end, after the concluding remarks.

1.5 References

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2 WATER RESOURCES MANAGEMENT BY LARGE DAMS

The pressure on world´s water resources is increasing alarmingly. Economic growth in the developing countries is creating stress on water resources. Water withdrawals are increasing when industrial, agricultural and domestic sectors are competing for the decreasing water resources. Environmental degradation is deteriorating the already grave situation. Extremities in natural phenomenon have increased: floods and droughts have worsen. This means that the already unevenly distributed water resources will be even more difficult to use and manage.

Large dams have an unique feature to store excess water during the seasons when water is abundant and release it when there is scarcity.

2.1 Regional Examination of the Construction of Large Dams and Hydropower

Currently there are some 45,000 large dams in the world which store about 6,000 km^3 water.

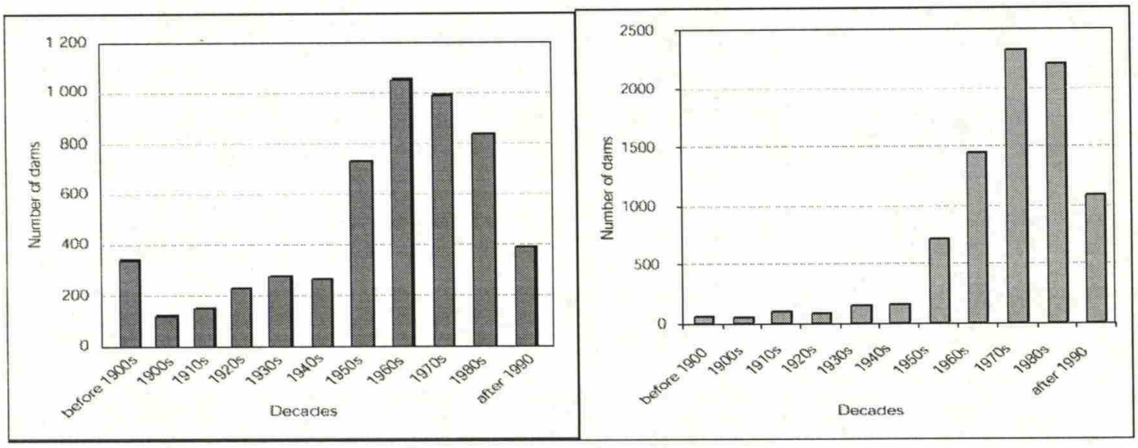

***Figure 2.1**: Number of Large Dams Constructed in Europe (on the left) and Asia by Decades*

Source: WCD, 2000

When investigating the figure 2.1 above it can be noticed that in Europe the construction of large dams has begun well before 1900s. Since then dams have been built with a growing pace (with the exception of the 1940s when the Second World War retarded the development). The development reached its peak in the 1960s after which the number of completed dams has been declining.

The reason for the decline is clear. Great bulk of the economically feasible dam sites have been constructed. The focus in dam development in Europe has moved towards the refurbishment and upgrading of the actual dams.

In Asia the construction of large dams has been relatively slow during the first decades of the 20th century. The rapid growth has started in the 1950s and continued till the 1970s, when the construction of dams has reached its maximum. During the last two decades the construction pace has remarkably slowed down. One reason is the rising opposition to the construction of dams due to the negative environmental and social impacts the dams create.

When looking at the number of constructed dams in the study regions (table 2.1), it can be noticed that China and India are by far the leading countries in the development of large dams. In total 87.5 % of all dams have been constructed in China. India with its 2,481 large dams or 10.0 % of the total is evidently the second one in the list.

Table 2.1: *Number of large dams and percentage of electricity production by hydro in the study regions*

Source: The International Journal on Hydropower & Dams, 1999

Region/Country	No. of Large Dams	Percentage of electricity production by hydro
Southeast Asia		
Cambodia	2	N/A
Indonesia	96	13.7
Laos	2	97.5
Malaysia (Peninsular)	52	10.2
Myanmar	3	40
Philippines	15	20
Thailand	204	8
Vietnam	>100	63
South Asia		
Bangladesh	1	6
Bhutan	0	99.6
India	2,481	25
Nepal	4	90.3
Pakistan	71	43
Sri Lanka	47	67
China	21,611	17.2
Total	24,689	

When looking at the percentage of electricity production by hydro in the study regions it can be easily noticed that hydropower plays a crucial role in many parts. In Laos, Bhutan and Nepal more than 90% of the electricity is produced by hydropower. In addition to meet the national electricity needs hydroelectricity brings export earnings when sold to neighbouring countries.

Asia is the region where greatest amount of hydro development activity is under way or planned. Ambitious plans are prepared to harness the remaining free flowing rivers such as the Lower Mekong in Southeast Asia to generate hydroelectricity (see Ch. 3.2 Hydropower Potential and Development in the Area). The world´s largest dam project, the Three Gorges Dam with an installed capacity of 18,200 MW, is under construction on the Yangze River in China (Ch. 4.5).

The intense development of hydropower is intelligible when investigating figure 2.2 below where the hydropower potential and production are represented. In addition to the fact that there is a lot of hydropower potential in the study areas, only a friction of it is developed. Data for Bangladesh and Pakistan was not available. China´s technically feasible hydropower potential of 1,923,304 GWh/year is in a class of its own. Out of the potential 192,000 GWh is produced annually.

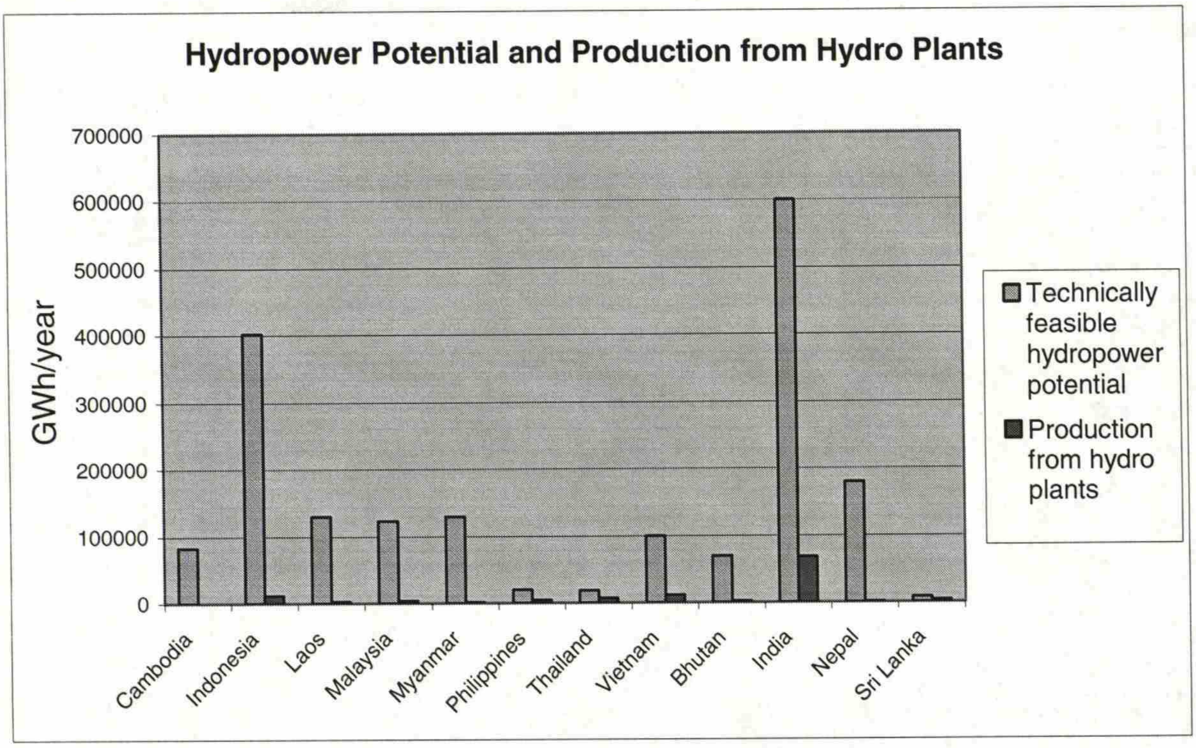

Figure 2.2: *Hydropower Potential and Production from Hydro Plants*

Source: The International Journal on Hydropower & Dams, 1999

2.2 Other Purposes Besides Hydropower

Besides hydropower, large dams are constructed for irrigation, flood control and water supply purposes. In addition there are so called multipurpose dams, in which several above-mentioned purposes are integrated.

Figure 2.3 presents the number of large dams in Asia by purpose. It can be noticed that irrigation dams dominate with a share of 63 %. The second numerous are the multipurpose dams which count 25 % of the total. Figures exclude China. More information on the purposes of large dams in China is provided in Ch. 4.3.

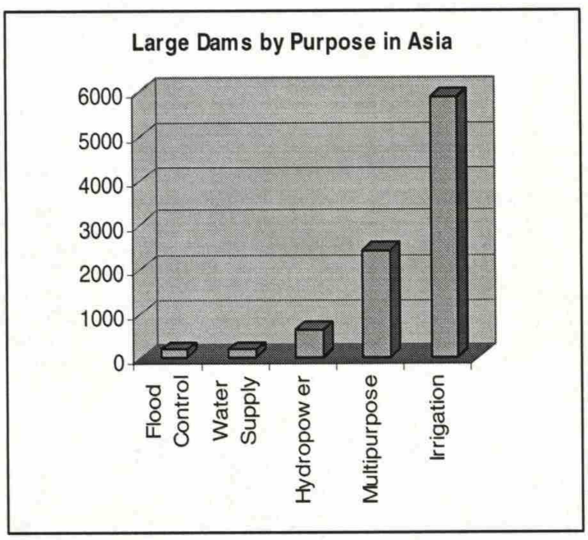

Figure 2.3: *Large Dams by Purpose in Asia*

Source: WCD, 2000

2.3 Dams are Fundamental to the Development

There is no doubt about the fact that dams have brought great benefits to the people and societies for centuries. Dams have provided water for irrigation and water supply. Dams have saved numerous human lives by storing flood waters in the reservoirs. From the 19th century dams have also provided environmentally friendly electricity by hydropower. It is clear that dams are essential in sustaining life on our globe.

Dams have provided water for irrigation since the ancient times. Dujiangyan Irrigation Project in China, which is introduced in chapter 4.4, has already served the farmers of Sichuan for over 2000 years. At present, most of the dams (63%) in Asia are built for irrigation purposes. On global scale some 30 – 40% of irrigated land rely on dams (WCD, 2000). This means that 800 million people benefit from food produced by dam related irrigation.

More dams are needed in the future to meet the growing needs of the increasing population. It is expected that over the next 25 years world food production will have to double to feed the global population. This can only be achieved by increasing irrigation which requires water. According to Lafitte et al. (2001) it is estimated that an increase of 10 to 15% in global storage is needed to meet the growing food production. In populous countries like China and India the figure is estimated to be as high as 60%.

Although great progress during the recent years have been achieved in the water supply sector still 1.1 billion people are without access to improved water supply. When taking into account the population growth during the next decades, almost 3 billion people will need to be served with water supply to reach universal coverage by the year 2025 (WHO & UNICEF, 2000). When additionally considering that the water resources are unevenly distributed in space and time it is hard to imagine that universal water supply coverage could be achieved without water storage.

According to Energy Information Association (EIA, 1999) energy consumption in the developing world is expected to more than double over the projection period (1996-2020), with highest growth rates expected in developing Asia and Central and South America. EIA also predicts that the use of renewable energy will increase by 62 percent over the period out of which almost half is expected in the developing world.

Approximately 80% of energy today is produced from coal, gas and oil which are fossil fuels and thus accelerates the climate change. When considering that air pollution is a serious problem in many parts of Asia renewable energy should be favoured. Hydropower is renewable and clean. In addition when a great undeveloped hydropower potential remains in Asia hydropower is a competitive option. Today hydropower supplies about 20% of the world´s electricity (IHA et al., 2000).

2.4 No More Dams

In the past two decades opposition to dams has arisen greatly. Public awareness of the negative impacts of large dams has increased. Main reasons for the opposition are the environmental and social concerns.

The resistance to the dams has generated anti-dam movements. One of the best known is Narmada Bachao Andolan (Save the Narmada Movement), an organization established to fight the

Narmada Valley Development Project in Western India. NBA has organized large demonstrations and even hunger strikes to stop the dam development in the Narmada Valley (see the country review of India Ch. 5.2.3). It seems that opposition has been worthwhile. World Bank, the largest financier of large dams, receded from the Narmada Project in 1993. Withdrawn from the Narmada Project was followed with the recession from the Arun III dam project in Nepal in 1995. Since then the funding of large dams by World Bank has been declining (IRN, 1999).

2.5 Searching for the Golden Mean

The World Commission on Dams (WCD) was established in May 1998 to review the development effectiveness of dams and assess alternatives for water resources and energy development. The other aim of WCD was to develop internationally accepted standards, guidelines and criteria for decision-making in the planning, design, construction, monitoring, operation and decommissioning of dams. The work was carried out by a team composed of representatives from all stakeholders including affected regions (Struggle to Save the Narmada River), communities and private (ABB Ltd.) and public sectors (universities). As an outcome, a final report Dams and Development: A New Framework for Decision-Making was published in November 2000.

The report indicates that shortfalls in technical, financial and economic performance of large dams have occurred. WCD also found that significant social and environmental impacts have emerged which are often fell on the poor people, indigenous people and other vulnerable groups. In addition the report states that substantive evaluations of completed projects are few in number, narrow in scope, poorly integrated across impact categories and scales, and inadequately linked to decisions on operations.

The findings of the report are pleasing to the organizations opposing the construction of dams. The World Conservation Union (IUCN) considers the report as a landmark in the history of the development and operations of dams. IUCN value especially the report´s honest look at the true costs of dams. Patrick McCully, the campaign director of the International Rivers Network, says that the WCD report indicates much of what dam critics have long argued and that if the builders and funders of dams follow the recommendations of WCD, the era of destructive dams should come to an end.

Dam proponents have reacted as well to the final report of WCD. The International Commission on Large Dams, the International Commission on Irrigation and Drainage, and the International Hydropower Association have composed joint major comments on the WCD report. According to the organizations referred to above (Lafitte et al., 2001) the report has two main deficiencies. Firstly the overall tone is undoubtedly negative as regards the role of dams, giving a bleak picture of the social, environmental and economic costs, while barely recognizing their benefits. Secondly the conditions proposed in the 26 guidelines for planning and implementation of future dams are, in many instances unrealistic. They will have the effect of preventing or at least seriously delaying future water resources projects.

One of the WCD´s aim was to develop internationally accepted guidelines concerning the construction of large dams. It seems that it is not possible. If nothing else, the WCD report has at least inspired a great amount of discussion. The debate concerning large dams will continue as long as dams are constructed.

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3 SOUTHEAST ASIA

Southeast Asia is a region situated east of the Indian subcontinent and south of China. It consists of two dissimilar portions: a continental projection which is called mainland Southeast Asia and a string of archipelagoes to the south and east of the mainland called insular Southeast Asia (EB, 2000).

Mainland Southeast Asia consists of the following countries: Cambodia, Lao People´s Democratic Republic (Lao PDR, referred to in this paper as Laos), Myanmar, Thailand and Vietnam. Some basic information about the countries is given in the Country Reviews.

In this study the emphasis is given to the mainland Southeast Asia due to its substantial transboundary water resources which are approached in the following chapter.

3.1 Southeast Asia and its Water Resources

Mainland Southeast Asia is drained by five major river systems, which from west to east are: Irrawaddy, Salween, Chao Phraya, Mekong and Red River (see Map 1). Some characteristics of the river systems are given in table 3.2.

3.1.1 Irrawaddy

Irrawaddy, with a length of 2,170 km, is the principal river of Myanmar. It rises from the glaciers of the high and remote mountains of northern Myanmar and flows through western Myanmar, draining the eastern slope of the country's western mountain chain. Finally the river empties into the Andaman Sea, forming a remarkable delta. With its base width of nearly 200 km, the Irrawaddy Delta is one of the world´s major ricegrowing areas.

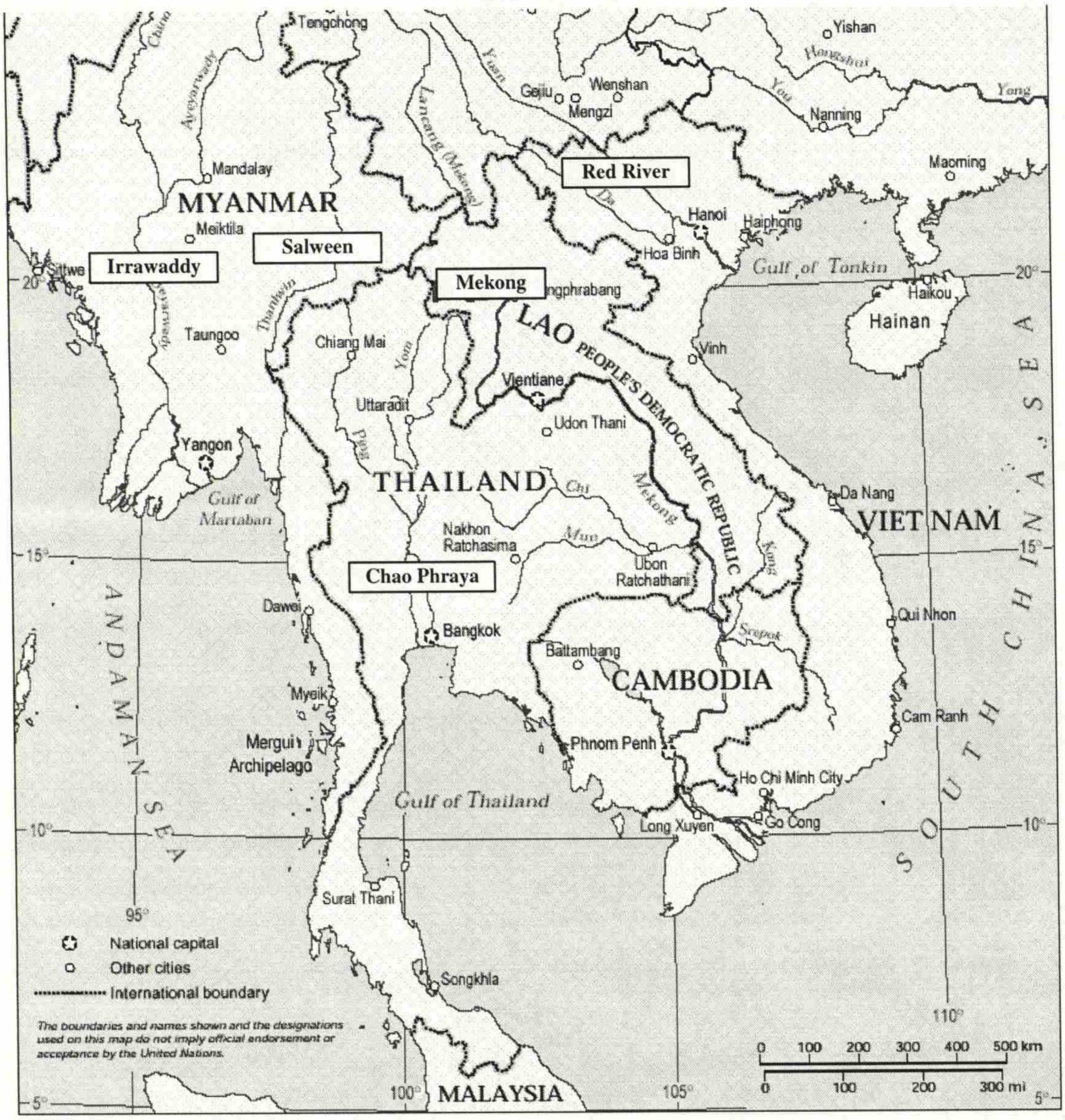
Due to the monsoon rains, which occur between June and September, the discharge of Irrawaddy River varies greatly. During the summer months, rapid melting of glaciers add the flow. Near the head of the Delta, a mean low and flood discharge of 2,300 m^3/s and 32,600 m^3/s have been determined (EB, 2000).

3.1.2 Salween

Salween rises from eastern Tibet and flows several hundred kilometres through southern China. After entering Myanmar it forms the border with Thailand for about 110 km and continues through eastern Myanmar to empty into the Andaman Sea.

Since the navigation facilities are restricted, due to the dangerous rapids on the river, the major economic use of the river is in floating teak logs from the forests of southeastern Myanmar to the sea. Although the catchment area of Salween is limited and sheltered from seasonal rains, its water volume fluctuates considerably from season to season (EB, 2000; FAO, 2000).

Despite its huge hydropower potential, Salween River is still untapped.



***Map 1**. Mainland Southeast Asia and its major river systems*

Source: http://www.un.org/Depts/Cartographic/english/htmain.htm

3.1.3 Chao Phraya

Chao Phraya is the most important river in Thailand. It originates from the mountains of northern Thailand and flows through the kingdom´s fertile plains. Before entering the Gulf of Thailand, the river and its numerous laterals, divide the nation´s capital Bangkok in two parts.

