WASSA Project Reports, Volume 1:

WATER DEMAND – SUPPLY GAPS IN SOUTH ASIA, AND APPROACHES TO CLOSING THE GAPS

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Project on "Water and Security in South Asia" (WASSA)

A Project Sponsored by the Carnegie Corporation of New York

And Implemented by the
South Asia Program/FPI, School of Advanced International Studies (SAIS),
Johns Hopkins University, Washington, D. C.
And
Global Environment and Energy in the 21st Century (GEE-21),
Honolulu, Hawaii

Final Report, January 2004

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PREFACE

More than 1.3 billion people live in South Asia. Almost half of these depend on river systems for their water needs. Many of these major rivers, some of which are amongst the world's largest, flow across national borders and have been a source of tension in the region. At times, when the snow melts in the Himalayas, or during the monsoon, there is too much water, and frequent floods. At other times, there is too little water available, and intense competition for it arises between countries, and between upstream and downstream provinces or states even within the same country.

In the western part of the sub-continent, the waters of the Indus basin are shared by Pakistan and India. In the North and Northeast, the basins of the Ganges, Brahmaputra, and Meghna are shared by India, Nepal, Bhutan, and Bangladesh, and in some areas by China. Although some arrangements presently exist to share the waters between the respective countries, their implementation has not always been satisfactory, and there is a widespread perception that these arrangements could be inadequate in times of increased water scarcity.

There are also disputes within India and within Pakistan regarding the equitable distribution of water between the states or provinces. As the populations of the countries increase, and water availability declines, tensions over water rights are likely to increase as well.

The project on "Water and Security in South Asia" focuses on the critical issues mentioned above. It has several goals:

- Identification of the key issues regarding water resources in the subcontinent;
- An examination of the provisions of the Indus Water Treaty of 1960 between India and Pakistan, and the other water Treaties or Agreements critical to the region;
- Identifying approaches to water conflict issues within and between the countries of South Asia that could be used throughout the region;

- Examining some of the climate change and investment aspects of water availability that could affect the future availability of water in the region.

The Carnegie Corporation of New York has identified water availability as a priority area for its Program. In his report to the Board of the Corporation, President Vartan Gregorian has pointed out that ”Much less heed is being given to the most basic human need ---- water. In 1996, the United Nations Development Programme reported that there were ten countries in the world, largely in Africa, where more than half the population did not have access to potable water. The sharing of water resources has the potential of bringing rival nations together in common cause, just as the manipulation of the water supply by those who control it can lead to conflict and violence, as we already see in the Middle East and could witness in Asia and Africa”. In keeping with this priority, the Carnegie Corporation of New York provided the funding for the WASSA project.

Issues relating to a resource as critical as water can obviously only be negotiated by the various governments themselves. Projects like WASSA could make several important contributions such as:

- Highlight the issues through a regional prism;
- Offer constructive alternatives to conflict in addressing the critical issue of water, whereas governments in the subcontinent have largely tended to focus on these issues in the shadow of conflict;
- Create a joint stake in the solution of issues relating to water through creative thinking on future actions by experts who understand the political world that shapes decisions;
- Deal with questions of trust which influences the entire range of water as well as other important issues in South Asia;
- Create conditions for cooperation through the development of a network of technical experts placed to make a difference with their respective governments.

Teams consisting of persons from Bangladesh, India, Nepal, and Pakistan have prepared the reports of the WASSA project. Consultants based in South Asia, Japan and the USA have provided additional input. The participants met several times during the project in working groups as well as in Workshops for the whole team.

The project work has been carried out under the following themes:

- Gaps between water demand and supply;
- Approaches to meeting the gaps;
- Water sharing conflicts within countries and possible solutions;
- Water sharing conflicts between countries and possible solutions;
- Possible impacts of global climate change on water availability;
- Investment requirements for enhancing water supply.

Participants from each of the following organizations (and in one case, two eminent consultants) took the lead on one of the above topics, and provided input in other areas:

- Bangladesh Unnayan Parishad (BUP);
- Economic Development Consultants (EDC), Pakistan;
- Jalsrot Vikas Sanstha (JVS), Nepal;
- Nepal Water Conservation Foundation (NWCF);
- Pakistan Institute for Environment-Development Action Research (PIEDAR);
- Trust for Water, Environment and Development Studies (TWEDS), Bangladesh;
- Water and Power Consultancy Services (I) (WAPCOS), India;
- Dr. M. S. Reddy and Mr. N. V. V. Char, India.

Dr. James E. Nickum (TJK College, Japan), Dr. Murari Lal (India), Dr. Amir Muhammed (Pakistan), Mr. P. B. Shrestha and Dr. H. M. Shrestha (Nepal), and Mr. George Verghese (India) have made valuable contributions to individual volumes.

Although we have listed the participating organizations above, the views expressed in this and other reports of the WASSA project are those of the individual authors, and not necessarily those of their organizations. In most cases, the views expressed in the Reports reflect those of all the authors of that Report. In a few cases, the authors had differing opinions that have been identified as such.

Distinguished persons with close links to policymakers in the four countries are serving as Policy Advisors for the project. They are:

- Major-General Mahmud Durrani (Pakistan), former Chairman, Pakistan Ordnance Factories Board;
- Mr. Salman Haidar (India), former Foreign Secretary, Government of India;
- Mr. Farooq Sobhan (Bangladesh), former Foreign Secretary, Bangladesh;
- Ambassador Bhekh Thapa (Nepal), Ambassador of Nepal to India.

The Policy Advisors have given generously of their time and provided valuable input. The authors of the project reports have incorporated this input in the Final Reports.

The Final Reports are being printed in three volumes, covering the following major themes:

1. Water Demand-Supply Gaps and Approaches to Closing the Gaps;
2. Water Conflicts *within* Countries, and Approaches to resolving them;
3. Water Conflicts *between* Countries, and Approaches to resolving them;

The Final Drafts of the volumes were reviewed by water resource specialists not associated with the WASSA project. Input received from them, as well as from the project Conferences in February 2003, has been incorporated in the Final Reports. In addition, a comprehensive Executive Summary has been prepared. Some of the individual reports can be downloaded from the GEE-21 web site (www.gee-21.org).

Toufiq A. Siddiqi and Shirin Tahir-Kheli
Project Coordinators

January 2004

Acknowledgements

We would like to thank the Carnegie Corporation of New York, its President Vartan Gregorian, and Senior Program Officer Stephen Del Rosso for their continuing support of the project on "Water and Security in South Asia". We are grateful to all the authors for their cooperation with each other and with the project coordinators during the lengthy period of three years. We especially appreciate the willingness shown by the coordinating authors of each volume --- Dr. M.S. Reddy and Mr. N. V. V. Char for volume 1, Mr. Ayub Qutub for volume 2, and Dr. Umesh Parajuli for volume 3, to incorporate the input received from the project advisers, external reviewers, and from other stakeholders during the project workshops and conferences.

It is a pleasure to thank the policy advisors --- Mr. Farooq Sobhan (Bangladesh), Mr. Salman Haidar (India), Ambassador Bhekh Thapa (Nepal), and Maj.-Gen. (ret.) Mahmud Durrani (Pakistan) for their valuable input and advice throughout the project.

Crucial support during the preparation of the several Drafts of the Reports was provided by Ms. Ulrike Siddiqi and Ms. Amy Funk of GEE-21. Dr. Q. K. Ahmad and the staff of Bangladesh Unnayan Parishad made excellent arrangements for the project workshop in Dhaka, as did Mr. Ayub Qutub and the staff of PIEDAR for the Conference in Islamabad. We are grateful to Dr. Thomas Keaney, Ms. Courtney Mata, Ms. Nilofer Afridi-Qazi, and other staff members at FPI/SAIS for organizing so well the Policy Briefing held in Washington, D.C., and to Mr. R. K. Mishra and the staff of the Observer Research Foundation for hosting and making excellent arrangements for the project Conference in New Delhi in September 2003.

Toufiq A. Siddiqi and Shirin Tahir-Kheli, *Project Coordinators*

November 2003

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Abbreviations and Acronyms

	A	
AMIS	-	Agency Managed Irrigation System
ASD	-	Agriculture Statistics Division
AWPs	-	Area Water Partnerships
	B	
BAU	-	Business - As –Usual
BAMWSP	-	Bangladesh Arsenic Mitigation Water Supply Project
BBS	-	Bangladesh Bureau of Statistics
BCM	-	Billion Cubic Meters
m bgl	-	meters below ground level
BOD	-	Biochemical Oxygen Demand
BOO	-	Build - Own - Operate
BOOT	-	Build - Own - Operate - Transfer
BMD	-	Bangladesh Meteorological Department
BMPP	-	Bagmati Multi-Purpose Project
BRRI	-	Bangladesh Rice Research Institute
BUP	-	Bangladesh Unnayan Parishad
BWDB	-	Bangladesh Water Development Board
	C	
CAT	-	Catchment Area Treatment
CETP	-	Common Effluent Treatment Plant
CGWA	-	Central Ground Water Authority
CGWB	-	Central Ground Water Board
CPCB	-	Central Pollution Control Board
COD	-	Chemical Oxygen Demand
CRZ	-	Coastal Regulation Zone
CSIR	-	Council of Scientific & Industrial Research
CWC	-	Central Water Commission
CWPs	-	Country Water Partnerships

	D	
DVC	-	Damodar Valley Corporation
DTW	-	Deep Tube Well
	E	
EH	-	Eastern Hill (Region)
ERM	-	Extension, Renovation & Modernization
EWC	-	East West Center
	F	
FAO	-	Food and Agricultural Organization
FMIS	-	Farmer Managed Irrigation System
	G	
GBM	-	Ganga- Brahmaputra - Meghna Basin
GCA	-	Gross Command Area
GDA	-	Ganges Dependent Area
GDP	-	Gross Domestic Product
GNP	-	Gross National Product
GIA	-	Gross Irrigated Area
GIT	-	Ground Water Irrigation Thanas
GK	-	Ganges Kobadak (Project)
GOI	-	Government of India
GSA	-	Gross Sown Area
GWP	-	Global Water Partnership
GWT	-	Ganges Water Treaty
	H	
HP	-	Horse Power
HYV	-	High Yielding Variety

I

IBIS	-	Indus Basin Irrigation System
ICID	-	International Commission on Irrigation and Drainage
IIMI	-	International Irrigation Management Institute
IMD	-	Indian Meteorological Department
INBO	-	International Net Work of Basin Organizations
IPM	-	Integrated Pest Management
IRRI	-	International Rice Research Institute
IRSA	-	Indus River System Authority
ISO	-	International Standards Organization
IWMI	-	Irrigation Water Management Institute
IWP	-	India Water Partnership
IWRM	-	Integrate Water Resources Management
IWRMP	-	Integrate Water Resources Management Plan
IWRS	-	Indian Water Resources Society
	J	
JVS	-	Jalsrot Vikas Sanstha
	K	
KW	-	Kilowatt
	L	
LLP	-	Low Lift Pump
Lpcd	-	Liters per capita per day
	M	
MAF	-	Million Acre Feet
MCM	-	Million Cubic Meters
Mha	-	Million Hectares
MLD	-	Million Liters per Day
MOEF	-	Ministry of Environment and Forests
MOWR	-	Ministry of Water Resources
MS	-	Monsoon Season