The importance of Chao Phraya river is obvious. The river is the basis for the irrigation in the country. The basin area is 160,079 km^2 of which 46 % is cropland and 92 % of the cropland is irrigated. Besides the irrigation, Chao Phraya is also a valuable waterway. It serves the transportation of teak and rice to the south.

3.1.4 Mekong

With its length of 4,200 km and average discharge of 15,000 m^3/s, Mekong River is obviously the largest water resource in Southeast Asia. At low flow it carries 1,600 – 2,000 m^3/s , which makes it the third in size in Asia after the Yangtze in China and Ganges in India (Öjendal, 1995).

The Mekong originates from Himalayas in Tibet, passes through the deep and thinly populated gorges of Yunnan province in China and enters the Lower Mekong Basin near the Burmese-Laotian border. It continues through Laos to mark out the Thai-Lao border. At the Khone Waterfalls the river enters rageously Cambodia before it slows down and discharges into the South China Sea through the Mekong Delta in the southern part of Vietnam.

Mekong River is essential to the people living in the basin area. With a total number of 244 fish species, the river provides remarkable fish catches, which are the major sources of protein throughout the basin. To Vietnam the importance of the Mekong River is also obvious. In 1998, the rice production of 15,45 million tons (49 % of the total food production in Vietnam) in Mekong Delta reached its new record (Vientiane Times, 29 October 1998).

Table 3.2: *Characteristics of the major river basins in Southeast Asia*

Sources: EB, 2000; ADB, 1996; WRI, 2000; FAO: Aquastat, 2000.

River	Annual Average Discharge (m^3/s)	Length (km)	Basin Area (km^2)	Population Density (people/km^2)	Large Dams
Irrawaddy	13,000	2,170	411,000	80	3
Salween	4,980	2,400	271,866	76	0
Chao Phraya	954	365	160,079	118	3
Mekong	15,000	4,350	805,627	78	4
Red River	4,340	1,200	169,000	142	3

3.1.5 Tonle Sap

When discussing the water resources of Southeast Asia, Tonle Sap, the Great Lake of Cambodia, can not be bypassed. Tonle Sap, a unique hydrological and ecological system located within Cambodia, is a natural resource of great regional importance to the Greater Mekong Subregion. It has one of the most productive freshwater fisheries in the world, with an annual yield approaching 200,000 tons, worth about $70 million to Cambodia.

At its smallest in the dry season, the lake area is about 2,500 km^2 and its depth is about one metre. During the wet season it expands to about 16,000 km^2 with a maximum depth of 10 m. Tonle Sap River reverses its flow, draining the lake into the Mekong River during the dry season, and partially filling the lake from the Mekong River during the wet season (ADB, 1998).

The hydrology of Tonle Sap is strongly influenced by upstream development in the Mekong River Basin from Laos to PRC. More than 60 % of the floodwater in the lake comes from Mekong. At full flood the lake temporarily stores about 72 billion m^3 of water, or 16 % of the annual discharge of the Mekong River, thus buffering the annual flood in downstream areas. The functioning of this hydrological system is critical to the productivity of the agricultural areas of the Mekong River Delta in Cambodia and Vietnam (ADB, 1998).

3.1.6 Red River

The Red River (*Yuan Chiang* in Chinese; *Song Hong* in Vietnamese) rises in the mountains of Yunnan Province in the People´s Republic of China (PRC) and flows through Vietnam to the South China Sea, where it forms an extensive delta. Its catchment area is 169,000 km^2 and has a population of 24 million people, out of which 17 million live in the Delta.

The climate is tropical to sub-tropical and is dominated by the East-Asia monsoon which causes the significant seasonal variation of rainfall. Consequently, the basin discharge is highly variable from a minimum recorded dry season discharge of 370 m^3/s, to a maximum of 38,000 m^3/s. The major problem of the river basin are the floods. In the Delta Region, river and coastal flooding occur. In the steep upper parts of the catchment area, changed land use and deforestation have intensified flood runoff (ADB, 1997).

3.2 Hydropower Potential and Development in the Area

This chapter focuses on hydropower potential and development in Southeast Asia. The emphasis is given to Mekong River for two reasons. Firstly Mekong mainstream in the Lower Mekong Subregion is still untapped, but plans to dam the river have been prepared since the 1950s. Secondly, development plans concerning the other major river systems, especially Irrawaddy and Salween, are not well known and information is hard to find. The development plans of the upper Mekong or *Lancang* flowing in China are discussed in chapter 4.6 as a part of the China section. Projects concerning Chao Phraya and Red River will be discussed in the country reviews of Thailand and Vietnam.

Mekong has huge hydropower resources. Many estimates are given for the hydropower potential of Mekong River varying from 31,200 MW (Phanrajsavong, 1995) to at least 60,000 MW (Kuusisto, 1998). The distribution of hydropower potential among the riparian countries is presented in figure 3.1.

Despite the great potential, only less than five percent of the Mekong's catchment area and annual discharge is regulated by dams. Over the past ten years, however, more than 100 large dams have been proposed for the region (IRN, 2000).

In 1957 Mekong Committee (MC) was established by governments of Laos, South Vietnam, Cambodia and Thailand. The committee was set up under the auspices of the UN Development Programme to promote, coordinate, supervise and control the planning and investigation of water resources development projects in the Lower Mekong Basin.

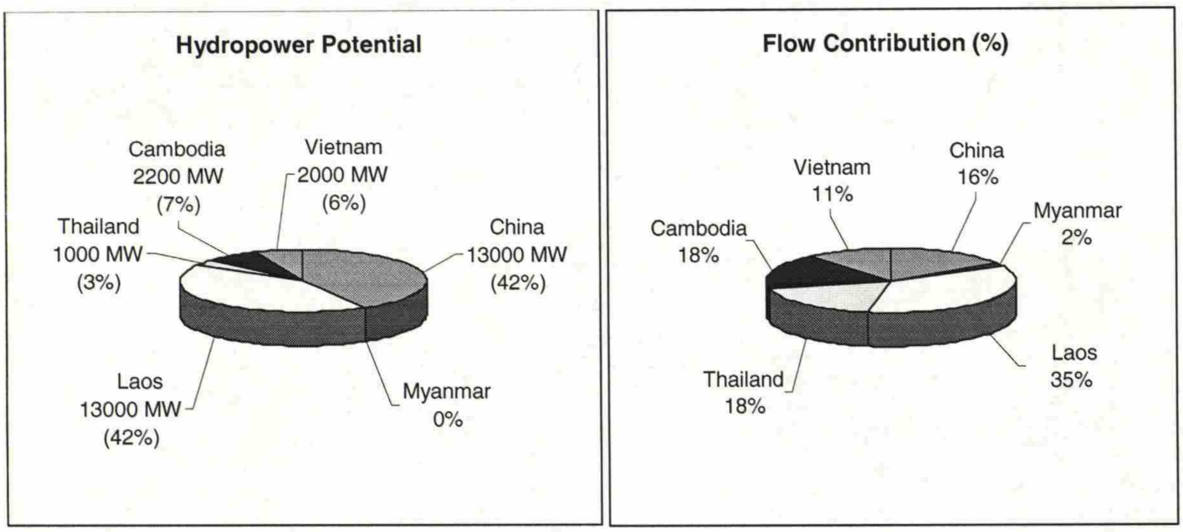


***Figure 3.1**: Hydropower Potential and Flow Contribution of Mekong River*

Source: Phanrajsavong, 1995 and Hayes, 1999.

Ambitious plans for transforming the region through giant dams were developed. American engineers designed seven dams for the Mekong mainstream: Luang Prabang, Pamong, Thakhek, Khemarat, Khone, Sambor and Tonle Sap (if considered as a mainstream site). According to the plans the total capacity of the schemes would have been 23,300 MW with a reservoir capacity of one-third of the river´s annual flow.

Three dams were given priority by Mekong Committee: Pamong, Sambor and Tonle Sap.

Pa Mong was planned to be built along the border between Thailand and Laos, near Vientiane the capital of Laos. The project consisted of three dams: the 1,360 m long and 115 m high maindam on the mainstream and two dams on the tributaries; one on Nam Lik in Laos and the other one on Nam Mong in Thailand. The Pa Mong Project would have had a power production capacity of 4,800 MW and flooded an area of 3,722 km^2. In total, 1.6 million ha of land could have been irrigated in Laos and Northeast Thailand. The negative impacts were stated to be the resettlement of 345,000 people and the flooded land, which is among the most fertile in the whole basin (Lacroze, 1998).

The feasibility study of Sambor Dam was carried out between 1962 and 1969. According to the plans it would have flooded 1,197 km^2 of land and generated 875 MW of electricity with a reservoir capacity of 10 billion m^3. Other benefits beside the hydropower were stated to be the improved navigation facilities and the irrigation of 34,000 hectares. The installed hydro capacity and irrigated land could have been increased to 3,000 MW and 621,000 ha respectively, if the scheme would have been integrated with the Pamong Project. The only costs of the project were estimated to be the 10,000 displaced people.

Tonle Sap Project was the only priority project without the benefits gained by electricity production. The purpose of the dam, located in the outlet of Tonle Sap River, was to improve the reservoir capacity of Great Lake (see Chapter 3.1.5). During the rainy season, when Tonle Sap River flows from Mekong to the lake, the flood gates would have been opened to fill the natural reservoir. Correspondingly the gates would have been opened during the dry season to release the water to increase the discharge in the Mekong Delta. The dam was planned to intensify irrigation and decrease the intrusion of sea water, thus salinization, in the delta region (Lacroze, 1998).

Throughout the 1970s, due to the war in Indochina, the planning of dams on Mekong was stagnated. The activity, mainly concentrated on the old schemes, continued slowly after the establishment of Interim Mekong Committee in 1978. Only from the late 1980s some progress took place. Environmental aspects and the concept of sustainable development were involved in the planning process of dams. The main report, Mekong Mainstream Run-of-River Hydropower, was completed in 1994. The Mekong Secreteriat presented a lower impact alternative to the cascade schemes of 1970 and 1987. The projects have been carried out mainly as a desk study so far, using existing data (AusAID, 1996). The projects are categorized into four different categories, depending on the environmental impacts and population resettlement of the scheme. Three projects belong into the first category and are given priority: Don Sahong, Ban Koum and Sambor.

Some information about the proposed mainstream run-of-river dams is given below in table 3.3.

Several dam projects on Mekong tributaries will be discussed in country reviews.

***Table 3.3**: Proposed Mekong mainstream run-of-river[*] dams*

Source: Mekong Secretariat, 1994

Name	Distance from River Mouth (km)	Capacity (MW)	Population Displaced	Area Flooded (km^2)
Stung Treng	670	980	9,160	480
Sambor	560	3,300	5,120	590
Don Sahong	719	240	0	0
Ban Koum	928	2,330	2,573	90
Pa Mong "A"	1,651	2,030	23,260	40
Pak Lay	1,818	1,010	8,710	70
Sayabouri	1,930	1,260	1,720	20
Luang Prabang	2,036	970	5,200	85
Pak Beng	2,188	1,230	1,670	50
Total		13,350	57,413	1,425

[*] **Run-of-river dam:** A hydroelectric generating power plant that operates based only on available streamflow and some short-term storage (hourly, daily or weekly)

3.3 For and Against the Proposed Dams

Large projects concerning water resources management do always have positive and negative impacts on environment and people of the river basin. The proponents of large dams are conviced of the benefits and pushing forward the projects, meanwhile the opponents are assured that damming of the river do have some disastrous consequences.

The proposed dams on the Mekong River are primarily for electricity generation purposes. Electricity is needed in Southeast Asia to meet the needs of developing industries and economies. In addition to satisfy the national electricity needs, hydropower has also proved to be a remarkable source of income. In 1997 Laos earned $21 million by selling electricity to Thailand.

Other benefits besides the electricity generation are increased water discharge during the dry season and decreased floodwater levels during the rainy season. The former would enable improved irrigation facilities below the dam site and alleviate the salinization problem in Mekong Delta area.

When talking about the negative impacts of proposed Mekong mainstream dams, the main concerns are the environmental impacts. How will a big dam and a reservoir affect the downstream areas, especially Tonle Sap and Mekong Delta, two areas providing food for 15 million people? What will happen to the aquatic biodiversity including 244 fish species when the fish migration is blocked by a dam?

Reductions in the amount of water acting to flush the Mekong Delta could significantly alter its fertility. Potential impacts to the delta-sea-estuary from loss of streamflow include (Van der Most, 1992):

- Increase of salinity in the estuary (in rainy season)
- Decrease of organic and inorganic matter thus decreasing the fertility of the soil
- Increased retention times
- Increased concentration of pollution
- Decreases in estuary fish populations

Dam construction upstream on the Mekong in Laos and Cambodia will change the hydrology of the delta, reducing seasonal flow peaks and the extent of flooding. This is likely to have a disastrous effect not only on waterfowl populations but also on those fish species which utilize the floodplain wetlands for spawning. Changes in water quality and the timing of peak flows are likely to have adverse effects on fish migrations and spawning, and dams will create obvious problems for long distance longitudinal migrants. The dams will reduce sediment flow, particularly in the main channels, and thereby affect the nutrient regime in the delta (Pantulu, 1986)

Tonle Sap area would also be affected. If a dam is constructed on the Mekong mainstrean the reservoir could take the role of Tonle Sap as a natural regulator of water discharge in the lower parts of Mekong. The annual hydrological cycle of Tonle Sap would be changed and the fisheries in the lake would be negatively affected.

Mekong is one of the last untapped rivers in the world and has remained surprisingly pristine and protected from development. To minimize the impacts on nature and people, all the projects concerning Mekong mainstream should be prepared with a co-operative manner among the riparian countries with an emphasis given to the environmental and social aspects.

3.4 Country Reviews

In this section the hydropower development and large dams of Southeast Asian countries including Cambodia, Laos, Myanmar, Thailand and Vietnam are discussed. Three different projects are represented more in depth: The Nam Theun 2 Hydropower Project in Laos, The Kok-Ing-Nan Water Diversion Project in Thailand and The Hoa Binh Hydroelectric Dam in Vietnam. Some statistics concerning hydropower potential and production, installed hydro capacity and electricity consumption in Southeast Asia are given in Appendix 2. In the end of this chapter the issues concerning large dams and hydropower development in the rest of Southeast Asia are shortly discussed.

3.4.1 Cambodia

Cambodia´s hydropower potential is under evaluation, but was estimated in the past as 83,000 GWh/year. There are two large dams in the country. The installed hydrocapacity is 11 MW, which produces annually 74 GWh of electricity. Hydropower development has been almost non-existent due to several reasons including political tension, landmines, lack of infrastructure between provinces, lack of access roads to sites and the Asian economic crisis. Additionally, power demand has been insufficient to justify large hydropower projects (The International…,1999).

Two hydropower projects are planned: Prek Thnot and Kamchay, with capacities of 18 MW and 120 MW, respectively. One hydropower project, Stung Mnum, is proposed. It will have an capacity of approximately 470 MW and locate near the border with Thailand. The main consumers of the electricity and water would be in Thailand (The International..., 1999).

3.4.2 Laos

Laos is endowed with abundant water resources. The Mekong River and its tributaries drain 90 % of the total area of the country. With an average annual rainfall of 1,600 mm, the total renewable water resources of Laos are estimated to be 334 km^3/year (FAO, 2000).

Laos has a large technically feasible hydropower potential. Out of the 18,000 MW only 423 MW is developed. Despite the low installed capacity, 98 % of Laos´ electricity generation is contributed by hydropower. Moreover electricity is an important export to the country. From 1981 to 1997, selling of electricity to Thailand has provided a cumulative income of about US$ 357 million to Laos. In 1997 the country earned US$ 21 million (being equivalent to 11% of the total exports) by exporting electricity. (The Inter..., 1999 and ADB, 1999).

The Government of Lao PDR has long regarded the export of electricity as the most promising option for increasing government revenues and raising the standard of living of the Lao people. With the help of the Mekong River Commission, the Lao Government has identified up to 60 possible large-scale hydropower projects and expects to develop some 7,000 MW hydro capacity by 2020. Out of the 7,000 MW about 3,000 MW are targeted for export to Thailand by 2006 and 1500 - 2000 MW to Vietnam by the year 2010.

Nam Theun 2 Hydropower Project

Nam Theun 2 Hydropower Project (NT2) is the largest and most controversial of all the hydropower projects planned for Laos. The main features of the proposed hydropower project are a 50 meter high dam on the Mekong tributary Nam

Theun river, a 450 km^2 reservoir, a 681 MW powerhouse, and a transmission line to connect NT2 to the Thailand national grid. Revenues to the Government would be substantial, but the project would entail significant social and environmental impacts, including the resettlement of approximately 4,500 villagers. The total cost of NT2 is estimated at about US$1.3 billion.

According to World Bank´s Project ID, LA-PE-4929, the objectives of the NT2 project are to:

(i) generate long term net revenues and foreign exchange for the Government

(ii) encourage the use of those revenues in support of economic growth and poverty alleviation through investments in rural and human resource development

(iii) fulfill the Government's commitment to supply Thailand with 3,000 MW of electricity by 2006.

(iv) link hydropower development with environmental and social objectives (e.g. long-term financing for the Nakai-Nam Theun watershed, a globally significant biodiversity site).

The project also aims to develop a model for public-private partnerships which could stimulate future private sector participation in Lao PDR, a country with limited domestic financing resources.

A non governmental organization, International Rivers Network (IRN), dedicated to protecting and restoring the world´s rivers and watersheds, has followed closely the Nam Theun 2 Project since 1995. According to IRN (IRN, 1999) the project contain following main points of concern:

(i) The large economic, social and environmental impacts of the Nam Theun 2 project, coupled with the size of the project compared to the size of the Lao economy, renders it a high risk project for the Lao government.

(ii) The project has soaked up an enormous amount of Lao government human and financial resources since the late 1980s, diverting attention away from other hydropower projects within Laos. Meanwhile, it is not even certain that Thailand will require the power from Nam Theun 2.

(iii) Significant environmental destruction has already occurred, despite the fact that the dam may never be built. Since 1993, the military-run logging company has logged more than 1 million m^3 of timber on the Nakai Plateau to clear the reservoir area.

(iv) Project proponents, including the World Bank, claim that the Nakai Plateau is so degraded that it is not worth saving, and that the dam should be built to provide revenue to protect the watershed area. Yet the project will have a severe impact on the environment and livelihoods of people living in three important river basins in Central Laos.

(v) Around 4,500 people will be resettled to make way for the dams´s reservoir. The natural resource base of these people has been steadily eroded as a result of anticipatory logging on the Nakai Plateau, and their expectations have been raised by promises of new homes and land. The dam has precluded alternative development programs and options for the villagers, leaving them in a high vulnerable position whether or not the dam proceeds.

The Nam Theun 2 Project is close to its implementation phase. The negotiations between Thailand and Laos over the price of electricity have been time consuming but are now almost completed. The World Bank has also signalled its readiness to provide a project loan for the dam on the Theun river in Central Laos.

3.4.3 Myanmar

Total renewable water resources of Myanmar are 1,046 km^3/year, which makes the country rich in water resources. The technically feasible hydropower potential of 37,000 MW, is largest in Southeast Asia. With an installed hydrocapacity of 328 MW, it is still undeveloped (The Inter...,1999). Government has given priority to hydropower, which will remain the principal source of electricity in the long term. Several dams are proposed on the Salween River for power export to Thailand. In June 1997, a Memorandum of Agreement was signed between Myanmar and Thailand. Electricity Generating Authority of Thailand (EGAT) with other Thai state agencies agreed to purchase up to 1,500 MW of electric power from burmese projects by the year 2010 (Watershed, 1998).

Opposition to dams has arisen. Non governmental organizations including environmental groups disagree the projects. Salween is one of the last untapped big rivers. Its ecosystem is very rich and diverse and thus very fragile. Large hydropower dams will have destructive environmental impacts on nature and animal species.

Picture 1: *Khao Laem Reservoir.*

Khao Laem Reservoir in western Thailand is one of the biggest reservoirs in the country. Besides the established dwellings of 1000 families around the reservoir, boathouses are a common sight on the reservoir. ***Photo:*** *Tommi Kajander*

3.4.4 Thailand

Thailand has 204 large dams (>15 m) in operation, with a total water storage of 51.5 km^3. Despite the numerous dams, Thailand does have considerable unexploited hydroelectric reserves. Hydropower potential is estimated to be 15,155 MW out of which only 2,873 MW is in operation (The International…, 1999). The remaining resources are, however, considered difficult to exploit due to the environmental concerns. Domestic opposition to dams is strong. Environmental groups consider the negative impacts of large dams are fatal to the fragile ecosystem. Due to the resistance, no pure hydro capacity is under construction or planned.

Water shortage is the main concern in Thailand, especially in the northern parts of the kingdom. In November, 1998, water levels in the country's dams were 50-60 percent below the normal level. Decreasing water resources in the river basins stem from the lack of rain and increasing population and extended agriculture in the North (Bangkok Post, 3 Nov. 1998, 30 Jan. 1999).