MW	-	Megawatt
	N	
NA	-	Not Available
NARC	-	Nepal Agricultural Research Council
NC	-	North Central (Region)
NCIWRDP	-	National Commission on Integrated Water Resources Development Plan
NE	-	North East (Region)
NEA	-	National Electricity Authority
NGO	-	Non-Government Organization
NMIC	-	National Minor Irrigation Census
Non MS	-	Non - Monsoon Season
NSA	-	Net Sown Area
NW	-	North West (Region)
NWCF	-	Nepal Water Conservation Foundation
NWDA	-	National Water Development Agency
NWFP	-	North West Frontier Province
NWMP	-	National Water Management Plan
NWP	-	National Water Policy (India)
NWPo	-	National Water Policy (Bangladesh)
NWSC	-	Nepal Water Supply Corporation
NWRC	-	National Water Resources Council
	O	
O&M	-	Operation and Maintenance
OFWM	-	On Farm Water Management
	P	
PIEDAR	-	Pakistan Institute for Development Action Reasearch
PIM	-	Participatory Irrigation Management
PSP	-	Private Sector Participation

R

RBO	-	River Basin Organization
RBM	-	River Basin Management
R&D	-	Research and Development
R&M	-	Remodeling and Modernization
	S	
SASTAC	-	South Asia Technical Advisory Committee
SASNET-RBO	–	South Asia Net Work – River Basin Organization
SC	-	South Central (Region)
SC	-	Soil Conservation
SC/ST	-	Schedule Caste/Schedule Tribe
SE	-	South East (Region)
SSTCC	-	State Science and Technology Commission of China
SITE	-	Sind Industrial and Trading Estate
STW	-	Shallow Tube Well
SW	-	South West (Region)
	T	
TCA	-	Total Cultivable Area
TWEDS	-	Trust for Water, Environment and Development Studies
	U	
UFW	-	Unaccounted for Water
UN	-	United Nations
USA	-	United States of America
UNDP	-	United Nations Development Programme
UNEP	-	United Nations Environment Programme
	V	
VIKSAT	-	Vikram Sarabhai Center for Development Action
	W	
WAPCOS	-	Water & Power Consultancy Services (India) Ltd
WAPDA	-	Water and Power Development Agency (Pakistan)
WARPO	-	Water Resources Planning Organization

WASSA	-	Water and Security in South Asia
WB	-	World Bank
WEAP	-	Water Evaluation and Planning (Model)
WRCP	-	Water Resources Consolidated Project
WRD	-	Water Resources Development
WRM	-	Water Resources Management
WSM	-	Water Shed Management
WSS	-	Water Supply Sanitation Services
WUA	-	Water Users Association

CHAPTER 1: INTRODUCTION

1.1 General

Water is a renewable resource, but a finite one. Only about 3% of the world's total water resource is fresh (not saline) water, of which roughly one-third is inaccessible. The rest is unevenly distributed. In many areas, the existing water resources are increasingly contaminated with wastes and pollution from industrial, agricultural and domestic sources. Over the years, rising population, growing industrialization, and expanding agriculture have led to a rising demand for water.

South Asia is one of the most densely populated regions of the world. It houses roughly one-fifth of the world's population, and this share is likely to increase to one-fourth of the total world population by the year 2025 The region is emerging as the poorest, the least literate, and the most malnourished region of the world. The per capita income in South Asia is lower than that of any other region in the world, with a share of the global income of only 1.3%. The region has 40% of the poorest people in the world.

Several social indicators illustrate the economic backwardness of the area. The level of education is one such indicator. With an adult literacy rate of 48%, nearly 50% of the world's illiterate population lives in South Asia. Despite the significant economic growth during the last few decades, including increases in food grain production, the region has the greatest number of malnourished children.

The economies of the countries in the region are heavily dependent on agriculture, which contributes about 40-50% of the Gross Domestic Product (GDP) and provides nearly 70% of the rural employment. A large proportion of the food grain production comes from irrigated agriculture, and irrigation is the major user of fresh water supplies in the region.

The main limitation to increasing the food production in the region is the availability of water. In the monsoon-dependent climate of the region, the amount of utilizable water for year round activities depends on the inter-seasonal transfer of water through conservation over ground as well as underground. There is also extreme variability in the region's yearly rainfall. Thus large storage structures for conservation are inevitable. Of the various measures necessary for economic development, water resources development is one of the most important. In addition, cooperation between various countries of the region will greatly help sustainable water resources development.

The project on "Water and Security in South Asia" (WASSA), which covers the countries of Bangladesh, India, Nepal and Pakistan, focuses on the security aspects of the region that are related to water. Security is defined in its broader context, including food availability, economic development, and long - term sustainability.

Protecting individuals and communities from the consequences of environmental decline is also a security issue. Since water has been, and remains, one of the most persistent sources of conflict at both international and national level, the project examines the various dimensions of water related security. During a recent revision of the 1987 National Water Policy, in view of the increasing gravity of the problems associated with water, India recognized water security as an over-riding national objective not only with regard to food security but also in its own right (MOWR, NWP, 2002). India has also recognized that the community is the rightful custodian of water and exclusive control by the government machinery would not help the cause of the community management of water resources. The National Water Management Plan (NWMP) of Bangladesh, an offshoot of the National Water Policy approved in 1988, has been formulated with food security as the top priority for a medium term strategy (WARPO, 2001).