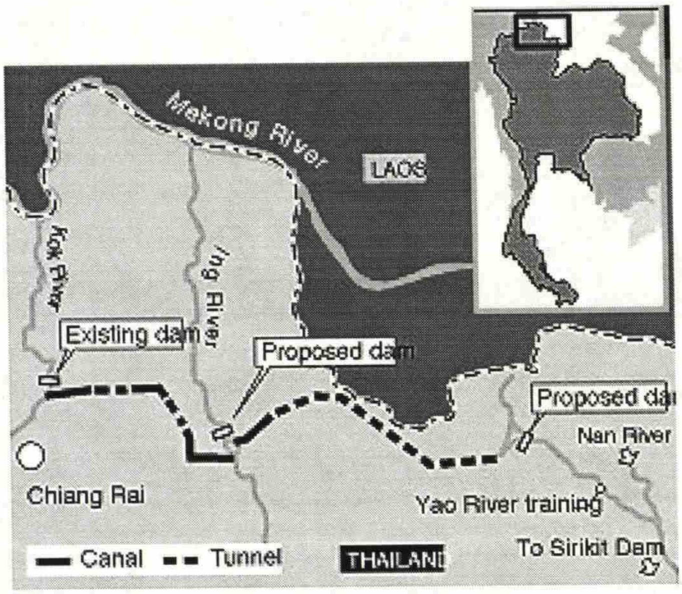
Although dams for hydropower are not planned, dams for other purposes are needed as Boonchob Karnchanalak, former senior hydrologist of World Bank, stated:

> *"As an agricultural country, Thailand needs dams to store water during the dry season. There's no doubt about that"* (Bangkok Post, 3 September 1997).

<u>Kok-Ing-Nan Water Diversion Project</u>

To solve the water shortage problem, water diversion schemes have long been promoted by the Government of Thailand. Beside the need to meet water demand for irrigation, industry and domestic use, particularly in Bangkok, the additional objective of the water diversion schemes is to increase water supply to the two largest reservoirs of Thailand. Bhumibol and Sirikit reservoirs, with water storage capacities of 9.66 km^3 and 6.66 km^3, respectively, have not been fully filled since constructed in 1960s and 1970s (Watershed, 1998).

With an estimated cost of US$ 860 million, construction of Kok-Ing-Nan Water Diversion Project is planned to begin this year, 2000, and to continue for eight years. The scheme site is the area of the three northern provinces of Chiang Rai, Phayao and Nan. The project would divert annually, mainly during the rainy season, 2.2 km^3 of water from Kok and Ing rivers in the Mekong River Basin. The project will consist of two diversion dams, Kok (previously constructed) and Ing, Yao flood control dam, 117.4 km of tunnels and canals and Yao River Training. The latter comprises widening and strengthening of the river banks and deepening of the river bed to improve the water-carrying capacity of Yao River (Watershed, 1998).



***Map 2**: The Proposed Kok-Ing-Nan Water Diversion Project*

Source: Watershed, Vol. 4 No. 2, Nov 1998 – Feb 1999.

The benefits gained by the project are evident. RID, the Royal Irrigation Department, is striving for the solution of water shortage in the central and lower northern region of Thailand. According to Pramote Maiklad, Director General of the Royal Irrigation Department, the water diversion project is a perfect, almost problem-free answer for Thailand's perennial dry-season water shortages (Bangkok Post, 30 December 1998).

For the local people in Kok, Ing and Nan provinces, the project is not a problem-free answer. During the dry season, farmers in the Kok and Ing river basins face water shortage problem. Correspondingly, during the rainy season, people rely on the flood water which brings fish and signals that the rice farming season has come. Livelihood of the local people will be negatively affected if water is withdrawn from the rivers. In addition the Ing diversion dam will flood a large area of fertile floodplain.

Several other water diversion projects are also proposed in Thailand. Up to 23 dams are planned by the Thai government, some in cooperation with Myanmar for transbasin water diversion and hydroelectricity from Salween River. Biggest of the water diversions is the Salween-Bhumibol Project with an estimated average discharge of 317 m^3/s (Watershed, 1998).

3.4.5 Vietnam

With an annual precipitation of 1,861 mm and 2,360 rivers, Vietnam has abundant water resources and hydropower potential. The technically feasible hydropower potential is estimated to be 17,700 MW, of which 35 % is located in the Red River.

By the end of 1999, the total capacity of power plants in Vietnam was estimated at about 5,500 MW, of which the serviceable capacity was about 5,300 MW. Hydropower plants contribute the major part accounting for 54% (2,862 MW) of the total installed capacity. There is 1,265 MW of hydro capacity under construction, including four hydropower plants: Yali (720 MW), first on Se San river (Mekong tributary), Song Hinh, Ham Thuan and Da My. They are expected to start operating in 2000 (Minh Huan, 2000).

Plans include construction of 4,770 MW to 5,970 MW further hydro capacity. All the projects will be for multipurposes. The plan contains nine projects of which two are at the detailed design stage and the rest at the feasibilty or pre-feasibilty stage. Vietnam has already more than 100 large dams in operation (The International...,1999).

Hoa Binh Hydroelectric Dam

Hoa Binh hydroelectric dam, biggest in Southeast Asia, supplies one quarter of the country´s total electric supply with an installed capacity of 1,920 MW. The dam is built on Vietnam´s largest river, Red River. The storage capacity of the multipurpose reservoir is 8,5 km^3. The other main purpose of the dam, beside the hydropower, is downstream flood control.

Problems, concerning the production of electricity, have occurred in Hoa Binh. Occasionally, seasonal water scarcity and sedimentation constrain the full use of hydrocapacity. In 1998, during the dry season, electricity production approached zero, when the water level of reservoir went under the turbine intake level (White, 2000).

Besides causing abrasion damages in the turbines, sedimentation is reducing the reservoir storage capacity. Siltation, caused by the settling of suspended particles in the reservoir, has been high. In recent years, annual siltation in Hoa Binh reservoir has reached 60 million m^3. In 1990 and 1991 the figures were even higher at an approximate annual siltation speed of 90 million m^3. Compared to design, siltation speed has doubled (Quy An, 2000). The severe deforestation in the upper parts of the river basin will deteriorate the sedimentation problem.

***Table 3.4**: The Benefits and Costs of the Hoa Binh Dam*

Source: Quy An, 2000

The Benefits	The Costs
• Water supply for agricultural production and domestic use (In dry season Hoa Binh release 240 m^3/s of water) • An electricity production of 7 –8 billion kWh per year • Flood control: reduced floodwater level (2 m in Hanoi) • Improved navigation • Developing of tourism in the reservoir area	• Inundated area, including 27 km^2 of rice field and 24 km^2 of crop land • Resettlement of 51,600 people • Hydrologic impacts: sedimentation, scouring of riverbed below the dam, decreased water quality • Ecological impacts: decreased number of animal species, increased deforestation in the reservoir area

The energy sector of Vietnam urgently needs to be developed. In the General Development Plan of the Power Sector of Vietnam three various projections of electricity power demand are given for the period 2000 - 2010 with an outlook for 2020. In the base scenario, the average annual growth rate of electricity demand is estimated to be 9.75 %. If coming true, the base scenario will create a need of 30,000 MW extra capacity of which 9,000 MW is hydrocapacity (Minh Huan, 2000).

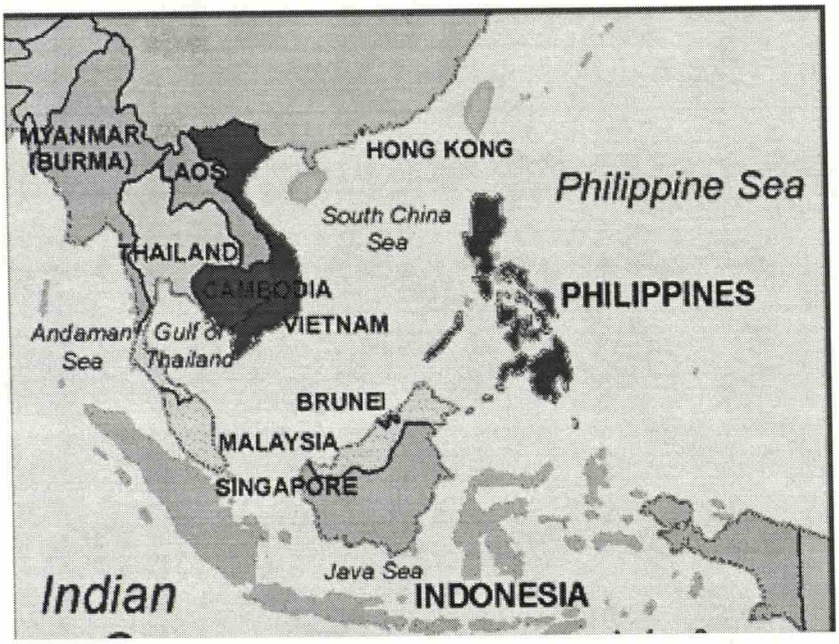
It is expected that half of the additional capacity to 2010 will come from BOT* projects. Therefore, the Government of Vietnam is intensively attracting private and foreign participation (The International..., 1999).

3.4.6 Other Countries in Southeast Asia

Southeast Asian countries not mentioned heretofore include Brunei, Indonesia, Malaysia, Philippines and Singapore.

Indonesia, with its area of 1,948,700 km^2 and population of 202.95 million, is the largest country in Southeast Asia. It has a runoff of 2,128 km^3/year and 96 large dams which store about 6 km^3 of water. Despite the fact that Indonesia has a huge technically feasible hydropower potential of 402 TWh/year only 4 %, representing an installed hydrocapacity of 3,046 MW, is developed. Due to the high number of undeveloped potential many hydropower projects are planned or under construction. In forthcoming years the hydrocapacity will more than double: 2,100 MW is under construction and 2,182 MW is planned (EB, 2000; The Inter...,1999)

* **BOT (Build-Own-Transfer):** A form of privatized project development in which a government grants a concession of defined and limited duration to private sector sponsors to build a project, hold an ownership position in it, arrange the balance of financing from third parties, and operate the project for the life of concession. Usually the concession life is significantly shorter than the facility´s economic life. Usually the project ownership transfers to the government at no cost after the concession term.



Map 3: *Southeast Asia*

Source: http://www.maptown.com/southeastasiamaps.html

Malaysia is composed of two separate regions: West Malaysia on the Malay Peninsula and East Malaysia on the northwestern part of the island of Borneo. The country has an area of 329,749 km^2 and a population of 22,18 million. Malaysia is abundant with water resources. In 1996 the total renewable water resources per inhabitant was 28,183 m^3/year. The technically feasible hydropower potential of Peninsular Malaysia is only 16,000 GWh/year, while there is about 87,000 GWh/year in Sarawak and 20,000 GWh/year in Sabah. Although 25 per cent of the hydropower potential in Peninsular Malaysia has been developed, only 5 per cent of the total has been developed. Malaysia has 100 large dams out of which many are multipurpose (ADB, 1999; EB, 2000; The Inter..., 1999; FAO, 2000).

Table 3.5: *Characteristics of Hydropower Development in Indonesia, Malaysia and Philippines*

Source: The International Journal on Hydropower & Dams, 1999

Country	Number of Large Dams	Technically Feasible Hydropower potential (GWh/year)	% of Technically Feasible Potential in Use	Installed Hydrocapacity in Use (MW)
Indonesia	96	401,646	4	3,046
Malaysia	100	123,000	5	1,970
Philippines	15	20,334	17	2,273

Republic of the Philippines is an archipelago located between the South China and Philippine Seas. It consists of 7,100 islands and has an area of 300,000 km^2. In 1998, the country's population was 75,2 million (EB, 2000; ADB, 1999).

The average annual precipitation in the Philippines is 2,373 mm/year, which produces annually total renewable water resources of 6,914 m^3 per inhabitant. There are 15 large dams in operation, which store 5.76 km^3 of water.

The installed hydropower capacity is 2,273 MW, thus providing 17,5 % of national power production. There is another 555 MW of hydro capacity under construction, and 1,036 MW is planned. The biggest dam under construction is the 200 m high San Roque multipurpose dam, which will provide hydropower, irrigation water, flood control and improve water quality for communities in Northern and Central Luzon. Two other dams under construction are the 11 m high Bakun AC hydro project and the 25 m high Casecnan hydro project (The Inter…,1999).

Brunei is a small country located on the island of Borneo. It is surrounded by West Malaysia and has an area of 5,765 km^2. The independent Islamic sultanate has two dams with a total storage capacity of 45,013,000 m^3. The Tasek reservoir used for water supply has a total capacity of 13,000 m^3 and a catchment area of 2.8 km^2. The Benutan dam, an impounded reservoir used to regulate the Sungai Tutong River, has a total storage capacity of 45,000,000 m^3 and a catchment area of 28.6 km^2. There is at present no hydropower dam though one suitable site has been located within the National Forest Reserve of Temburong (EB, 2000; FAO, 2000).

Republic Of Singapore is located at the southern tip of Malay Peninsula. The capital city, Singapore, is administratively equivalent to the Republic of Singapore, which comprises Singapore Island and 60 other islets. Country's area is 622 km^2 and population 3.87 million. A dense network of short streams drains the island; the longest being the Seletar River, which is less than 16 km long. Although Singapore has an average annual rainfall of about 2,400 mm, it is still dependent on neighbouring Malaysia for more than two-thirds of its water supply (ADB, 1999; EB, 2000)

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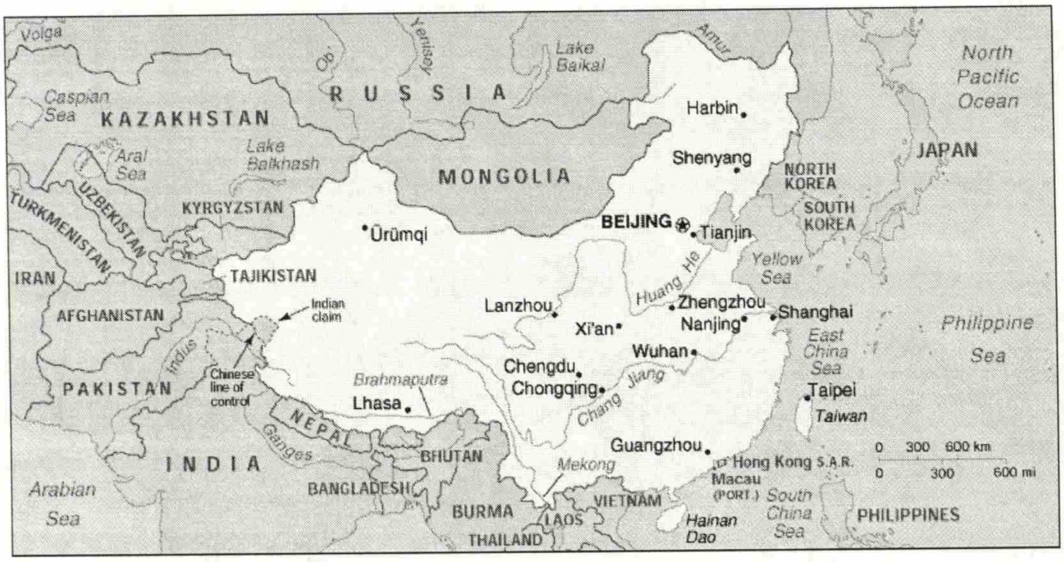
4 CHINA

4.1 China and its Water Resources

The People´s Republic of China is the largest of all Asian countries and has the largest population of any country in the world. Occupying nearly the entire East Asian landmass, it stretches for about 5,000 km from east to west and 5,500 km from north to south and covers an area of about 9,572,900 km^2, which is approximately one-fourteenth of the land area of the Earth. China´s population has exceeded 1,2 billion (EB, 2000).



***Map 4:** Map of China*

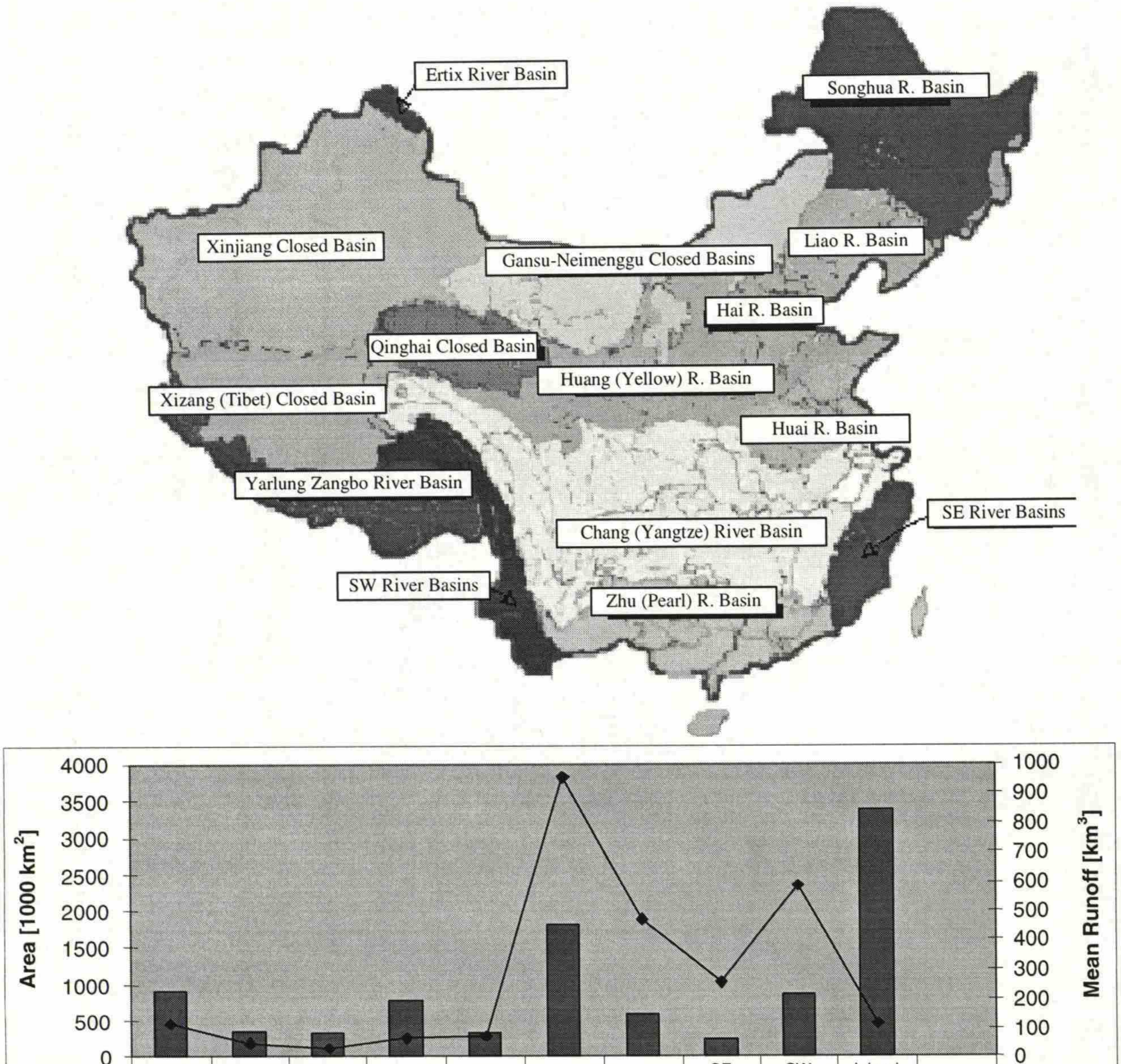
Source: www.lib.utexas.edu/Libs/PCL/Map_collection/cia99/China_sm99.jpg

China has enormous water resources. With more than 50,000 rivers and an annual average precipitation of 648 mm, China´s annual runoff is estimated to be 2,711 km^3. The net water resources, including groundwater resources, are 2,812 km^3. When considering the water resources in per capita terms, they are not that abundant anymore. China´s water availability per capita is only about 35 % of the world average (Wang et al., 1999; MWR, 1992).

The water resources are regionally and seasonally unevenly distributed. The area south from Yangtze comprises 81 % of the water but only 54 % of the population and 35 % of the arable land. Per capita water availability is thus considerably lower in the north than in the south. In three regions, Hai-Luan, Huai and Yellow, the availability per capita is below 1,000 m^3 /capita which is an internationally accepted definition for water scarcity (Hydrosult, 1999).

According to river systems, the whole country is divided into 10 major regions (MWR, 1992): the Yangtze River Region, the Yellow River Region, the Pearl River Region, the Huaihe Region (Huai River Basin), the Haihe Region (Hai River Basin), the Liaohe Region (Liao River Basin), the Heilongjiang Region (Songhua River Basin), the Region of Zhejiang-Fujian-Taiwan (SE River Basins), the Region of Southwest China and the Region of Inland Rivers (All the closed basins and Ertix River Basin).

The major river basins and their annual run-offs are illustrated below in Figure 4.1.



	Songhua	Liao	Hai	Yellow	Huai	Yangtze	Pearl	SE Rivers	SW Rivers	Inland Rivers
Area	903.418	345.027	318.161	794.712	329.211	1808.5	580.641	239.803	851.406	3374.44
Runoff	117	49	29	66	74	951	468	256	585	116

Figure 4.1: *Regional Distribution of Water Resources in China*

Source: Map from WCD, 2000, Data from MWR, 1992 (The period 1956-79 was used as the base period).

4.1.1 Yangtze

The 6,300 km long Yangtze River (*Chang Jiang*), originating from the Tibetan Plateau and discharging to the South China Sea, is the longest river in Asia and third longest in the world. It runs mainly in deep valleys and mountainous regions. After the world famous segment of the Three Gorges in Hubei Province, the Yangtze slows down, broadens and continues its steady flow towards its delta in South China Sea.

The Yangtze has eight principal tributaries. Most of the stream´s discharge, accounting for approximately 90 % of the total flow, come from the tributaries of the middle and lower courses. When the average discharge in the delta is 31,150 m^3/s, it is 23,980 m^3/s in Wuhan, 14,980 m^3/s in the end of the Three Gorges area and "just" 1,980 m^3/s in the upstream areas. Due to the monsoon rains in summer the discharge reach its maximum value in August, when devastating floods often occur (see table 4.6), and its minimum water level in February (EB, 2000).

The area of river basin of the Yangtze is 1,808,500 km^2, thus accounting for 19% of the total land area of China. When considering the population of the basin, the figures are awesome as well. With an average population density of 224 people/km^2, the watershed is inhabited by 405,104,000 people. It is clear that the environment of the Yangtze watershed is under pressure and deteriorating. In total, 85% of the original forest cover is lost and 27% of the watershed area is eroded (WRI, 2000).

In spite of the destructive floods and environmental degradation, the Yangtze River is vital to China. It is the most important inland waterway in the country and its basin contributes nearly half of the crop production in China. The sparsely populated upper reaches in the mountains have also a great potential for hydropower development.

The biggest dam project in the world, the Three Gorges Project (TGP), is under construction in the middle course of the Yangtze. It has raised great opposition by environmentalists due to its ecological impacts.

The Three Gorges Project is presented as a separate case study in Chapter 4.5.

4.1.2 Yellow River

With its length of 5,464 km, the Yellow River (*Huang He*) is the second longest river in China. It originates from the Qinghai province in the Tibetan Plateau and continues toward northeast until it drains to the Yellow Sea.

The mean annual flow of the Yellow is 1,770 m^3/s. However, the variations in the Yellow´s discharge are extreme. Disastrous floods are common in the rainy season while the river often dries out during the dry season (EB, 2000).

The annual water scarcity on the downstream section of Huang He is worsening. In 1970s the flow of the river stopped for an average period of 21 days, while in 1997 the river dried up for 226 days. The problems are consequences of the increased industrialisation and urbanization in the upper and middle reaches of the river. In addition thousands of reservoirs, water works and canals have been constructed, which have destroyed the river´s vitality and mobility (Wang et al., 1999).

What makes the Yellow River also exceptional is the huge sediment load it carries. The annual sediment load of 1.6 billion tons or 37 kg/m^3, coming from the loess plateau, makes Huang He the most silted river in the world. This causes the rising of the river bed in the lower reaches, which leads to floods and changes of the river course (Leung, 1996)

4.2 Construction of Large Dams and Reservoirs

China has long history in constructing dams and reservoirs. Reservoirs have been built since 598 BC, when the construction of Shaopi dam, which is still in operation, started in Anhui Province. Modern technology learnt from abroad was introduced in the first five decades of 20th century. First concrete dams were built in 1941 in Northeast China. In all there were only 22 large dams before 1949 (Zhang, 1999).

Since 1950, the construction of dams has been fast. By the end of 1999 there were 22136 large dams in operation higher than 15 m: 17526 dams rising up to 15 – 30 m, 4578 dams exceeding 30 m and 32 dams higher than 100 m. According to the most recent information available (ICOLD, 2000a), there are now 45 dams in China, which are higher than 100 m. In two years the number of registered large dams has increased from about 1900 to 4434. In 1997 the total water storage capacity of all dams was 458,3 km^3 (China Statistical Yearbook, 1998). Figure 4.2 below provides information on multipurpose storage projects in China. Information about storage capacities of China´s river basins is given in table 4.7.

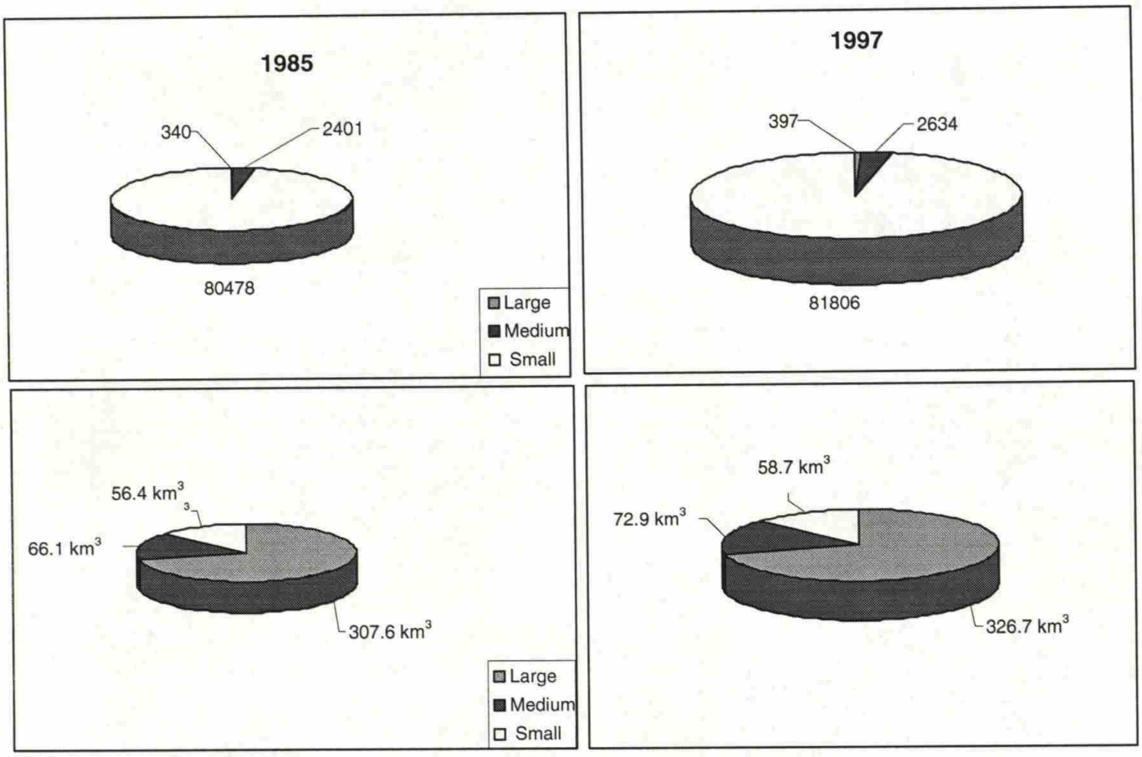


Figure 4.2: *The Number and Storage Capacity of China´s Multipurpose Storage Projects by Size in 1985 and 1997.*

Note: Large > $1 \cdot 10^8$ m^3 > Medium > $1 \cdot 10^7$ m^3 > Small > $1 \cdot 10^5$ m^3
Source: China Statistical Yearbook, 1998

4.3 Purposes of Large Dams

Large dams are constructed for many purposes including inter alia hydropower, irrigation, flood control, water supply and navigation. The benefits of large dams are often maximized by integrating several purposes. These multipurpose dams are favoured also in China. The number and purposes of China´s registered large dams are represented in figure 4.4.

4.3.1 Flood Control

Floods are a big problem in China. When looking at the historical records, between 206 B.C. and 1949, there have occurred one significant flood disaster every two years. From 1949 to 1988, the area affected by floods averaged about 79,000 km^2. Although the number of deaths has declined, the value of the damage has increased. The floods of 1996 and 1998 caused economical losses of US$27 billion (GDP reduced by about 4 %) and US$30 billion (3 – 4 % of GDP). Some major floods occurred in 20th century are represented in table 4.6.

Table 4.6: *Some Major Floods in China in the 20th Century*

Source: Hydrosult, 1999; ADB, 1999a

Year	Area	Inundated Area (km^2)	Number of Deaths
1931	Huai River and Yangtze	42,700 285,000	75,000 145,000
1933	Yellow River	36,000	18,000
1954	Huai River and Yangtze	161,000	30,000
1996	Nationwide	310,000	4,400
1998	Songhua, Liao and Yangtze	250,000	3,656

Table 4.7 compares total storage in 1993 with average annual runoff in different river basins. The degree of control varies greatly. In the Hai-Luan basin the storage capacity as % of annual runoff is 110.8, giving major protection against floods. With the exception of Yellow and Huai basins the storage percentage is 20 % or less. The potential for future control is also variable. Even with the completion of Three Gorges Project the storage capacity in the Yangtze Basin remains well below average annual discharge, and uncontrolled runoff below dams will remain a major cause of floods (Hydrosult, 1999).

The severity of floods depends on many factors including watershed characteristics such as forest cover and soil erosion. Due to the deforestation and decreasing forest cover the run-off in the catchment area intensifies. In the absence of the water holding forest and vegetation, the peak discharges increase. This leads to worse floods and erosion. Hence, river basins should be managed as a whole. Integrated water resources management should be applied when planning flood control measures. In addition to the construction of dams watershed conservation and afforestation is needed. Large dams alone can not prevent the year by year worsening floods.

Table 4.7: *Storage Capacity of River Basins in China*

Source: Hydrosult, 1999. Data from 1993.

River Basin	Large Scale Storage Projects	Storage Capacity [km³]	Storage Capacity as % of Runoff
Songhua-Liao	51	32.5	19.7
Hai-Luan	31	32.1	110.8
Yellow	18	68.8	93
Huai	50	43.6	66
Yangtze	116	158.8	16.7
Pearl	55	66.9	14.3
SE Rivers	23	51.2	20
SW Rivers	1	2.3	0.4
Inland Rivers	14	9.9	8.5
Total	359	466.1	17.2

4.3.2 Hydropower

China has the biggest technically feasible hydropower potential in the world. Out of the 1923.3 TWh/year (378,000 MW), only about 10.5 % (14 % in terms of capacity) has so far been developed. The major exploitable potential is in the Yangtze basin (197,000 MW or 52 % of the total) and in the southwest river basins (23 %). The current installed hydropower capacity of 63,500 MW is scheduled to increase to 125,000 MW by 2010. About 36,000 MW of hydro capacity is under construction and 45,000 MW is planned. In 1997, 17.15 % of China´s electricity production was provided by hydropower. Most of the hydro plants are multipurpose. (Hydrosult, 1999; The Inter…,1999)

It is estimated that the newly commissioned hydropower capacity will exceed 5,500 MW, annually, during the future decades. The reasons why China will develop hydropower rapidly in future can be summarized as follows (The Inter…,1999):

- The heavily polluting coal-fired plants have long been the predominant electric generation method. China will not only improve the old coal-fired power plant and build cleaner new ones, but will also accelerate the exploitation of hydropower and other clean energy power plants in future years

- Although China´s electricity production has been increasing tremendously in recent years, there is only 0.2 kW of installed capacity and 900 kWh/year consumption per capita. Electricity consumption will continue to increase steadily in the future, along with economic development, and living standards will progressively rise. Figure 4.3 illustrates electricity production and consumption in China.

- To control floods and improve water supply, water resources management is a very high priority in China. More reservoirs will be built in future years that will also include hydropower development

The most promising sites for hydroelectric development are in the Upper Yangtze and the Upper Mekong (the Lancang River). Among the sites already developed are Ertan (3300 MW) in the Upper Yangtze, and Manwan

(1,500 MW) on the Lancang (WCD, 2000).

Major hydro projects planned in China are presented below in table 4.8.

***Table 4.8**: Major Hydro Projects Planned in China*

Source: The International Journal on Hydropower & Dams, 1999

Project	Province	River	Dam Type	Height (m)	Reservoir Volume (10^6 m^3)	Capacity (MW)	Project Status
Laxiwa	Qinhai	Yellow	Arch	250	1	3720	F
Gongboxia	Qinhai	Yellow	Rockfill	133	0.55	1500	D
Xiaoguanyin	Gansu	Yellow	Arch-gravity	143	7.02	1400	F
Xiangjia	Sichuan	Jinsha	Gravity	150	5.46	6000	F
Xiluodu	Sichuan	Jinsha	Arch-Gravity	295	14	14400	F
Hongjiadu	Guizhou	Wujiang	CFRD	178	4.59	540	D
Goupitan	Guizhou	Wujiang	Arch	225	5.69	2000	F
Siling	Guizhou	Wujiang	Gravity	122	1.2	840	F
Pengshui	Sichuan	Wujiang	Gravity	115	1.16	1200	F
Jinping	Sichuan	Yalong	Gravity	49	3000	20.97	F
Pubugou	Sichuan	Dadu	Rockfill	188	5.55	3300	D
Xiaowan	Yunnan	Lancang	Arch	290	15.2	4200	D
Nuozadu	Yunnan	Lancang	Rockfill	254	22.7	5000	F
Longtan	Guangxi	Hongshui	RCC	192	16.21	4200	D
Sanbanxi	Guixhou	Qingashuijiang	Gravity	170	4.72	680	D
Shuibuya	Hubei	Qingjiang	CFRD	228	4.74	1200	D
Tongbai	Zhejiang	P-S				1200	D
Xianshuijian	Anhui	P-S				1000	D
Langyashan	Anhui	P-S				600	F
Zhanghewan	Hebei	P-S				1200	D
Xilongchi	Shanxi	P-S				1000	D
Taian	Shandong	P-S				1000	D

F = feasibility study stage; D = design stage; P-S = pumped-storage plant; CFRD = Concrete Faced Rockfill Dam; RCC = Roller Compacted Concrete

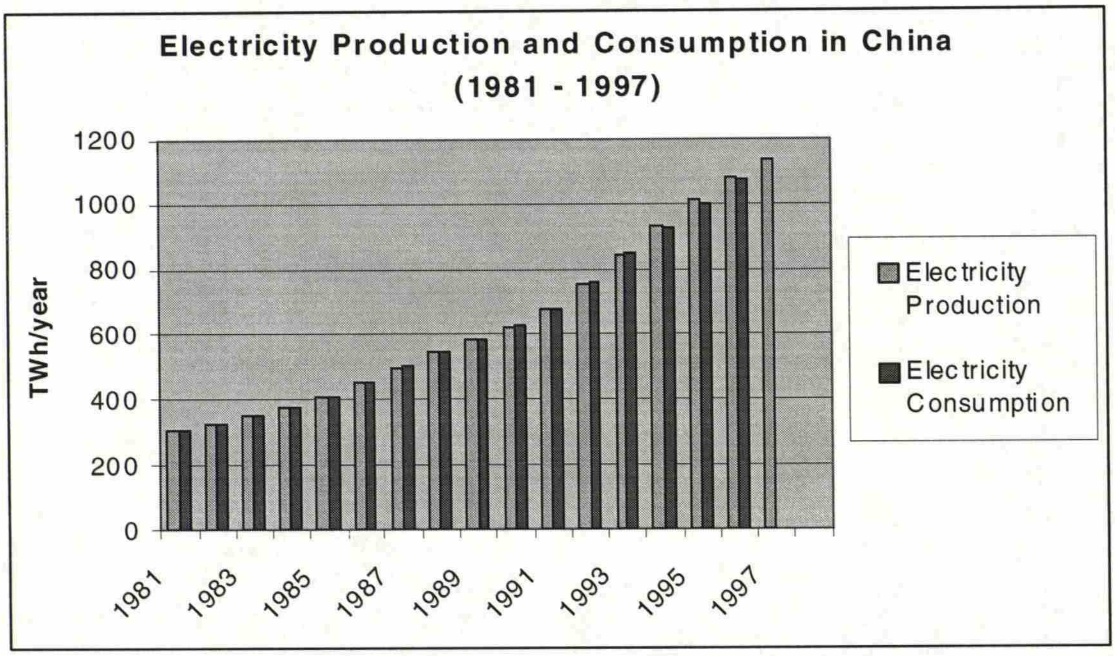


***Figure 4.3**: Electricity Production and Consumption in China*

Source: ADB, 1999

4.3.3 Irrigation and Water Supply

When examining the irrigated area by source of supply, the biggest part of the irrigated area (31 %) depended on reservoirs in 1985. During the same year, reservoirs supplied 108 km^3 of water (30 % of total) for agriculture. Relative to the effective area, the stable irrigated area tends also to be higher in reservoir and pump schemes than in diversion schemes (World Bank, 1997).

Due to the wide variations in rainfall within a year, especially in the area north of the Yangtze and the northern parts of Yellow River basin, irrigation is essential to the farmers. The peak demands for irrigation come in the fall and spring when the rivers are at their lowest. Therefore, dams are needed to store the abundant flows during the rainy season and release water in the dry season (WCD, 2000).

Reservoir water will become increasingly important as the water demand in industrial and domestic sectors grows and groundwater sources decline in quantity and quality. There are already some large single purpose dams for water supply in China. For example the Miyun Reservoir, with an area and volume of 188 km^2 and 0.43 km^3 respectively, was built solely to supply water to Beijing (ILEC, 2000).

4.3.4 Other Purposes

Other purposes of large dams include sediment control and navigation.

Thousands of sediment control dams have been built in China. The construction of such dams has been intensive especially in the Yellow River, which carries more sediment than any of the world´s large rivers. The sediment, coming from the Loess Plateau, deposits in the river channel and causes the rising of river bed above the surrounding land. In order to keep the river within its channel during floods, it is necessary to periodically raise 700 km of flood embankments, strengthen 1,000 km of levees, and reconstruct and repair over 5,000 river training spurs.

The dams are homogenous earthfill dams from 15 m to 30 m in height. The cost of dams is low because the loess soil, ideal for earthfill dams, is abundant near the dam sites. The most recent dam for sediment control in Yellow River is Xiaolangdi dam. It will intercept sediment during its early years of operation and allow the raising of levees in the lower reach to be deferred. It is expected that the sediment storage space in the Xiaolangdi reservoir will fill in about ten years. After that the process of deposition in the river´s lower reach will begin again (WCD, 2000).

Improved navigation facilities gained by construction of large dams do often intensify shipping. Reservoirs are more navigable compared to rivers which have sections with shallow water and rapids.

Three Gorges Dam is a good example of navigational benefits. After the completion of the 660 km long reservoir, ships up to 10,000 tons are able to reach Chongqing. This will increase the annual one-way navigation capacity from present 10 million tons to 50 million tons and decrease the navigation costs 35 – 37 % (CTGPC, 1999).

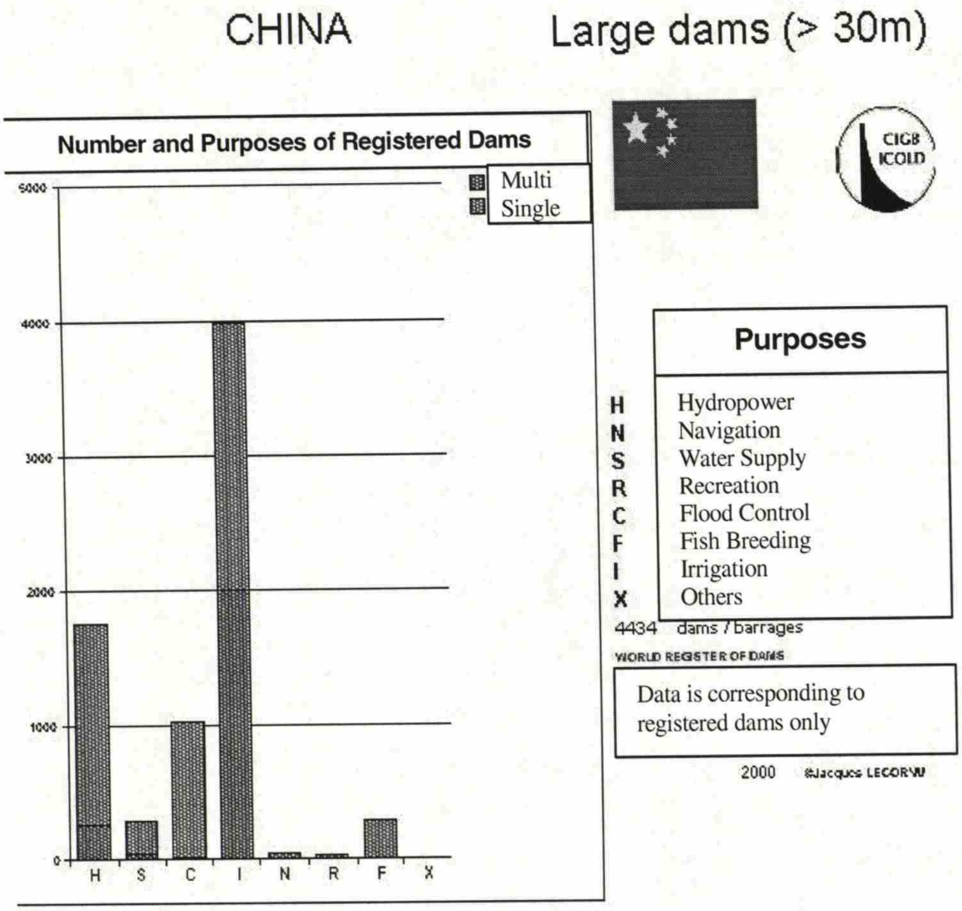


***Figure 4.4:** Number and Purposes of Registered Dams in China*

Source: ICOLD, 2000a

4.4 Dujiangyan Irrigation Project

Dujiangyan Irrigation Project is located in Sichuan Province in Southwest China on Yangtze's tributary Minjiang River, 60 km upstream from the province's capital Chengdu. It is world's oldest functioning irrigation project. The construction of the project started 2,250 years ago around 250 B.C. under the direction of Li Bing, the governor of the Shu Prefecture. United Nations Educational, Scientific and Cultural Organization (UNESCO) is considering placing the Dujiangyan Irrigation Project in its world heritage list (People's Daily, 2000a).