From the above perspective, an important element of the WASSA project's approach to identifying water security problems and needs is the estimation of demand-supply gaps and the elaboration of strategies to address these gaps. Large gaps, present or looming, are a clear indicator of water insecurity and, possibly, of a growing need to negotiate across sectors or hydrological or administrative boundaries for possible solutions. This approach is elaborated in the following sections.

The supply and demand approach to the security synthesis of food, livelihood, health and the environment in the WASSA context are evaluated in the four countries concerned viz., India, Bangladesh, Nepal and Pakistan by identified organizations/agencies and consultants with varying perceptions. The World Water Vision documents (GWP, 1999), prepared by the Global Water Partnership (GWP) and the regional documents prepared by GWP – SASTAC (GWP-SASTAC, 1999), have also been heavily drawn upon in the country reports prepared for WASSA.

Water demand - supply gap is a commonly used technique for water project planning, and as such has formed an important component element of this project analysis. Our perception of demand, supplies and gaps in this WASSA analysis define “demand” as the requirements based on needs at current prices, and “Supply” as the resource availability at source or to the consumer.

We address two types of Gaps:

1. Difference between demand and availability at source; and
2. Difference between demand and supply at the consumer end.

The approaches to bridge the gaps address both types of gaps.

Demands are projected for various uses in this analysis up to the year 2025, and compared with the projected supplies in that year. The estimation of gaps is a powerful and useful tool for framing water security policy, but It has to be used judiciously with due cognizance of its limitations, particularly in its coverage, in estimating the gap, and in determining the strategies to "fill" the gap. It is necessary to recognize that the projections are midpoints of estimated ranges that can sometimes be quite large.

The methodological issues addressed in calculating the gaps have included:

a) Quality of data;
b) Institutional reporting biases;
c) Identification and definition of appropriate demand sectors;
d) Quantification of demand;
e) Making realistic projections of demand;
f) Defining water supply, both quantitatively and qualitatively, and in deliverable terms, not just hydrological ones; and
g) Accounting for annual and seasonal variations in supply.

Other methodological aspects addressed in defining approaches to closing the gaps are:

1) Taking adequate account of water quality and environmental dimensions;
2) Choosing among potential projects and policies; and
3) Estimating the likelihood, timing, effects and value of improved cost recovery and institutional reforms such as greater user participation, or clearer specification of water rights.

A general perspective of the four countries is given below before the analysis of demand and supply gaps and approaches to bridging the gap are discussed.

1.2 India

India is an agrarian country with the majority of its population dependent on agriculture. Many schemes were taken up as a part of Five Year Plans in the post-independent phase to develop irrigation facilities in the country. Irrigated agriculture has been, and is likely to remain, the key contributor to India’s agricultural development. The development of irrigation facilities was one of the key factors in ushering the green revolution in the country. Over the years, rising population, growing industrialization and expanding agriculture have pushed up the demand for water.

The three studies, which are addressed in this analysis, in the order of their relevance to the Government of India's policy decision-making process, are:

- The assessment done by the National Commission for Integrated Water Resources Development Plan (NCIWRDP) for the time frame up to 2025 (GOI, NCIWRDP, 1999);
- The India Water Vision 2025 by India Water Partnership for SASTAC GWP (Institute for Human Development & GWP SASTAC, 2000); and
- The India Water Resources Society's (IWRS) study up to the year 2050 (IWRS, 1999).

1.3 Bangladesh

Like the other countries of the region, Bangladesh is predominantly an agricultural country, with fertile land and abundant water resources. However, the water resource is unevenly distributed during the year. The country experiences two extremes, too much water during the monsoon and too little water during the dry season. The excess water in the monsoon months becomes a hazard, as large parts of the country are flooded.

With a population density of 834 persons per square kilometer (BBS, 2001), Bangladesh is one of the most densely populated countries in the world. Even though the share of agriculture in national Gross Domestic Product (GDP) has declined during the last 10 to 15 years as the contribution of the manufacturing and services sector has grown, the agriculture sector remains the largest provider of jobs.

The National Water Policy of Bangladesh (GoB, 1999), the draft National Water Management Plan 2000 & 2001 (WARPO, 2000; WARPO, 2001), and the Water Vision documents prepared for GWP SASTAC have been used in the analysis in the following sections.

1.4 Nepal

Nepal is a land - locked country with an area of 147,181 km^2. Its elevation drops rapidly from 8,848 meters, the highest elevation on earth at Sagarmatha (Mt. Everest) in the North to less than 100 m in the South (Terai), within a mere 160 – 270 km. Nepal has abundant water resources, which are looked to as a key driver for the overall development and economic growth of the country.

Nepal is considered to be one of the least developed countries (LDCs) of the world. If managed properly, the abundant water resources potential of Nepal can alleviate poverty and contribute substantially to economic development, ensuring food security and the health of the country's population, as well as preserving vital ecosystems.

The present population of the country is estimated to be about 23 million, with an annual growth rate of 2.4%. About 66% of the population have access to safe water supply WECS, 2002). Irrigation is available in about half of the total irrigable area. Only 41% of the total irrigated area has year-round irrigation. Hydropower is the major source of electricity in the country, but only about 18% of the population have access to electricity. Water induced disasters, including floods and landslides, and food scarcity due to dry spells, are now common occurrences in some areas of the country. Other uses of water for environmental and eco-system preservation, navigation, recreation are also gaining in importance and competing with water supply, irrigation and hydropower requirements.