Prior to the construction of the irrigation system, the Minjiang River running across the vast Chengdu plain used to do harm to the people. Flooding often occurred in summer seasons in downstream areas of Minjiang River basin. The geographic disadvantages accelerated the seriousness of the floods. Water courses became wider and with no dikes or dams became unstable during the rainy seasons.

Picture 2: *Dujiangyan Irrigation System with its water-dividing dyke*

Photo: Tommi Kajander

The headwork of Dujiangyan Irrigation Project consists mainly of three projects: the water inlet channel (Baopingkou), the water-dividing dyke (Yuzui) and the spillway for discharging flood and silt (Feishayan). Workers using only hand tools cut the water inlet canal through the towering Mount Yulei to feed an extensive system of canals on the plains. In the middle reaches of the Minjiang River, a dyke was built to divide the river into two parts: the inner river and the outer river. The inner river was designed to provide water for irrigation, while the outer river was for flood discharge. During the flood season, 40 % of the discharge flows in the inner river and 60 % in the outer river. During the dry season major part of the flow (60 %) is divided to the inner river for irrigation purposes. In addition to the flood control and irrigation benefits, the diversion of the flow provides also a natural removal of the sediment. 80 % of the sedimentation sands can be washed away automatically by water discharge in the outer river (Dujiangyan Irrigation..., 1999).

Over two thousand years, the Dujiangyan Irrigation System has brought considerable benefits to the region. The irrigated area has expanded from 126,000 ha to nearly 660,000 ha of land, covering 36 counties and cities, average food production per hectare has increased from 3,750 kg/ha in 1949 to more than 7,000 kg/ha and 700 million m^3 of water is supplied for urban industry and domestic use annually.

Adverse impacts have been small. Biggest problems in Minjiang River Basin are the decreased low flow and the deteriorating water quality. In 1945, the low flow was 150 m^3/s, whereas today it is 100 m^3/s. Since 1958 the water quality has been deteriorating due to the intensified use of fertilizers in agriculture (Bin, 2000).

According to Lubiao Zhang (Zhang, 1999) four aspects of good practices and experiences can be summarized from the Dujiangyan Project. Following is drawn from Zhang, 1999:

1) *Good location of a dam is vital for its success.*

Dujiangyan Irrigation Project meet the following criterion for a good site for constructing an irrigation dam:

- Favorable natural geological conditions
- Proneness to natural removal of sediment
- Appropriate technique for the dam
- Keeping the displaced people to a minimum

80 % of the silt is naturally washed away by the outer river. The appropriate technique was applied: the Dujiangyan Weir did not require a large dam, but a dike less than 10 m high. 2200 years ago it meant higher technological guarantee and less uncertainty and risks for the downstream people.

2) *Scientific project planning and programming is the key to technological, economic, environmental and social feasibility of a dam.*

Identification of a good dam construction technique is an integral component of scientific project planning of a dam. Some approaches for Dujiangyan dam construction were well practised and extended to many large dam projects for irrigation in China. The "Movable Steel Matrix Trestle Approach" for dam construction, invented in 1949, is still used by dam engineers and investors.

Basin-wide planning for water management is the key element to maximize the benefits and minimize the costs. Not only the impacts of a dam on the upstream but also on the downstream should be taken into full consideration

3) *Effective and sustainable management system is a guarantee for the success of a dam.*

Institutional arrangement was set to allocate the responsibility of dam management and management system to provide incentives for managing the dam well. Mistakes and wrong decision-makings concerning the management of the dam were punished.

Before 1935, a special staff or envoy was always assigned to be responsible for the Dujiangyan Irrigation Project Dam under direct supervision of ministry. At that time, the staff's main tasks included water monitoring, sedimentation removal and canal maintenance.

In 1935, a special Dujiangyan Engineering Division under the Department of Construction of Sichuan Province was set up because the project had become more diversified and far-reaching. In 1949, a formal Dujiangyan

Administration was established to be responsible for the dam, canal maintenance and water allocation plans. Since 1950s, Participatory Management Approach, was involved to the management system. Various non-governmental organizations (NGOs) and individuals, such as the sub-canal administration committee composed by farmers, water management groups of villages and water delivering team, joined the management groups. They were assigned the responsibility for the management of sub-rivers and small canals in the fields.

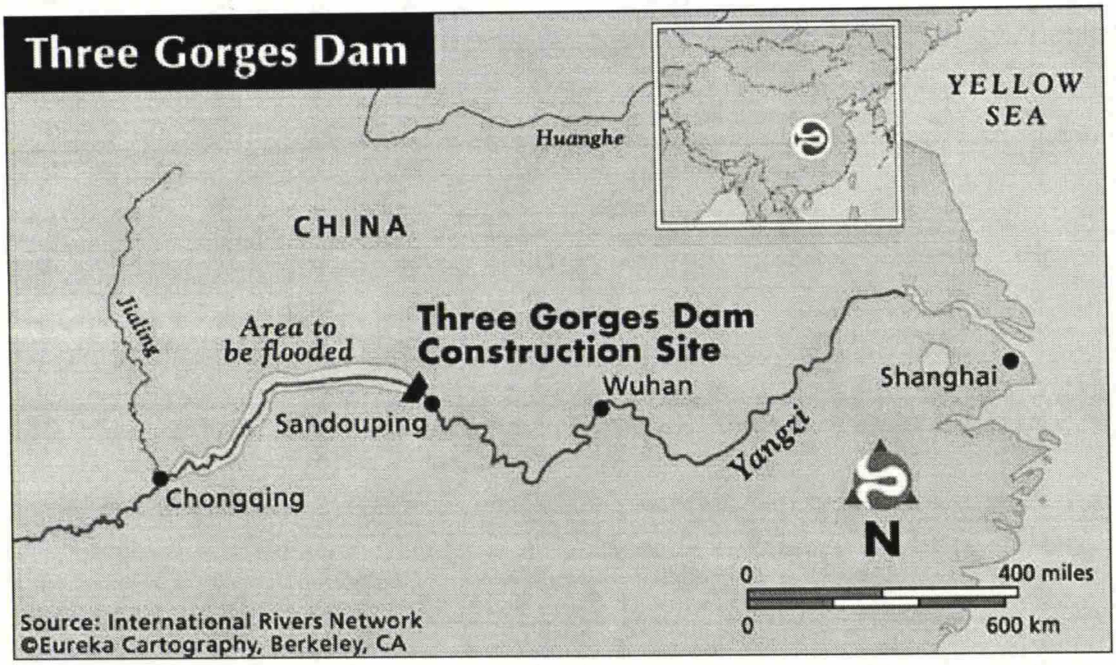
Furthermore NGOs and governmental organizatios were all involved in the dam management decision-making process. This participation provided the NGOs and governmental organizations strong incentives to save water resources, to manage and utilize well the canals and water engineering facilities and to increase the water use efficiency in order to make agricultural production more stable and sustainable.

4) To increase social equity between poor and rich farmers, and to help achieve efficient control of water fee collection, block water charging approach has been one feasible option

Dujiangyan Irrigation Project and other chinese dam and reservoir experiences in sustainable water management disclosed that block water charging approach is feasible and acceptable to both, farmers and policy-makers. It was proved that chinese farmers can accept this kind of water pricing approach all over the country. They are willing to pay different prices in different regions upstream and downstream the river. Water fee collection is not a problem in these areas where such approach was used in general. For the less developed areas, water fee could be considered as a burden for the farmers. The experiences disclosed that water fee could not exceed 1-3 % of the farmers income level in poor areas of China (Zhang, 1995).

4.5 Three Gorges Project

Three Gorges Project (TGP) is the largest and probably the most controversial water conservancy project ever built in the world. The dam site is situated in Sandouping of Yichang City, Hubei Province, about 38 km upstream from the existing Gezhouba Project, on Yangtze River. TGP is composed of a dam, two powerhouses and navigation facilities.



Map 5: *Three Gorges Project area*

Source: http://irn.org/programs/threeg/map.shtml

The dam is of a concrete gravity type and has a total length of 2,309 m, with the crest elevation at 185 m. There are 14 sets of hydro turbine generator units installed in the left powerhouse and 12 in the right one. Thus, there are 26 sets of turbine generator units in total, 700 MW each, totalling 18,200 MW in installed capacity. The hydro plant will produce 84,7 TWh (about 7 % of the total power generation) electricity output annually.

The total estimated cost of TGP is 209.90 billion RMB Yuan (US$ 24.63 billion, exchange rate of 9 October 2000) by rough estimate. The total duration of construction will last 17 years, divided into three stages. The first stage construction is completed and lasted from 1993 to 1997. The second stage construction lasts till 2003. The construction work of the three gorges project will be finished in 2009.

The total storage capacity of the reservoir will be 39.3 km^3, with the normal pool level at 175 m. The dams´s flood control storage capacity will be 22.15 km^3 (CTGPC, 1999).

Table 4.9: *Numerical Data on Three Gorges Project*

Source: CTGPC, 1999

Three Gorges Project in Figures	
Total length of the dam	2,309 m
Crest elevation	185 m
Number of turbine generators	26 (700 MW each)
Total installed capacity	18,200 MW
Annual electricity output	84.7 TWh
Normal pool level	175 m
Flood season pool level	135 m (during the first ten years) 145 m (from 11^{th} year)
Reservoir´s total storage capacity	39.3 km^3
Flood control storage capacity	22.15 km^3
Reservoir´s surface area	1,084 km^2

Picture 3: *Scale Model of Three Gorges Project and its Structures in Yichang next to the TGP construction site*

Photo: Tommi Kajander

4.5.1 Major Concerns Encountered by Three Gorges Project

Resettlement of People

According to 1992's survey, the TGP reservoir will inundate 278 km^2 of farmland and 844,000 thousand residents living in the inundated area. Taking into account the population growth and second relocation during the construction period, the total population resettled would be over 1 million. According to NGO Probe International, the Three Gorges dam will be a tragedy for nearly two million people (Probe International, 2000). 42 % of the resettled people live in rural areas and will loose their farmlands. According to the resettlement programme, 60 % of the rural population will continue agricultural production and the remaining 40 % need new jobs in industries and third estates. Due to the loss of farmland, 120 to 150 thousands tons of grain has to be imported from other regions (Ziyun, 1998).

Picture 4: *The new homes of the resettled people are often in the upper parts of the hillside near the old buildings.*

Photo: Tommi Kajander

Although a relatively small number of people have been relocated problems have already emerged. The resettlement has been plagued by mismanagement, official corruption, inadequate compensation, and a shortage of farmland and lack of jobs for the resettlers. Demonstrations against the dam and clashes between police and local people has occurred (Ming, 1998; Mykkänen, 1999).

Environmental Concerns

Construction of large dams do always have negative effects on the environment. Due to the great size of the Three Gorges Dam, the environmental impacts in and around the reservoir will be severe, with physical, ecological and social changes in the area along the Yangtze and its tributaries. The migration of fish will be blocked, sedimentation will increase, as will the temperature in the upstream end of the reservoir. As water seeps into the dry land, and as reservoir levels fluctuate, the reservoir shoreline will begin to erode. Stratification and chemical changes in the reservoir will effect water quality. The dam builders predict that both natural fish populations and aquacultural production will increase in the reservoir. Experience with other large dams shows that productivity in reservoirs normally plummets after an initial boom. The original species of fish will probably not be able to adapt to the changed environment (FIVAS, 1996).

The risks of landslides and earthquakes do exist. The possibilities of induced seismic activity have not been sufficiently studied. A failure of the Three Gorges dam would create one of history's worst man-made disasters. 75 million people live along the intensely cultivated river banks downstream of the dam (FIVAS, 1996).

In addition to adverse environmental impacts, there are also some environmental benefits. One of the biggest benefits gained by the Three Gorges Dam, is obviously the clean energy it will produce. If the same amount of energy is produced by thermal plants it would need burning of 50 million tons of raw coal, which means emissions of 100 million tons of CO_2, 2 million tons of SO_2, 370,000 tons of NO_x and, 10,000 tons of CO annually. Decreasing siltation of the Dongting lake, a large lake downstream which is silting up, is also listed as one of the positive environmental effects. In addition, increased water flow in the dry season is supposed to improve downstream water quality (CTGPC, 1999).

The Environmental Impact Assessment System of Three Gorges Project is provided on the next page in figure 4.5.

Sedimentation

Sedimentation is a crucial factor when considering the lifespan of a reservoir: the higher the sedimentation rate, the shorter the lifespan of the reservoir. Deposition of sediment has arisen to one of the main issues concerning three Gorges Project.

On average about 500 million tons of sediment passes the dam site every year. At the beginning of operational period of the reservoir, around 70 % of the sediment would settle in the reservoir. As time goes on and sediment builds up, the capacity of the reservoir will decrease and flow velocity increase until the inflow and outflow of sediment will become broadly in balance. Deposition and erosion is investigated by three physical scale model experiments for the neighborhood of the TGP in China. The results are similar to each other (WCD, 2000; Fang et al., 2000; Fang, 2000)

The opponents of the dam are not convinced of the chinese research results. According to Prof. Leopold (Leopold L., 1998) the sedimentation conditions at various times during the first 100 years of operation have been forecast by use of mathematical models and physical analogues that involve many assumptions of unverified reliability. After american experience the conditions after 50 years in the future are usually quite different from any forecast, and 100 years in the future are simply not forecastable. Another problem is in the ability of designers to forecast the rate of sediment accumulation in a reservoir. Even when the records of sediment inflow are reliable, the deposit rate is often quite unanticipated.

A study by the Beijing Water Institute´s Siltation Study Centre in July 1988, entitled "Study on impacts of 1954 flood on Chongqing Port", demonstrated that silt deposit would be a severe problem at Chongqing port when the Three Gorges reservoir level is raised to 175 metres. The devastating flood in 1998 indicated that the flood volume was only 4.7 percent more than the 1954 flood, however, the silt content carried by the flood was 17.7 percent more than that of 1954. This points to a more serious siltation problem (Three Gorges Probe, 2000).

Three more dams are proposed at the upper reaches of Yangtze to block some

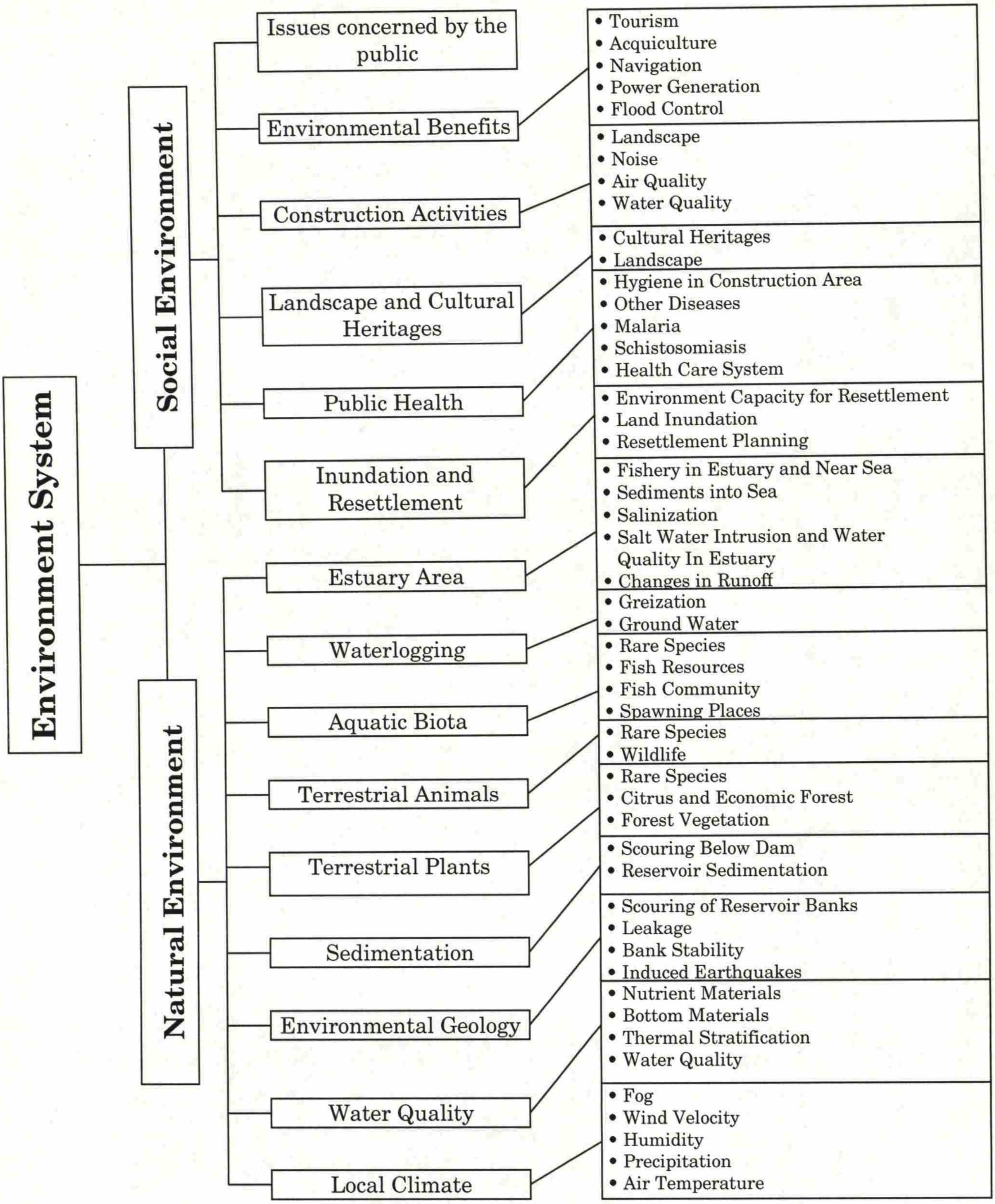


Figure 4.5: *Environmental Impact Assessment System of Three Gorges Project*

Source: CTGPC, 1999

of the silt inflow at the Three Gorges Dam. They are the Xiluodu and Xiangjiaba dams on Jinsha River and the Jianting Zikou project at the Jialing River. Combined, they are expected to control 304 million tons (60 %) of silt flowing into the Three Gorges reservoir annually.

Flood Control

Flood control has arisen to one of the main issues in China´s water resources management. Floods have caused significant economical and human losses during the past century (see table 4.6).

The main purpose of the Three Gorges dam is flood control by regulating the flood flow and reducing the catastrophic flood peak. Although the flood control volume of Three Gorges reservoir is not so big, compared with the volume of flood flow in Yangtze, according to dam proponents, it has a significant effect of reducing the flood peak.

For a one in 100 year flood event it can reduce the flood peak from 83,700 m^3/s to 56,700 m^3/s at the Zicheng station, the control station for flood protection. Hence the Jinjiang Flood Diversion would not be used. For a one in 1000 year flood event, like that of the 1870 pattern flood, it can reduce the flood peak from 110,000 m^3/s to 80,000 m^3/s. In this situation , the Jinjiang area from Yichang to Chenlingji, could be protected by remedial measures of diversion (Ziyun, 1998).

Today the 180 kilometres long Jingjiang dike is the area's most important flood protection. Opponents claim that strengthening the existing dikes will provide sufficient protection against the floods. They also claim that the dam's potential for flood control is exaggerated, and that the dam will not be able to protect the areas further down the river as it doesn't control the large tributaries downstream of the dam.

The severe floods of Yangtze in 1998 were caused by two simultaneous monsoons which normally appear separately. The southwestern monsoon from South Asia affected the upper reaches of Yangtze while the monsoon from Pacific Ocean hit the lower parts (downstream of the TGP) of the river. Together they caused such a destructive flood that the TGP would not have been able to prevent it (Varis, 2000).

It has also been pointed out that erosion of the dikes along the river could increase after the dam has been built, as the river will contain less sediments, and that the danger of flooding along the reservoir has been underestimated (FIVAS, 1996).

Table 4.10: *Beneficial and adverse impacts of Three Gorges Project*

Source: Veltrop, 1998

BENEFICIAL IMPACTS	ADVERSE IMPACTS
• Regulate the flood flow and reduce the catastrophic flood peaks. 15 million people and 120,000 km^2 of farmland will benefit from the flood control.	• Resettlement of 1.3 million people
• The hydro plant will produce 84.7 TWh of electricity annually	• Inundation of 632 km^2, of which 278 km^2 is productive farmland
• The produced hydroelectricity reduces air pollution and manages to avoid burning of 50 million tons of coal annually	• Decrease of water quality in the reservoir due to: - Industrial, domestic and agricultural effluents - the reduced flow velocity which decrease the level of dissolved oxygen and dispersion of pollutants
• Navigational improvements will enable 10,000 ton vessels to reach Chongqing and open up the middle and upper reaches of the Yangtze River for economic improvements	• Changes in aquatic ecology will deteriorate conditions for survival of rare and endangered species
• Reservoir fisheries and tourism	• Changes in scouring and sediment deposition may affect water quality in the upper regions of the reservoir, as well as existing water supply and drainage facilities in Chongqing
• Augmented discharge during the dry season improves the downstream water quality	• Submerging of cultural and historic relics
• Protection against flooding and waterlogging of the lake areas downstream of Gezhouba Dam	• Worsening of salt water intrusion in the estuary
• Slowdown of sedimentation in Dongting Lake	
• Future transfer of water from South to North China	

4.6 Lancang River Development

The Upper Mekong, called Lancang River in China, is a 2,100 km long river with a total drop of 5,000 m. Its catchment area is 174,000 km^2 out of which 91,000 km^2 is in the province of Yunnan (ICOLD, 2000b).

Although the plans concerning the tapping of the lower Mekong (see chapter 3.2) are still on the table, the plans concerning construction of large dams on the upper Mekong *(Lancang Jiang)* in China are already under execution.

The planning of a cascade of eight large dams on the Lancang River in Yunnan started in the 1970s. The dams were planned primarily for the production of electricity for national needs in Yunnan, one of the poorest provinces in China and the neighbouring provinces as well as for export to Thailand. The planned dams and some of their characteristics are presented below in table 4.11.

Table 4.11: *The planned dams on the Lancang River*

Source: Mekong Development Research Network, 1993

Name	Dammed Waterhead (m)	Active Storage (million m^3)	Installed Capacity (MW)	Total Cost ($US millions)
Manwan[a]	99	250	1,500	516
Dachaoshan	80	370	1,350	810
Jinghong	67	250	1,500	1,000
Xiaowan	248	990	4,200	2,270
Nuozdahu	205	1,220	5,500	2,410
Mengsong*	28	-	600	280
Gongguoqiao	77	120	750	460
Total		3,200	15,400	7,746

* Run-of-river dam (See definition in Ch. 3.2)
[a]Completed

The Manwan Dam is the first completed dam of the cascade. All the five generating units were put into operation in 1995 with a total installed capacity of 1,500 MW.

Dachaoshan Dam is under construction. The implementation of the project started in 1996 and is supposed to be finished in 2002.

The feasibility study for the Jinghong Station, located 300 km from Northern Thailand, has been completed. The governments of China and Thailand signed a letter of intent on the construction of the Jinghong Station last June. The Thai party will hold 70 percent share of the project while the Chinese side will share the remaining 30 percent. It is initially planned that construction will begin in 2006. The station will provide Thailand 1.5 million kW of electricity by 2013 (People´s Daily, 2000b, 2000c).

What will be the impacts downstream in the Lower Mekong Region? In the lowest section of the river the impacts will probably be minor. Lancang River contributes 16% to the total discharge of Mekong in Phnom Penh in Cambodia. When considering the mainstream discharge in the upper parts of the river the impact is greater. The discharge contribution of Lancang Jiang to Mekong is 65% and 61% in Luang Prabang and Vientiane respectively.

The expected completion of the reservoir at Xiaowan before the Year 2010 will have a major effect. Mean discharge from Xiaowan between November and April is expected to increase from 689 m^3/s to 968m^3/sec. When Nuozhadu is added to the system the mean dry season discharge near the Yunnan-Laos border is estimated to total 1,869m^3/sec, an increase of 1,180m^3/sec or 171 per cent (Chapman et Daming, 1996).

The additional water in dry season will increase available water supplies in Laos and the water scarce regions of North and Northeast Thailand. It will also have an effect on the water diversion schemes planned in Thailand (see the country review of Thailand Ch. 3.4.4). In addition the increased dry season flow will also benefit the upper schemes of the proposed Mekong run-of-river dams (if implemented) by providing more water for hydropower generation.

The construction of dams on the Lancang Jiang will have costs as well. There will be effects on the environment. Fisheries and river side cultivation downstream of the dam will be negatively affected.

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5 SOUTH ASIA

5.1 South Asia and its Water Resources

South Asia has several transboundary rivers which are among the largest rivers in the world. The subcontinent is drained by four major transboundary river systems: Indus, Ganges, Meghna and Brahmaputra, which all originate from the Himalaya mountain range. These rivers have many characteristics in common including e.g. great variability in flow discharge, floods during the monsoon, drought in dry season, considerable hydropower potential and high population densities in the basin areas (see table 5.12).

The transboundary rivers are covered separately in the following sub-chapters. The national water resources of each South Asian countries are slightly discussed in the country reviews (Chapter 5.2).

5.1.1 Indus

Indus River is the eastest river of the great trans-Himalayan rivers of South Asia. It originates from the Southwestern Tibet and flows northwest across Jammu and Kashmir in North India, then bends to the southwest and pours onto the hot, dry plain of the western Punjab in Pakistan. The Indus receives its most notable tributaries from Punjab, called the land of five rivers. The five rivers are Jhelum, Chenab, Ravi, Beas, and Sutlej.

Indus River, the lifeline of Pakistan, plays a crucial role in the economy of Pakistan. Farmers of the area have used Indus waters since prehistoric times. Irrigation from the Indus and its tributaries makes possible the cultivation of the arid land along their courses. Besides the irrigation, the Indus Basin generate almost half of the electricity produced in Pakistan.

The river's volume is greatest from July to September, when snows are melting in the mountains and the southwest monsoon brings rain. Embankments are used to prevent flooding, but occasionally they give way and floodwaters spread rich alluvial soils over vast areas of the plain.

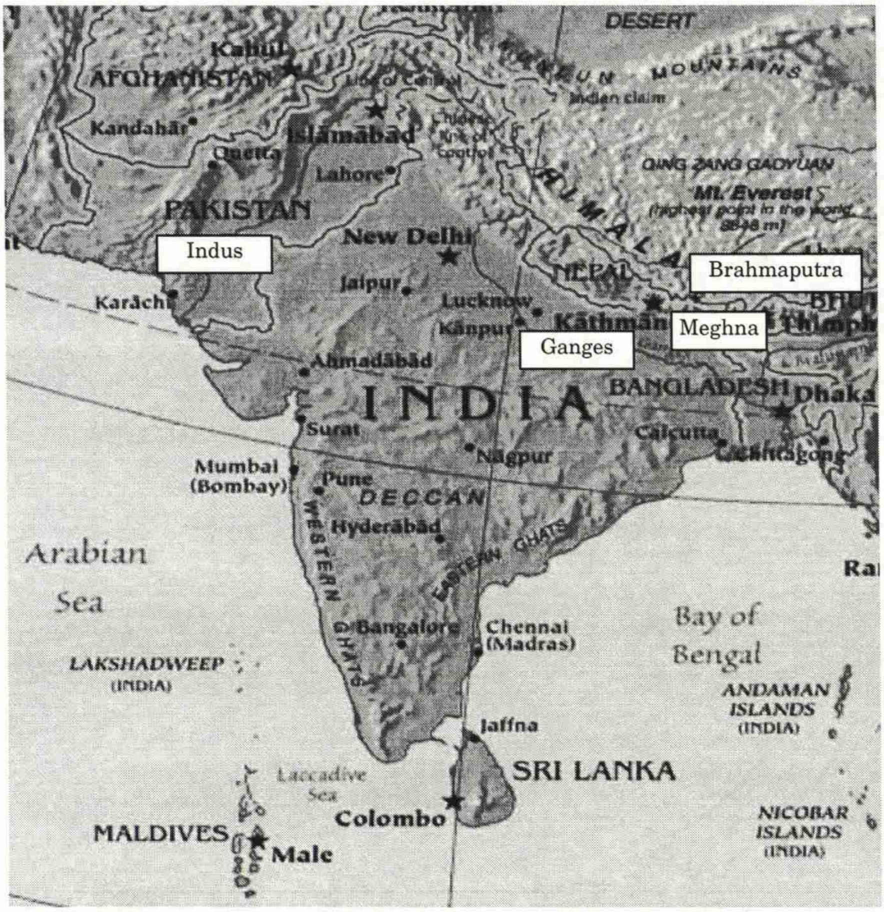
The use of Indus water is defined in the Indus Water Treaty between India and Pakistan. According to the treaty, signed in 1960, all the waters of the eastern rivers, i.e. the Sutlej, Beas and Ravi rivers taken together, shall be available for the unrestricted use of India. All the waters, while flowing in Pakistan, of any tributary which in its natural course joins the Sutlej main or the Ravi main after these rivers have crossed into Pakistan shall be available for the unrestricted use of Pakistan. This flow reserved by treaty is estimated at 11.1 km^3/year.

According to the Indus Basin Studies (WAPDA, World Bank Consultants) conducted in the early sixties, the Indus System has over 30,000 MW of economically developable hydropower potential. Presently, the hydropower generating capacity of the entire Indus River System is slightly under 5000 MW.

5.1.2 Ganges

The Ganges River´s headstreams all rise in northernmost Uttar Pradesh state in India. The river continues flowing southeast through the Gangetic plain and the indian states of Bihar and West Bengal. In central Bangladesh the Ganges is joined from the north by the great Brahmaputra and from the northeast by the Meghna River. Their combined waters (the Lower Meghna) empty into the Bay of Bengal through an extensive and ecologically diverse delta. With a width of 320 km, the delta covers an area of ca. 60,000 km² in Bengal and is mostly located in the territory of Bangladesh (EB, 2000).

The Ganges Basin is densely populated. The basin area is nearly 1 million km² while it carries 420 million people or one third of the Southasian population. Agriculture is intensive in the basin area; 71 % of the Ganges watershed is cultivated (Kuusisto,1998; WRI, 2000).



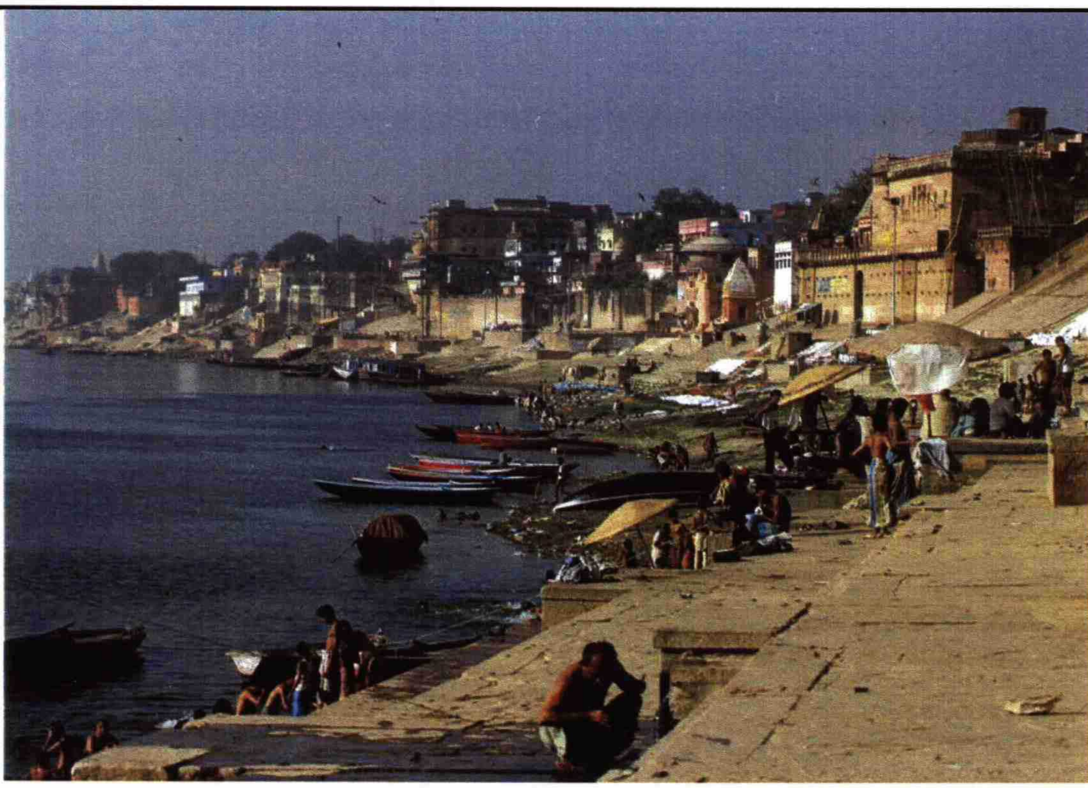
Map 6: *South Asia and its Major River Systems*

Source:
http://www.lib.utexas.edu/Libs/PCL/Map_collection/middle_east_and_asia/Asia_ref_2000.jpg

The water supply of the Ganges system is dependent partly on the rains brought by the monsoon winds from July to October, as well as on the flow from melting Himalayan snows in the hot season from April to June. Although Nepal´s share of the basin area is just 14 %, it contributes about 60 % to the annual discharge of the Ganges. The main tributaries of Ganges, originating from Nepal are the Karnali, Gandak and Kosi Rivers.

The mainstem of the Ganges was unregulated until 1974 when the Farakka Dam was constructed. India built the dam unilaterally to increase the discharge and flush the silt in the Hooghly River. This was necessary to sustain the commercial viability of Calcutta port. The Farakka Dam is discussed as a case study in the country review of India (Chapter 5.2.3).

In the Ganges River Basin, effective water resource management is constrained by the lack of data sharing among neighboring countries. The security of millions of people is endangered through increasing water scarcity, floods, excessive sedimentation, drastic changes in river morphology, reduced dam safety, salinization of fresh waters, loss of arable lands, and environmental degradation of unique habitats such as the mangrove forests of the Sundarbans in the Ganges delta (CMC, 2000).



Picture 5: *Middle Reaches of the Ganges River and the Holy City of Varanasi During the Dry Season in April 1999.*

Photo: Tommi Kajander

Besides the problems referred to above, water quality problems of the Ganges have reached a critical level. The heavy population concentration, the absence of strict environmental rules, and the failure to enforce whatever rules that exist, have resulted in the Ganges being one of the most polluted rivers in the world. 114 cities pour untreated sewage into India´s most important river. The Ganges´ tributary Yamuna alone drains 200 million litres of sewage and 20 million litres of industrial waste from Delhi to the mainstream. The poor water quality correlates with the occurrence of waterborne diseases such as hepatitis, amebic dysentry, typhoid, and cholera.

Table 5.12: Characteristics of the major river basins in South Asia

Sources: ADB, 1996; Bastola, 1994; FAO: Aquastat, 2000; WRI, 2000;.

River	Annual Average Discharge (m^3/s)	Length (km)	Basin Area (km^2)	Population Density (people/km^2)	Large Dams
Brahmaputra	18,960	2,580	580,000	174	0
Ganges	16,650	2,510	977,500	375	6
Indus	5,644	2,900	978,000	145	10
Meghna	5,160	950	80,200	N/A	0

5.1.3 Brahmaputra

Brahmaputra is the biggest trans-Himalayan river system. It stretches from the northern slopes of the Himalayas through Tibet, China and India to enter Bangladesh. From the border it flows south for 270 km to join the Ganges River at Aricha, about 70 km west of Dacca in central Bangladesh. The unified rivers form a mighty stream called Padma River which continues a further 100 km to receive the waters of Meghna River at Chandpur. The Lower Meghna then flows south for 160 km and discharges into the Bay of Bengal through the biologically diverse Meghna estuary. The discharge of the Lower Meghna (the combined discharge of the three main rivers, Brahmaputra, Ganges and Meghna) is among the highest in the world. Peak discharges exceeding 160,000 m^3/s have been recorded (FAO, 2000).

Floods are an annual phenomena with beneficial and adverse impacts (see the country review of Bangladesh, Ch. 4.2.1). For the agriculture purposes floods do have a positive effect. Part of the sediment is diposited as a thin layer over the delta, thereby renewing the fertility of the soils. Some sediment is deposited at the oceanward edge of the delta, where it creates new islands. Each emerging delta island is colonised by farmers desperate for new land. The Brahmaputra has flooded more often and with greater severity in recent years due to the rapid deforestation in the Himalayas.

The Brahmaputra is navigable as far as Dibrugarh in India about 1,100 km from the Bay of Bengal. The growth of heavy river transport has been important to the continuing development of the economic resources in the lower Brahmaputra valley, including tea estates, forests, and oil, coal, and natural-gas deposits in Assam and jute in Bangladesh. In Tibet, the river is navigable for a distance of about 640 km (EB, 2000).

5.1.4 Meghna

With an annual average discharge of about 5,000 m^3/s, Meghna River is the smallest South Asian major river system. The 210 km long river is the major watercourse of the Ganges-Brahmaputra delta, in Bangladesh. The name is properly applied to a channel of the Old Brahmaputra downstream from Bhairab Bazar, after it has received the waters of the Surma (Barak) River in Northeast Bangladesh. Flowing almost due south, the Meghna receives the combined waters of the Ganges and Brahmaputra rivers near Chandpur. After a course of 264 km it enters the Bay of Bengal by four principal mouths. The major tributaries of the Meghna are the Dhaleswari, Gomti, and Fenny Rivers.

A river of great depth and velocity, the Meghna is sometimes split up into several channels and sandbanks of its own formation. The river is navigable, but dangerous, all year. At spring tide the sea rushes destructively upriver in a single 6 m-high wave.

5.2 Country Reviews

5.2.1 Bangladesh

Bangladesh is a South Asian country located between India and Myanmar. With an area and a population of 143,998 km^2 and 128 million respectively, it is one of the most densely populated country in the world.

The country receives an annual average precipitation of 2,320 mm which brings about total renewable water resources of 1,211 km^3/year (FAO,2000). There are 230 rivers (including tributaries), out of which 57 are transboundary. The water resources are dominated by the three mighty rivers: Brahmaputra, Ganges and Meghna (see table 4.1). Together they form the majority of the country´s floodplain, which covers 80 % of Bangladesh. In addition this river system, which is world´s largest sediment dispersal system, forms the most extensive delta region in the world (Passmore, 1997).

The flow of the rivers is highly seasonal and fluctuates widely during the monsoon and the dry months. As a consequence, two major hazards are confronted with: severe scarcity of water during dry seasons and floods during the monsoons. As the lowest riparian of Brahmaputra, Ganges and Meghna, Bangladesh has to suffer from the continued development of upstream basins. Due to the deforestation in the upper watersheds, floods are worsening and causing serious environmental degradation and erosion. In 1998 the floods continued for more than two months, from the middle of July until late September. Three quarter of the country was submerged by flood. 860,000 ha of farmland and more than half of Dhaka, the capital city, were inundated. In total, more than 40 million people were affected.

During the dry season (October-May) the upstream withdrawals are causing severe water shortages across the country. In addition the decreasing low flow has devastating effect on the ecology: fish populations are threatened and the delta region is decaying due to the increased salinization (ADB, 1996).

Due to the flatness of the country there are no appropriate sites for large dams. Today there is one large dam in operation on Karnafally River in the southeast of the country. It was constructed in 1962 mainly for generation of hydropower. No large dams are under construction or planned. The total water storage capacity of all dams is 5.36 km^3 (The Inter..., 1999).

5.2.2 Bhutan

Bhutan, with an area of 47,000 km^2, is a small kingdom located on the eastern ridges of the Himalayas, neighbored by Tibet in the north and India in the south. Most of the 637,000 inhabitants live in the fertile river valleys and southern flatlands, where the land is fertile and cultivable.
Water resources are abundant in Bhutan. The average precipitation is roughly estimated around 4 000 mm/year. There are four major river basins, which all discharge into the Brahmaputra River in the plains of India. The total mean flow of the rivers is estimated at 1,325 m^3/s (UN, 1995).

Besides being the main source of water, the rivers carry a huge potential for hydropower development. Bhutan´s theoretical hydropower potential is equivalent to 20,000 MW of capacity, out of which as much as 16,000 MW is economically feasible. 100 potential sites for large or medium plants have been identified. So far, only 355 MW is developed. In 1995, hydropower generated 1,710 GWh of electricity, representing 99.6 % of national power production.

The biggest hydro project under construction is the 1,020 MW Tala hydro project. It should be in operation in 2004. Two further project are planned: the 180

MW Bunakha and the 900 MW Wang Chu. Tala and the planned hydro projects are located in the Wang Chu river valley (Inter...,1999).