1.5 Pakistan

Pakistan is basically an agricultural country with a total geographical area of 88 million ha. Most parts of the country have an arid climate. Rainfall exceeds 500 mm. per annum over only 7 percent of its area, mainly in the form of monsoon rain during the three summer months of the year. As such, a densely settled Pakistan relies on rivers and groundwater for most of its water needs. Around 18 million hectares are irrigated by various sources, mainly canals and tube wells (GoP, Economic Survey, 2001).

The present population of Pakistan is about 140 million, of which the rural population is about 94 million (67% of the total). The remaining 46 million people reside in urban areas.

1.6 In the next Chapters, we use the perspectives mentioned above to water supply and demand under the following titles, followed by conclusions and recommendations:

- Study of water availability estimates;
- Present utilization for various uses;
- Demand projections made in different studies;
- Gap analysis;
- The approaches to meet the gaps during the next 2025 years;
- Conclusions and recommendations.

CHAPTER 2: ESTIMATES OF WATER AVAILABILITY

2.1 Overview

In assessing the availability of water resources in the countries of the region, there are a number of data and information problems, including inconsistency in historical data because of changes in the technology of data collection, lack of access to some official data, wild guesses made in water use (both surface and ground water), and wide seasonal variations in the region's rainfall. Keeping all these factors in view, assessments of water availability have been made for countries of the region under study. The water availability (surface water and ground water) in the four countries of the region is summarized in **Table 1.**

The region included in the WASSA project covers 3.26 % of the world's surface area, but accounts for 21% of the world's population (1995). The annual average replenishable water resources are 6.8 % of the total replenishable water resources of the world (FAO, 1997 a).

The per capita availability of fresh water resources in different river basins of the country is an indicator of the water scarcity or stress. In the WASSA region, the per capita availability in 1995 was 2265 m^3 against the whole world average availability of 7000 m^3 per capita.

Table 1: Water Availability in South Asia

DATA	BANGLADESH	INDIA	NEPAL	PAKISTAN	TOTAL	WORLD
AREA (MILLION HA)	14.8	329.0	14.7	88.2	446.7 (3.32%)	13,422.3
POPULATION (MILLION, 1998)	126	980	23	132	1,261 (21%)	6,005
AVERAGE ANNUAL PRECIPITATION (MM)	2,360	1,170	1,530	238	[c]1,117	820
AVERAGE ANNUAL WATER POTENTIAL (INTERNAL RENEWABLE RESOURCE) BCM	[a] 373	1,870	237	236	2,716 (6.8)	40,000
AVERAGE ANNUAL UTILIZABLE SURFACE WATER POTENTIAL - BCM	[b]1160	690	225	180	2,255	
TOTAL GROUND WATER RESOURCE POTENTIAL -BCM	23	432	6-12	56		
TOTAL UTILIZABLE GROUND WATER RESOURCE POTENTIAL -BCM	23	396	6-12	56		
TOTAL UTILIZABLE SURFACE AND GROUND WATER POTENTIAL - BCM	[b]1183	1,086	237	236	2,742	
PER CAPITA AVAILABILITY OF FRESH WATER RESOURCES - BCM	10714 (1998)	1879 (2000)	10304 (2000)	1685 (2000)		

[a] 340 BCM GENERATED BY LOCAL FLOWS AND 23 BCM BY GROUND WATER FLOWS;
[b] INCLUDES CROSS BORDER FLOWS
[c] WEIGHTED AVERAGE FOR WASSA REGION

UNDER THE TOTAL COLUMN, FIGURES IN BRACKET SHOW THE PERCENTAGE VIS-À-VIS THE WORLD TOTALS
UNDER PER CAPITA AVAILABILITY, THE FIGURES IN BRACKET SHOW THE POPULATION YEAR CONSIDERED, AS REFLECTED IN FIGURE 2
SOURCES: GWP-SASTAC VISION DOCUMENTS; FAO COUNTRY PAPERS; NCIWRDP REPORT OF INDIA; WORLD BANK AND WASSA COUNTRY PAPER DRAFTS

The deficiency or otherwise of water availability in different basins/regions is defined in the following way (IWRS, 1999):

- Basins with fresh water resources of 1000 to 1600 cubic meters per capita per year are considered water stress zones with major problems occurring in drought years;
- Basins with renewable water resources of less than 1000 cubic meters per capita per year are deemed water scarce basins. In this threshold, water availability is considered a severe constraint on socio-economic development and environmental quality.
- Basins with renewable water resources of less than 500 cubic meters per capita are considered as absolute scarcity basins.

The per capita availability of water in the region is reducing progressively due to the increasing population in all countries of the region. The present situation in the four countries of the region for different population figures and projection for 2025 is illustrated in **Figure 1** (on the following page).

Thus, considering each country as a whole, the total precipitation, the surface flows and dynamic groundwater, except for Pakistan, the three other countries ---Bangladesh, Nepal and India, are apparently endowed with enough water that provides for a comfortable balance between “resource” and “requirement”. But this gives a somewhat distorted picture in the case of Bangladesh and Nepal, where the shortage is acutely felt in the lean season flows, particularly in the month of March. In the case of India, the shortages are felt in six river basins that are already water scarce or water stressed. The detailed analyses of the availability of the water resources in the four countries are given in the following sections.

2.2 Water Resources of India

The country can be divided into 24 river basins comprising 12 major and 12 medium and small river basins. The 12 major rivers have a total catchment area of 252.8 million hectares (M.ha). Of the major rivers, the Ganga-Brahmaputra-Meghna (GBM) System is the biggest, with a catchment area of about 110 M.ha. The other major rivers with catchment areas greater than 10 Mha are the Indus (32.1 M.ha), Godavari (31.3 M.ha), Krishna (25.9 M.ha) and Mahanadi (14.2 M.ha).

The river basin maps of the Ganga-Brahmaputra-Meghna (GBM) Basin, the Indus River basin, and the Central and Southern India River basins are shown in **Figures 2, 3 & 4** respectively on the next pages. The GBM river basin is shared with Bangladesh, Nepal, and Bhutan, whereas the Indus river basin is shared with Pakistan.

In India, the availability of water is highly uneven, spatially as well as temporally. The variation in rainfall could be attributed to the varied climates of the country, ranging from arid to tropical wet climatic zones.

The prime source of water in the country is rainfall, which is confined to only three to four months in a year. The annual rainfall also shows significant spatial and temporal variations. It varies from 10 cm. in the western parts of Rajasthan to about 1100 cm. at Cherapunji in Meghalaya (GOI, NCIWRDP, 1999).

The average precipitation including snowfall is estimated (GOI, NCIWRDP, 1999) to be of the order of 4000 BCM (billion cubic meters, or cubic kilometers), of which the monsoon rainfall during June to September is around 3000 BCM and the net annual inflow in the rivers in India is 1869 BCM (**Table 2**).

The assessment of the water resources of the country has been the subject of considerable study over the years by different agencies. The last analysis undertaken by the Central Water Commission (CWC) in 1993 is the currently accepted official version

(CWC, 1993). The NCIWRDP, in their report, have introduced a new figure on the basis of revision of figures of the Brahmaputra sub basin and the Krishna sub basin only, with figures of all other basins tallying with the CWC estimates. Since projections of demand for 2025 are being compared with other figures, the Water Resources numbers of both CWC and NCIWRDP are given in Table 2. (The * in Table 2 indicates Inter-state river basins; @Refers only to the three eastern rivers in India).

The utilizable flow in this assessment is 690 BCM against an average natural (virgin) flow of 1869 BCM. It is necessary to know the constraints and limitations considered in the studies done by various agencies, since the assessments were undertaken after upstream utilization had already taken place in most of the basins. The computation of natural flow was based on runoff, utilization for different uses, and the effects of storage, evaporation losses, and return flow from different uses.

Table 2 - Water Resources Potential

Sl. No.	Name of the river basin	Average Annual Surface Water Potential (BCM)	Estimated Utilizable Flow , excluding Ground Water (BCM)	Total replenishable Ground Water Resources (BCM)	Population in 1991	Per capita available Surface Water m^3	Per capita available Surface and Ground Water m^3
1	2	3	4	5	6	7	8
1	Indus (up to border)*	@73.31	46.00	26.49	41.90	1750	2382
2	a) Ganga*	525.02	250.00	170.99	356.80	1471	1951
	b) Brahmaputra,*	585.60	24.00	53.91	35.24	16617	18147
	Barak & Others*						
3	Godavari*	110.54	76.30	40.65	53.98	2048	2801
4	Krishna*	78.12	58.00	26.41	60.78	1285	1720
5	Cauvery*	21.36	19.00	12.30	29.33	728	1148
6	Pennar*	6.32	6.86	4.93	9.70	652	1160
7	East flowing rivers	22.52	13.11		23.60	954	
	between Mahanadi						
	and Pennar			18.22			831
8	East Flowing Rivers	16.46	16.73		45.20	364	
	between Pennar and						
	Kanyakumari						
9	Mahanadi*	66.88	49.99	16.46	26.60	2514	3133
10	Brahmini & Baitarani*	28.48	18.30	4.05	9.77	2915	3329
11	Subernarekha*	12.37	6.81	1.82	9.46	1308	1500
12	Sabarmati*	3.81	1.93		10.58	360	
13	Mahi*	11.02	3.10	18.42	10.48	1052	1120
14	West Flowing Rivers	15.10	14.98		22.10	683	
	of Kutch, Saurashtra,						
	including Luni						
15	Narmada*	45.64	34.50	10.83	14.70	3105	3842
16	Tapi*	14.88	14.50	8.27	14.80	1005	1564
17	West Flowing Rivers	87.41	11.94		25.80	3388	
	from Tapi to Tadri						
18	West Flowing Rivers	113.53	24.27	17.69	32.60	3483	3744
	from Tadri to						
	Kanyakumari						
19	Area of Inland drainage	NEG			7.10		
	in Rajasthan desert						
20	Minor River Basins	31.00			2.10	14762	14762
	draining into						
	Bangladesh & Burma						
	Total	1869.35	690.31	431.44	842.62		2731

Source: Water Vision 2050, Indian Water Resources Society (IWRS), 1999.

The following constraints also affected the assessments:

- Withdrawals for domestic and industrial uses are estimates made on the basis of population and available information on per capita for domestic and industrial uses, since data on withdrawals for these uses are not generally available.
- The actual evaporation losses recorded for a few reservoirs have been utilized, but for most reservoirs estimation is made on an assumption of 20% of the annual utilization.
- The Central Ground water Board has periodically estimated the total ground water draft for the country as a whole. Ground water utilization for different uses is estimated based on the ground water draft.
- Return flows from irrigation use of surface water are assumed to be 10 -20% whereas for ground water it is negligible for localized uses. The return flows from domestic and industrial uses either from ground water or surface water sources are assumed to be 80%.
- The irrigation efficiency of surface water was estimated at 30 to 40%, and efficiency of ground water use about 70 to 75%. The return flows worked out on the basis of these efficiencies may be an underestimate.
- The availability figures in each basin are of average virgin flows at the terminal point of a river with a probability of 50%. For planning irrigation and hydropower projects within the techno-economic viability norms prescribed by the Planning Commission, the probability values of dependable flows are taken as 75% and 90% respectively. For water supply schemes, it is based on 100% dependability of flow.