Great bulk of Bhutan´s export earnings come from power sales to India. In 1997 power exports provided Bhutan revenues of US$ 35.5 million (ADB, 1999).

5.2.3 India

India is a land of many rivers and mountains. Its geographical area of about 3.29 million km^3 is criss crossed by a large number of small and big rivers. The annual precipitation including snowfall is estimated to be 4,000 km^3. By the latest estimates of Central Water Commission, considering both surface and ground water as one system, natural run off in the rivers is about 1,869 km^3/year of which appr. 1,122 km^3/year is estimated to be utilizable.

The water resources of India are unevenly distributed. Brahmaputra and Barak basin with 7.3 percent of geographical area and 4.2 percent of population of the country has 31 percent of the annual water resources. Water scarcity (less than 1000 m^3 per capita/year) is faced in Cauvery, Pennar and Sabarmati basins. In Sabarmati basin the per capita annual availability of water is as low as 360 m^3. Other water scarce river basins include the east and west flowing rivers. The major river basins of the country are represented below in table

Table 5.13: *Major River Basins of India*

Source: FAO, 2000; Ministry of Water Resources of India, 2000

Name of the River	Origin	Length [km]	Catchment Area [km^2]	Average annual run-off [m^3/s]
Indus	Tibet	1,114	321,289	2,320
Ganges	Uttar Pradesh	2,525	861,452	16,650
Brahmaputra	Tibet	916	194,413	17,040
Barak & other rivers Flowing into Meghna, Like Gomti, Muhari, Fenny etc.			41,723	1,530
Sabarmati	Rajasthan	371	21,674	120
Mahi	Madhya Pradesh	583	34,842	350
Narmada	Madhya Pradesh	1,312	98,796	1,450
Tapi	Madhya Pradesh	724	65,145	470
Brahmani	Bihar	799	39,033	900
Mahanadi	Madhya Pradesh	851	141,589	2,120
Godavari	Maharashtra	1,465	312,812	3,505
Krishna	Maharashtra	1,401	258,948	2,477
Pennar	Karnataka	597	55,213	200
Cauvery	Karnataka	900	81,155	680
Total			**2,528,084**	**49,810 m^3/s**

India has a vast potential for hydropower generation, particularly in the northern and northeastern region. As per an estimate of Central Electricity Authority, the economically exploitable hydropower potential in the country is 84,000 MW of which 22,000 MW has been installed. A further 8,910 MW of hydro capacity is under construction and 3,557 MW planned. Most of the schemes are multipurpose schemes.

India has about 2,481 large dams in operation, of a total of about 4,000 dams. The several major dams under construction are listed below in table 5.14.

Table 5.14: *Major dams under construction in India in 1999*

Source: The International Journal on Hydropower & Dams, 1999

Dam Name	River	Height	Purpose
Tehri	Bhagirathi	261	I, H
Kishau	Tona	236	H
Lakhwar	Yamuna	204	I, H
Sardar Sarovar	Narmada	163	I, H
Ranjit Sagar	Ravi	168	I, H
Karjan Lower	Karjan	100	I
Indira Sagar	Narmada	94	I, H
Doyang	Doyang	88	H
Vyasi	Yamuna	88	I, H
Kallada	Kallada	85	I
Shrinagar	Alakhnanda	85	H
Dudhganga	Dudhganga	74	I
Tillari	Tillari	72	I
Nathpa Jhakri	Sutluj	68	I, H
Godriver Medium	God	67	I
Dulhasti	Chenab	65	I, H
Upper Indravati	Indravati	65	I, H
Ranganadi	Ranga	62	H

Note: Irrigation (I), Hydropower (H)

Farakka Dam

Negotiations on sharing of Ganges water at Farakka was started from 1960 at the time of signing of Indus Water Treaty between India and Pakistan. India decided to construct a barrage across the Ganges at Farakka in 1951 in order to divert 1,133 m^3/s of water to a Ganges tributary called the Hooghly River. Due to the sedimentation, the Ganges had changed its course and the low-flow in the Hooghly had decreased. The port of Calcutta was facing serious problems since the siltation had risen the river bed. Salinization of soil was another problem faced in the delta region.

Construction of the Farakka Barrage was started unilaterally by India in 1960. The 2,240 m long dam was designed for a maximum design discharge of 76,500 m^3/s with a head regulator for diversion capacity of 1,133 m^3/s. In 1974, the Indian Government completed the dam at Farakka, 19 km upstream from the India-Bangladesh border (Engineers Association of Bangladesh, 1997).

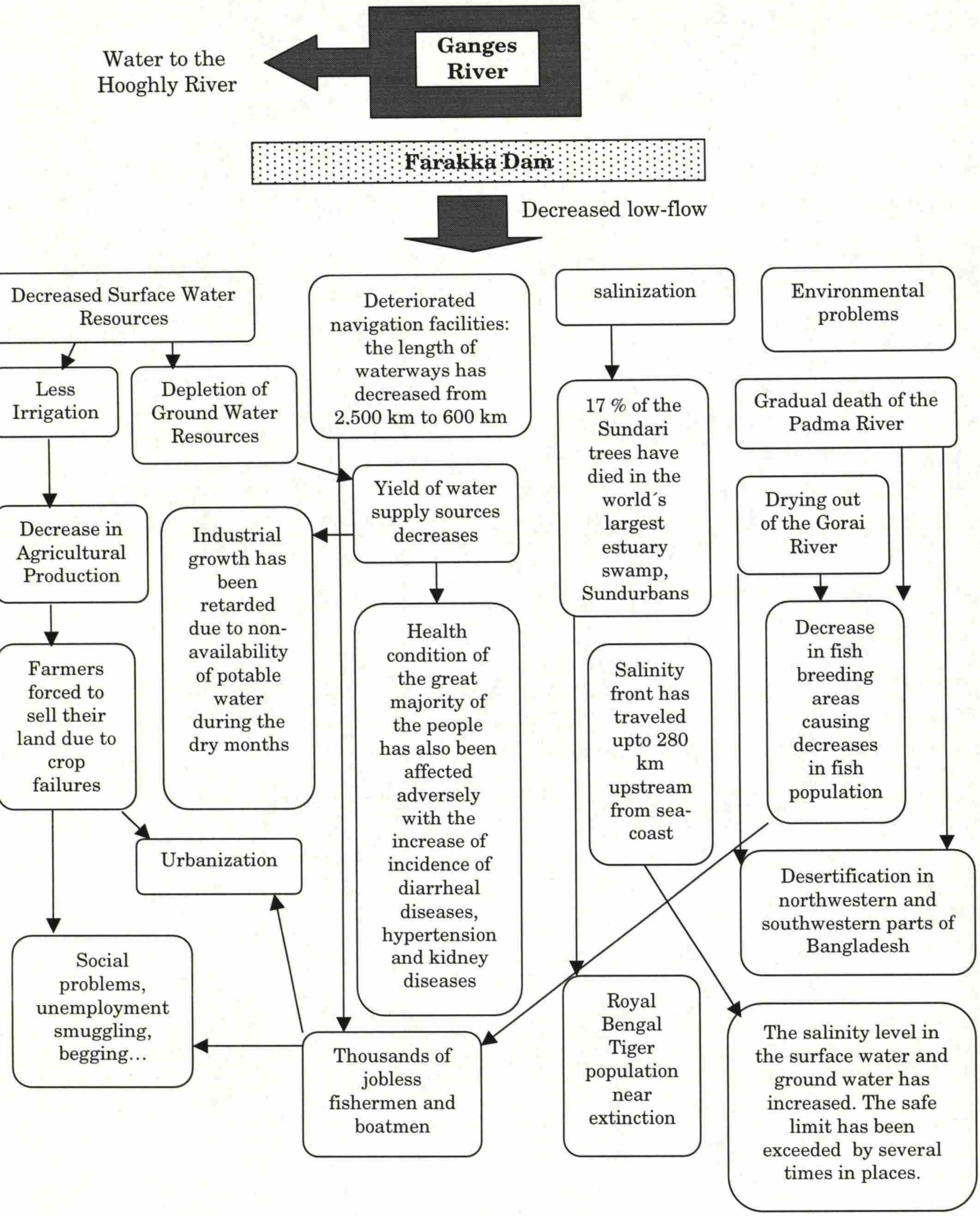


Figure 5.1: *Downstream adverse impacts of the Farakka Dam*

Source: Ahmed et Amin, 1998; Engineers Association of Bangladesh, 1997

Farakka Dam is a good example of negative downstream effects that construction of a large dam can create. The figure 5.1 above summarizes the adverse impacts and their consequences caused by the decreased dry season discharge in the Ganges Basin in Bangladesh.

Several agreements regarding the water sharing of the Ganges at Farakka has been made. The first one was announced in 1975 which was followed by the five year agreement signed in 1977. In 1982 a Memorandum of Understanding (MOU) came into effect. It was replaced by another one in 1985 which was valid up to 1988. From 1988 to 1996 no agreement existed between India and Bangladesh on the sharing of the Ganges water.

At present the two countries follow the treaty of 1996. It established a new formula for sharing the Ganges waters at Farraka in the dry season from 1 January to 31 May. According to the new arrangement both countries receive 50 % of the discharge if the Ganges flow at Farakka is 1,982 m^3/s or less. With a flow of between 1,982 and 2,124 m^3/s Bangladesh receives 990 m^3/s and India the rest of the flow. When the flow exceeds 2,124 m^3/s India receives 1,132 m^3/s and Bangladesh receives the balance. Further provision is made for the situation where the flow falls below 1,415 m^3/s. The sharing arrangements are to be reviewed every five years (Sands, 1996).

Although all the agreements between India and Bangladesh have had as their main objective the allocation of the available water there is simply not enough water for the competing demands and needs of India and Bangladesh. Since 1977 there has been discussion between the neighbors about the augmentation of the flow of the Ganges. India´s solution for the increase of low-flow at Farakka is water withdrawal from the Brahmaputra River. Bangladesh has rejected the proposal due to the environmental, social, political and economic consequences of the link canal between the Brahmaputra river and the Ganges. Bangladesh has proposed construction of storage reservoirs at the upper reaches of the Ganges in India and Nepal to store water during the monsoon for release in the dry season. India rejects the proposal; it wants to reserve the upstream waters of the Ganges for the future needs. In addition, India prefers the bilateral approach and doesn´t want to regionalize the issue thus involving Nepal in the discussion (Salman, 1998).

Due to the difficulties in co-operation, Bangladesh has started developing its own options for augmenting the dry season flow of the Ganges by reviving the idea of the Ganges Barrage. Although the barrage project was first conceived in 1961, it was not found to be practical without a permanent or long-term agreement on the sharing of the Ganges water between Bangladesh and India. The signing of the 30-year Ganges water sharing Treaty in December 1996 has opened up the prospect of implementation of the long-cherished Ganges Barrage Project. Bangladesh now plans to build a dam at Pangsha, 145 km west of Dhaka, to store the wet season flow of the Ganges for use during dry season. The barrage is expected to irrigate an area of 1.35 million ha of land, and to protect another 1.44 million ha from floods. If the idea of the Ganges Barrage comes true, it could assist in dealing with some of the main challenges of the Ganges; it could finally end the fruitless discussion between India and Bangladesh on a joint plan for augmenting the flow of the Ganges during the dry season (Salman, 1998; Mirza, 1998).

Narmada Valley Development Program

Narmada river is the largest west-flowing river in India. It carries an annual average flow of 1,450 m^3/s and drains an area of 98,800 km^2. The basin area covers some of the poorest states of India. It is inhabited by 40 million people and is subject to an intense population growth. Due to water and electricity shortages, living conditions are worsening. This leads to increased migration to cities (Vakkilainen & Varis, 1997).

The Government of India has prepared ambitious plans to solve the water related problems in the Narmada Valley. The Narmada Valley Development Program includes the building of 30 large, 135 medium and 3000 small dams to harness the waters of the Narmada and its tributaries. The proponents of the dam claim that this plan would provide large amounts of water and electricity which are desperately required for the purposes of development in the Narmada Valley.

Opponents of the dam question the basic assumptions of the Narmada Valley Development Plan and believe that its planning is unjust and inequitable and the cost-benefit analysis is grossly inflated in favour of building the dams. According to an international coalition of individuals and organizations, the Friends of River Narmada, the plans rest on untrue and unfounded assumptions of hydrology and seismicity of the area and the construction is causing large scale abuse of human rights and displacement of many poor and underprivileged communities. They also believe that water and energy can be provided to the people of the Narmada Valley, Gujarat and other regions through alternative technologies and planning processes which can be socially just and economically and environmentally sustainable (Friends of River Narmada, 2000).

The first survey´s of the Narmada Valley began in the mid-40s. The first dam of the project was the Bargi dam which was conceptualised in 1968 and completed in 1990. It submerged 162 villages and an area of 268 km^2. The dam project was carried out without proper assessment of how many people would be affected. Many of the resettlement sites built by the government got submerged when the reservoir was filled. Displaced people were just given cash with no means of sustenance.

The Bargi dam is not delivering the benefits that were promised by the government. Against the promised irrigation of 437,000 ha, irrigation of only 24,000 ha is achieved. There is no money to build the irrigation canals (Dharmadhikary, 1998).

Chronology of Narmada Development Project

1946 - 1969

Planning of 30 large (Sardar Sarovar and Narmada Sagar being the largest), 135 medium and 3,000 small dams in Narmada Basin. All the proposed dams are located in Madhya Pradesh, except the Sardar Sardovar in Gujarat.

1979

The central governement authorizes the construction of Sardar Sardovar to the height of 138 m and makes the sharing of benefits (irrigation water and electricity) between the states. 75,000 km of canals are planned to irrigate 1.8 million ha in Gujarat and about 73,000 ha in Rajasthan. Emergence of the opposition movement.

1985

The World Bank grants a loan of US$ 450 million for the construction of Sardar Sardovar.

1988	
	Construction works start. Medha Patkar takes the lead of the opposition movement called the Narmada Bachao Andolan (NBA). Convinced of the inequitable resettlement, NBA takes officially an anti-dam position.
1990	
	Completion of the first dam in Jabalpur confirms the problems concerning the resettlement. Pacific demonstrations and hunger strikes take place.
1992	
	An independent commission Morse, established by World Bank, accomplishes a report which impugns the quality of the feasibilty studies.
1993	
	World Bank recedes from the project.
1994	
	A hunger strike of 23 days, carried out by six militants, ceases when the state of Madhya Pradesh retreats from the project. Development in Gujarat and Maharashtra continue. The vigorous summer monsoon causes significant material damage on the dam site.
The Beginning of 1995	
	The construction of Sardar Sarovar is suspended at the height of 80 m.
The End of 1997	
	The dam opponents celebrates the 3 year-long interruption of Sardar Sarovar project. 25,000 people target the next construction site: the Maheshwar dam site.
1998	
	The government of Madhya Pradesh insists the termination of Maheshwar Dam Project.
January 1999	
	The legal action taken place in Supreme Court concerning Sardar Sarovar ends. The court permits the continuance of the dam construction to the height of 93 m.
May	
	Arundhati Roy, anti-Narmada Project activist, offers his Booker Prize to NBA and publishes a synthesis on the unacceptable human costs of the project.
Monsoon	
	Militants from all over the country gather to the Narmada Valley to face the rising water and oppose the inundation of new land areas.
23 November	
	The Ministry of Water Resources of the Government of India visits the Narmada Valley for the first time in 12 years.

Source: Blasco, 2000

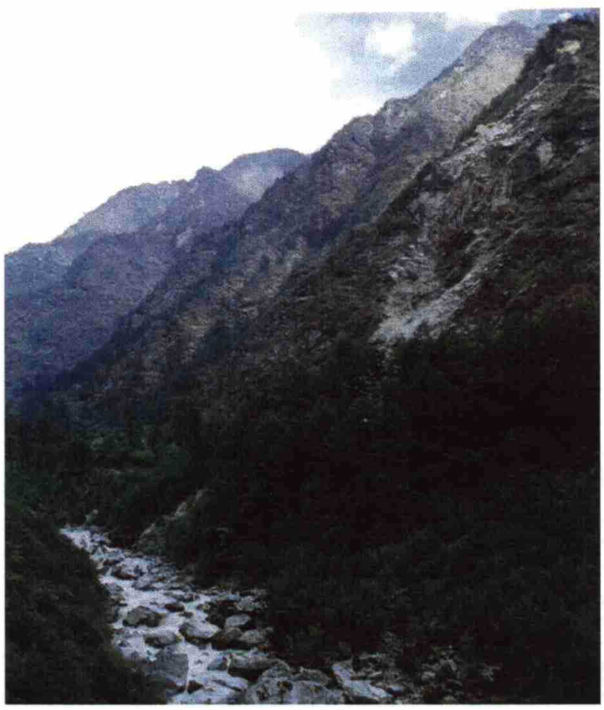
Map 7: *The Narmada River and its Main Dams*

Source: IRN, 2000

5.2.4 Nepal

Nepal is a relatively small kingdom on the southern slopes of the Himalayas. It is strategically located between the two giants: India and China. The country is topographically very diverse. The subtropical southern parts of the country, called Terai, belong to the Gangetic Plain while the northern Nepal is dominated by the Himalayan Massif and has the world´s highest peak Mt. Everest.

Nepal is one of the least developed countries in the world. The annual per capita Gross National Product (GNP) is only US$ 220. Its growth has been less than 2 % per year for many years, which means that Nepal will remain the poorest country of South Asia for a long time.



Picture 6: *The steep Himalayan river valleys do have a considerable hydropower potential.*

Trisuli River in the Langtang Valley during the low-flow.
Photo: Tommi Kajander

Nepal´s water resources are abundant. The average annual precipitation is 1,700 mm of which 80 % occurs during the monsoon season from June to September. The total annual average run-off from Nepal´s 6,000 rivers is 174.2 km^3.

Surface water resources are distributed in the river system consisting of four major rivers (the annual average discharge in brackets): the Mahakali River basin (580 m^3/s), the Karnali River basin (1,400 m^3/s), the Gandaki River basin (1,600 m^3/s)and the Kosi River Basin (1,500 m^3/s). All of them drain into the Ganges. Overall, the rivers of Nepal contribute more than 40 % of the total flow of the Ganges. During the dry season Nepal´s contribution to the low-flow of the Ganges is as high as 70 %.

Water storage potential in Nepal is 88 km^3. Nepal´s theoretical hydropower potential is 83,290 MW of which 43,442 MW is technically feasible. So far the hydropower development has been slow. Due to the high dam construction costs, and lack of infrastructure and capital only 262 MW (0.6 %) of hydrocapacity is installed.
At present 93 dam sites have been identified and 66 of these (42,000 MW in total) are found economically feasible. Some data about the largest planned dam schemes in Nepal is provided below in table 5.15.

Table 5.15: *Data about the largest planned dam schemes in Nepal.*

Sources: Kathmandu Post, 1997; Onta, 1998

Name	Location	Height (m)	Installed Capacity (MW)	Total Estimated Cost (US$ billion)	Other
West Seti Hydropower Project	West Seti River	195	750	1.2 (1997)	Almost all the power produced will be exported to Uttar Pradesh and Bihar states in India. Power purchase agreement with India is under negotiations.
Pancheswor Project	Mahakali River	315	6,480	2.98 (1995)	Irrigation benefits to Nepal: 930 km^2
Karnali Project (Chisapani Dam)	Karnali River	270	10,800	4.89 (1989)	

In Nepal one of the major problems in storage projects is the inflow of sediment which leads to the depletion of storage volume. The Kulekhani reservoir in the close proximity of Kathmandu lost 5 % of its storage volume due to one cloudburst in 1993! In general the Himalayan rivers are known to carry heavy sediment loads. The total sediment load of Nepali rivers is estimated to be 726 million tons annually. Due to the deforestation and mismanagement of the river basin areas the annual sediment load is expected to increase in forthcoming years (Pandey, 1998).

Water resources development of Nepal cannot be accelerated to the expected level without foreign investment. The foreign investment can not be attracted without solving the international river related issues. Till now none of the concrete agreements have been reached with India concerning the use of waters of major river basins of Nepal. The major river basins on the issue are Karnali, Kosi, Mahakali and Gandak.

5.2.5 Pakistan

Pakistan can be considered as a water scarce country. Most of the country is subjected to a semi-arid climate. The average annual precipitation is just 494 mm and the internal renewable water resources are estimated at 248 km^3/year, while the population of the country has exceeded 140 million.

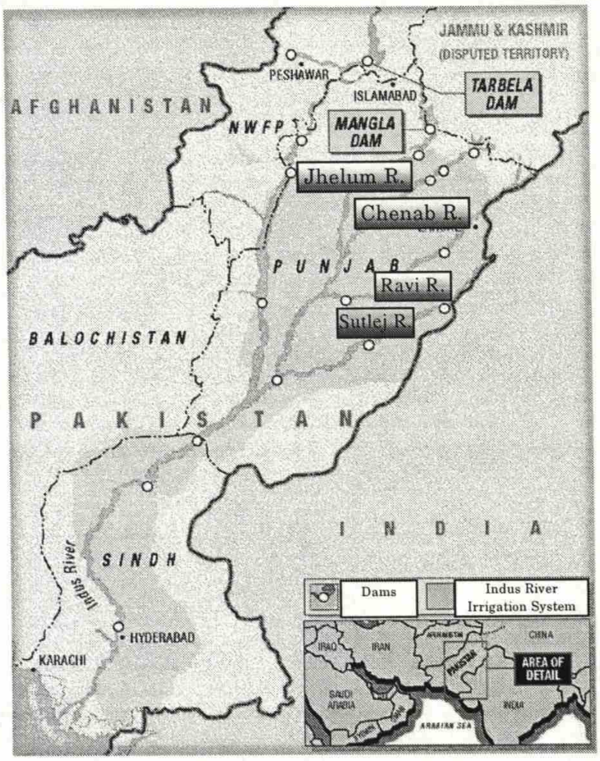
Pakistan is one of the largest nations in the world that depends on a single river system. The water from the Indus River and its tributaries supports the bulk of the agricultural water supply.

Dams on the main stem of the Indus River and its tributaries produce most of the electrical energy for Pakistan (45%) (Khan et al., 2000).

Mangla and Tarbela Dams

The Mangla and Tarbela dams play an important role in the economy of Pakistan. Not only do they provide water for irrigation, but also help to generate cheap hydroelectric power. The Tarbela and Mangla Reservoirs have power generating capacities of 3500 MW and 1150 MW, respectively. Since irrigation demand has the first priority on water released from the Mangla and Tarbela Reservoirs, the production of energy at these power plants occurs either as a by-product of irrigation releases or when surplus water for irrigation needs is available.

The reservoir levels start rising by the end of March and end of April for Mangla and Tarbela respectively and reach their maximum level by the end of August. The maximum drawdown occurs in March. The Chashma Reservoir is in fact a barrage with some storage capacity, and provides about 0.5 km^3 of storage. This is a very important regulation point in the system. Water released for irrigation from the Tarbela Reservoir to the four provinces is regulated at the Chashma Reservoir. Presently, a hydropower plant is also under construction at the Chashma Reservoir.



Map 8: *The Indus River Basin and its Main Dams*

Source: *WCD, 2000*

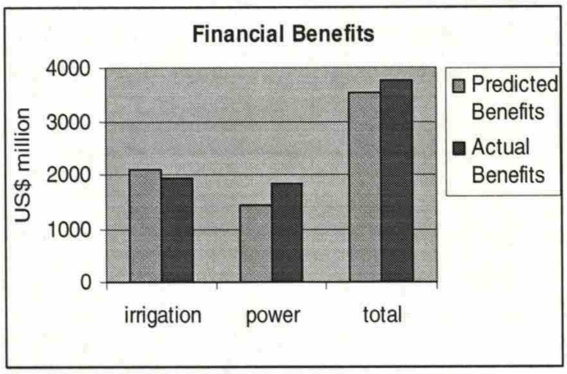


Figure 5.2: *Irrigation and Power Benefits of the Tarbela Dam Over the Period 1975 - 1998*

Note: Benefits are calculated according to the value of money in 1998.

In 1998 prices, the overall estimated water (storage) and power financial benefits were

US$ 3782 million (see figure above). As compared to this, the total capital expenditure was about US$ 4388 million. This performance over 23 years (about half of the originally estimated useful life of 50 years) was quite impressive.

All the outcomes (negative and positive) gained by the construction of the Tarbela dam could not have been predicted. Below are listed some issues with the unexpected outcomes occurred.

Table 5.16: *Unexpected outcomes gained by the construction of the Tarbela dam*

Source: WCD, 2000

Issue	Outcome
Schedule	Major problems experienced with seepage through upstream blanket, damage to tunnels, low level outlets and spillways.
Project costs	Overrun due to cost of remedial works.
Irrigation	Additional diversions lower than expected as other dams not constructed. Major expansion of groundwater irrigation from 31.6 km^3 in 1972 to 62.2 km^3 in 1997. Number of tubewells increased by 400 %. Shift in cropping patterns to sugarcane, cotton, rice, and wheat. Lower productivity of land and water.
Water logging and salinity	Low irrigation efficiencies.
Hydropower generation	Power optimization study undertaken leading to increased installed capacity.
Flood control	Reduction of flood flows to wetland areas downstream.
Sedimentation	Advance of sediment delta to within 14 km of the dam requiring modification of operating rules.
Resettlement	Continuing claims for settlement after completion resulted in establishment of a new commission; considerable number of indirectly affected people not eligible. Still 1953 affectees who hold valid allotment letters have not been given land due to non-availability. Sindh government decided in 1974 to withhold 7,826 ha of land originally promised for allotment to Tarbela Affectees.

5.2.6 Sri Lanka

Sri Lanka, an island covering a land area of 65,610 km^2, is located in the Indian Ocean. It is predominantly an agricultural country with a rural population making up almost 80 % of a total 18.8 million.

The country is endowed with water resources through intermonsoonal climatic directions from the southwest and northeast during two seasons of the year. With an average annual precipitation of 2,000 mm, the total amount of water available for use in the country is 127 km^3/year out of which 50 km^3 is surface water run-off.

Economic development, population pressure, and growing demands for electric power and adequate water and sanitation services are placing increasing pressure on water resources.

Mahaweli Project

Large dam projects have arisen discussion in Sri Lanka for many years. The Mahaweli Project, completed five years delayed in 1991, has been controversial among the people of Sri Lanka. The project, including several large dams, has benefited people by providing irrigation and hydropower. By 1986 almost all the major multi-purpose dam projects had been completed. They generated 1,442 GWh of power by the end of 1993, which was equivalent to 52 % of the power generated in Sri Lanka. The dams also act as storage tanks for the irrigation systems which serve over 100,000 hectares of new lands within the project area. In addition, the Mahaweli waters irrigate 68,000 hectares of farmland in other areas by augmenting existing water supplies. In 1991, 20 % of the rice and 55 % of the chilli consumption of Sri Lanka was produced in the Mahaweli command area.

Today many of the farmers are however facing various problems. Until the end of April 1992 more than 700,000 people were resettled by the Mahaweli Project. They lost their homelands. According to Environmental Foundation Ltd., Sri Lanka, the project has failed to bring the promised benefits, thus providing adequate water for the farmers. Environmental implications such as increased onsite soil loss rates, degradation of downstream water quality, loss of natural forest cover and change of seasonal flow regimes of rivers are critical. The reservoirs are facing sedimentation problems and water shortages. The total electricity generation from hydro plants was reduced by 28 % in 1996 due to dry weather. During the same year, the area of cultivated land in the project area decreased as well by 13 % to 119,100 ha (Withanage, 1998).

There are 47 large dams (more than 15 m-high) under operation. The technically feasible hydropower potential of Sri Lanka is 2,175 MW of which about 56 % has been developed. The total water storage capacity of all dams is 7.2 km^3 (The Inter...,1999).

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6 CONCLUDING REMARKS

After all it is time for conclusions. The following summarizes the ideas that emerged during the writing of this report. The points are commonly recognized for example in the report of the World Commission on Dams but are hard to realize. However, efforts should and can be taken to maximize the benefits and minimize the adverse impacts of large dams.

Multipurpose dams should be favoured. The construction of dams for just one purpose is in the past. As the competition in water use between different sectors is increasing, the benefits gained by dams should be directed to every sector. This can be achieved by the development of multipurpose dams and more efficient operation rules. As the renovation of existing large dams has increased, the possibilities of converting single purpose dams into multipurpose dams should be examined.

Water is a common good, thus everybody has a right to it. Benefits should be channelled to every person affected by a dam project. The living standards of the affectees should not decline. Instead their basic needs must be fulfilled by providing them e.g. water supply and sanitation. In addition to the extending of the benefits to everyone, the profit gained from dams should be shared equally. Affectees are not only those who are resettled, but also the population living downstream.

To fulfill the principles of sustainable development, the participatory approach has to be used in the project design. Consultation with the affected people should take place already in the feasibility study before the implementation phase starts. The negative impacts of a project should be revealed truthfully to the local people. Decision making is a continuous process which should involve all the stakeholders from the grassroots to the representatives of governments and sponsors.

Building dams for electricity export has proven to be a significant source of outcome for many developing countries. When dams are built to produce electricity for export, at least part of the export earnings should be used for the poverty reduction. The standard of living of the rural population should be improved by fulfilling their basic needs.

Efficient monitoring is essential after the completion of a dam scheme. The predicted outcomes, defined in the beginning of the project, should be reviewed and compared to the realized outcomes. There is rarely a perfect match between the two outcomes. Reasons for the deviations have to be studied and analyzed more in depth. This can be achieved by intensifying the current monitoring systems. Monitoring process is a continuous process beginning in the early stages of a project and proceeding through the implementation phase to the operational phase. In addition to the economical performance of a dam, environmental and social aspects have to be included in the monitoring process. Especially the often problematic resettlement issue needs efficient monitoring.

Alternatives for the large dams should be studied more in depth. In many cases the benefits gained by a large dam could have been achieved by another option. Especially the water demand aspect needs development. In developing countries water use is often inefficient. This applies to all sectors including agricultural, domestic and industrial sectors. Agriculture, which consumes well over half of the water used in Asia, still basically relies on old-fashioned irrigation systems with significant water losses. Similarly water consuming are the industrial processes in the developing countries. Water consumption in e.g. the paper or steel industry might be several times higher in developing countries than in the developed world. In addition to the excessive water consumption the out-of-date industrial processes are consuming a lot of electricity. Another source of water losses include the out-of-condition water supply systems. There is a lot of potential in improving the efficiency in water consumption. Methods include e.g. water recycling, modernizing of industrial processes, drip irrigation, rational pricing of water, and renovation of old water supply systems.

As the construction of dams will continue in any case the importance of the mitigation of negative impacts in dam projects is crucial. The following points concerns the mitigation of negative impacts.

Environmental Impact Assessment (EIA) should be involved in the project from the very beginning of the project till the end. It should be done by an independent party with adequate resources.

The ecological water demand has to be included in the design of the dam schemes. Nature needs some minimum amount of water to survive. If that is not taken into account, consequences are serious including e.g. desertification. The determination of the ecological water demand should be included in the project´s environmental impact assessment.

A sufficient natural regime of flow variation is crucial for the river biota and foodwebs. In monsoon affected regions the river ecosystem is accustomed to considerable fluctuation of water discharge. Water releases from reservoirs should pursue the natural flow variations at least to some extent. This can be achieved by further development of operational rules.

Watershed management as a whole should be involved in dam projects to mitigate the negative impacts. The characteristics of a watershed affect significantly the efficiency and operation of a dam scheme. Environmental degradation of catchment areas is common and serious in many parts of China, Southeast and South Asia. High deforestation rates have led to intensified runoffs and sedimentation rates as well as deteriorated water quality in the watersheds. In places, the designed lifespans of reservoirs have shortened up to half of the originally planned values due to extreme washing of sediment in the catchment areas. In addition when taking into account the often increasing deforestation around the reservoirs, reforestation in the watersheds is more than justified. Furthermore establishment of conservation areas in the watersheds is advisable.

APPENDIX 1

Some Useful Sources in WWW Concerning Water Resources Management and Large Dams

Asian Development Bank (ADB)

Key Indicators of Developing Asian and Pacific Countries 1999, Volume XXX
http://www.adb.org/Documents/Books/Key_Indicators/1999/

The 30th in a series of annual statistical publication, the 1999 *Key Indicators* provides historical and current economic, financial, and social statistics of ADB's 38 developing member countries (DMCs)

Encyclopædia Britannica

On-line service. Searching by keywords. http://www.britannica.com/

An extensive source for basic information (countries, geography, natural resources...)

Food and Agriculture Organization of the United Nations (FAO)

Aquastat. An on-line database of statistics on freshwater availability in agriculture and rural development.
http://www.fao.org/waicent/faoinfo/agricult/agl/aglw/aquastat/aquastat.htm

Aquastat contains regional analyses and country profiles on water resources development, with emphasis on irrigation and drainage.

International Rivers Network (IRN)

IRN is a non-governmental organization supporting local communities working to protect their rivers and watersheds. http://www.irn.org/

IRN´s www-site contains information on large dams from the point of view of dam opponents. Includes i.a. campaigns on SE Asia, South Asia and China, and the on-line version of the World Rivers Review, a publication devoted to river issues.

Online Newspapers

BANGKOK POST

Bangkok Post Archive (containing issues from 1.7.1996 to 31.3.2000) – *on-line service*. Searching by keywords.
http://scoop.bangkokpost.co.th/bkknews/query.asp

PEOPLE´S DAILY

Chinese newspaper
http://english.peopledaily.com.cn

VIENTIANE TIMES

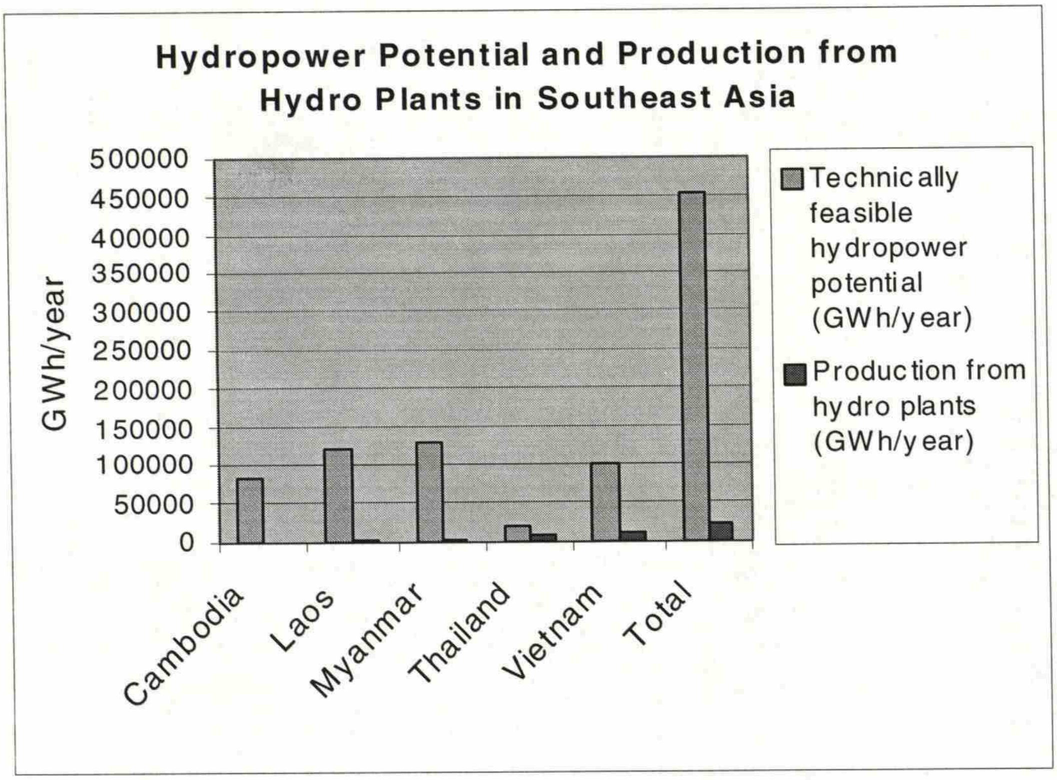
A Lao newspaper
http://www.vientianetimes.com

World Commission on Dams (WCD)

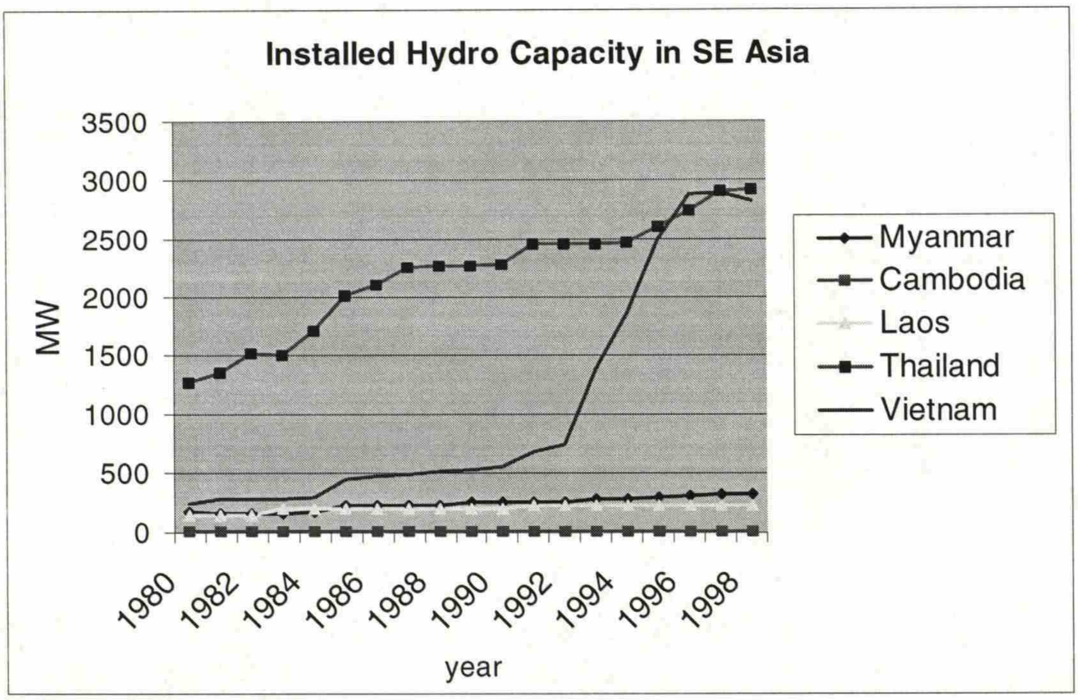
WCD is an organization composed of an international team of experts. The Commission's mandate is to research, review and write the most independent, authoritative and comprehensive cross-examination of dams and water and energy resource development.
http://www.dams.org

An extensive source for information about large dams in developing countries. Contains regional consultations, case studies, thematic reviews, cross-check surveys and submissions.

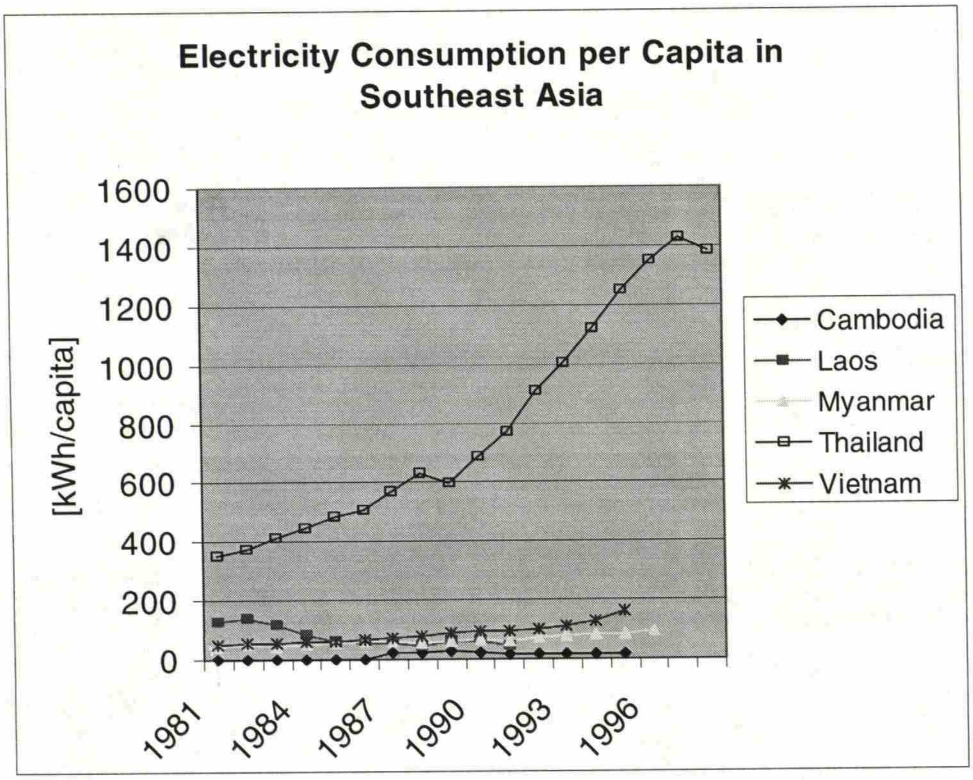
APPENDIX 2



Hydropower Potential and Production from Hydro Plants in Southeast Asia.
Source: The International Journal of Hydropower & Dams, World Atlas & Industry Guide, 1999



Installed Hydro Capacity in Southeast Asia.
Source: Energy Information Association, 2000.
http://www.eia.doe.gov/emeu/international/electric.html#Capacity



Electricity Consumption per Capita in Southeast Asia
Source: Asian Development Bank
http://www.adb.org/Documents/Books/Key_Indicators/1999/