The NCIWRDP, while examining the constraints referred to above, has recommended that "CWC should take up the work of further refining the assessment of water resources of various river basins and collect reliable data pertaining to observed flows, utilization from surface and ground water resources for irrigation, domestic and industrial use, and evaporation losses. The return flows from irrigation and from other uses for surface and ground water resources should be estimated after considering the prevailing efficiency of the system. More accurate observations on irrigation efficiency are needed." This recommendation opens up the possibility of higher utilizable flow (Resource) to bridge gaps between availability and use.

The utilizable ground water is estimated as 396 BCM out of a ground water potential of 432 BCM (dynamic source which can be extracted economically, annually), which is 92% of potential replenishment. It is also estimated that 21% of the ground water potential i.e., 89 BCM is due to recharge augmentation from canal irrigation, which again brings in an element of under - estimation.

Thus the total utilizable flow from surface and ground water is estimated as 1,086 BCM (690 BCM from surface water and 396 BCM from ground water). The contribution of each basin is also shown in Table 2. The same figures have been adopted in the IWP studies as well as IWRS projections.

The water availability in each basin, per ha of cultivable area water availability per year, and the per capita (for 1991 population figures) availability are given in **Table 3**, and shown pictorially in **Figures 5 & 6**.

Table 3:

Water Resources Availability in Individual Basins

River Basin	Average Annual Availability		
	Water Resource Potential (BCM)	**Per Capita (Cubic metre)**	**Per Ha of Cult. Area (cubic metre)**
Indus[@]	73.3	1,750	7,600
Ganga	525.0	1,471	8,727
Brahmaputra & Barak	586.0	16,617	44,180
Godavari	111.0	2,048	5,837
Krishna	78.1	1,285	3,847
Cauvery	21.4	728	3,692
Subernarekha	12.4	1,308	6,533
Brahmani -Biatarani	28.5	2,915	8,903
Mahanadi	66.9	2,514	8,369
Pennar	6.3	652	1,774
Mahi	11.0	1,052	4,977
Sabarmati	3.8	360	2,455
Narmada	45.6	3,105	7,727
Tapi	14.9	1,005	3,285
West flowing rivers from Tapi to Tadri	87.4	3,388	27,900
West flowing rivers from Tadri to Kanyakumari	114.0	3,483	36,078
East flowing rivers between Mahanadi and Godavari	22.5	954	5,199
East Flowing rivers between Pennar and Kanyakumari	16.5	364	2,400
West Flowing rivers of Kutch and Suarashtra incl. Luni	15.1	683	644
Area of inland drainage in Rajasthan desert	Negl.	-	-
Minor rivers draining into Bangladesh and Myanmar	31.0	14,762-	

@Refers only to the three eastern rivers in India

The major reason for declining water availability in the country is the substantial increase in the population. In addition, the population is not evenly distributed. Water availability and accessibility have always been principal criteria for human settlement, and it is not surprising that the population density is high in such areas. The Gangetic belt has been the main growth center of India.

The annual per capita availability of renewable fresh water in the country was 6008 m^3 /capita/year in 1947, which has steadily declined to a present level of 2246 m^3 /capita/year (GOI, NCIWRDP, 1999). This gives a broad indication of the growing water scarcity in the country. The declining trend of the water availability per capita in the last 50 years, as well as future projections for this parameter, are given in **Table 4**.

Table 4: Declining availability of water per capita in India

Year	**Average water availability (m^3 /person/year)**
1947	6,000
1957	5,300
1967	4,200
1977	3,500
1987	3,000
1997	2,246
2007	2,100
2017	2,000
2027	1,800

Source: Engleman and Roy (1993)

2.3 Water Resources of Bangladesh

Bangladesh, located in the delta of two of the world's largest rivers, i.e., the Ganges and the Brahmaputra, is the lowest riparian of the three major river basins, the Ganges, the Brahmaputra and the Meghna (GBM). About 93% of the catchment of the country's river system lies outside the country. The demarcation of various river basins of Bangladesh is given in **Figure 7**. The details of the catchment area of these basins are given in **Table 5**.

Table 5:

Catchment area of major river basins of Bangladesh

River	Total catchment area (km^2)	Catchment area in Bangladesh (km^2)	Percentage of the total catchment area in Bangladesh
Ganges	949667	34188	3.6
Brahmaputra	582750	50505	8.7
Meghna	78405	29785	38.0

Source: Bangladesh Water Development Board (BWDB) Report, 1998.

The National Water Policy (NWPo) was approved in November 1998 (GoB, 1999), and a parallel activity was started by the permanent Water Resources Planning Organization (WARPO) to prepare a National Water Management Plan for the country to achieve the Policy directives. The latter has now resulted in the draft NWM Plan. In evolving this plan, WARPO adopted the following principles for delineating the hydrologic regions of the country and to assess the total water resources potential of the country:

i) The entire country should be covered;

ii) The principal rivers and natural features should form boundaries;

iii) The principal rivers themselves should form a region; and

iv) Effective use should be made of previous studies.

Based on the above principles, Bangladesh has been divided into eight (8) hydrological regions. An overview of the eight regions of the country, based on regional water balances is summarized in **Table 6**.

The data available at the Bangladesh Meteorological Department (BMD) show that the annual rainfall in the country varies from 167 cm/yr to 320 cm/yr. The average annual rainfall in various hydrological regions is given in **Table 7**. The average rainfall of the country is 236 cm/year. In general, rainfall increases from west to east. About 80% of the rainfall is received under the influence of the monsoons between May and October. Localized rainfall of long duration in the monsoon months often generates localized floods due to drainage congestion. Such floods may reach catastrophic proportions when combined with the upstream runoff carried by the three major rivers. Bangladesh is periodically affected by cyclonic storms in the coastal districts. It has over 700 km of coastline on the mainland and several offshore islands in the Bay of Bengal.

The natural surface water resources in Bangladesh are mainly obtainable from the country's dense network of river systems, which include a combination of upstream inflows and runoff generated from rainfall within the country. Preliminary estimates at the inception phase of the NWMP (based on the draft National Water Plan of 1991) indicate the cross-border flows into the country amount to around 1010 billion cubic meters (BCM), and an additional amount of 340 BCM is generated from local rainfall, averaging 236 cm (MPO, 1991). Of this total amount of available water (1350 BCM), about 190 BCM of water is lost in the atmosphere through evaporation and evapo-transpiration, while the balance of 1160 BCM is available for use of flows into the Bay of Bengal. Eighty percent of this huge flow of water is concentrated in the five-month monsoon period of June to October. The details of surface and groundwater sources are given in Table 8.

Table 6:

Hydrological Regions of Bangladesh

Region	Assessment
South West (SW)	This region is clearly the one with greatest need of augmentation, due to multiple demands and the low flows entering the region when the Gorai is cut off in the dry season. The deficit could be made up by diversion from the Ganges, and options to do this are being reviewed. The region has a significant extent of arsenic contamination. The Ganges flow secured under the 1996 Treaty with India is critical to the sustenance of this region.
North East (NE)	There is relatively little exploitable groundwater in the area. However, there are large quantities of static surface water resources that could meet the demands outside the groundwater areas. However, the *haor* basins that contain this static water are of considerable environmental importance, and therefore water resource development of this region needs to be handled with particular sensitivity. The area is relatively highly contaminated with arsenic in the groundwater.
North Central (NC)	This region is in overall deficit, and available groundwater is not enough to meet domestic demands and net irrigation requirements. The shortage arises because regional inflows from the Old Brahmaputra and Dhaleswari are small compared with the flows needed for navigation in the busy waterways around Dhaka. Parts of the region are contaminated with arsenic, adjacent to the main river courses.
North West (NW)	Groundwater is generally in good supply; there are nonetheless significant parts, mainly along the border with India (notably the western part of the High Banind) that are in deficit due to low recharge. In the four Northemmost thanas, although groundwater is plentiful, there is a high occurrence of boulders, making drilling of tube wells difficult. The region is relatively free of high arsenic contamination, although low levels appear to occur throughout the Region.
South Central (SC)	There are inflows through the Arial Khan and the three Tetulia channels. These natural inflows can be used to meet the potential consumptive and in-stream demands in the region.
South East (SE)	The region experiences a deficit in the peak month of January. In the northern part, within the groundwater area, groundwater is available but is difficult to extract with suction mode pumps, as it often has a high content of gas. The area has the highest concentration of arsenic in the country, and is, therefore, the one where additional surface water would first be required if arsenic became a problem for agriculture.
Eastern Hills (EH)	This region may be viewed in two parts: the hills, where surface run-off and irrigation returns feed the plains, and the coastal plain, where they contribute to salinity control. The region as a whole is in deficit, and therefore will require a different approach vis-à-vis the rest of the country. In the hills, for instance, there are opportunities for drip irrigation of high value tree crops, which use less water. A concern is that over-irrigation on the coastal plain with groundwater will cause saline water to be drawn in.

Source: Draft National Water Management Plan of Bangladesh -2001

Table 7:

Average Annual rainfall in various hydrological regions of Bangladesh

Hydrologic Region	**Rainfall (cm/yr)**
South East (SE)	227
North West (NW)	174
North Central (NC)	196
Rivers Estuary (RE)	232
South West (SW)	167
North East (NE)	319
South Central (SC)	231
Eastern Hills (EH)	245
Average	**236**

Source: National Water Resources Database (NWRD) and National Water Management Plan (NWMP) Report, Volume-4, August-2000.

Table 8 :

Summary of Available Water Resources in MCM

Region	**Total Area** (km^2)	**Ground water** (Mcm)	**Standing Surface Water** (Mcm)	**Water in Rivers (MCM)** Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	**River Water Total** (Mcm)	**Total reso-urces** (Mcm)
NE	20,061	2,500	1,147	2,515	1,067	830	733	984	1,722	3,367	11,219	14,866
NC	15,949	5,066	203	1,212	459	247	179	234	408	1,078	3,818	9,087
NW	31,606	10,117	317	2,609	1,441	1,136	922	1,017	1,088	1,795	10,007	20,441
SW	26,226	3,172	336	2,455	1,190	416	489	932	1,081	1,379	7,942	11,450
SC	15,436	501	282	11,270	8,882	6,664	4,635	5,547	7,162	11,121	55,280	56,063
SE	10,284	1,540	368	568	199	259	301	418	452	531	2,727	4,635
EH	19,956	n.a.	15	1,068	824	1,112	1,526	1,757	534	1,099	7,921	7,936
RE	8,607	n.a.	26	17,701	12,342	8,879	6,421	7,663	10,122	17,763	80,890	80,916
Total	**148,130**	22,896	2,694	39,398	26,404	19,542	15,205	18,550	22,570	38,133	179,804	205,394
%		10%	1%	20%	13%	10%	7%	9%	11%	19%	89%	100%

Source: WARPO: Land and Water Resources (draft), June 2000

From the above Tables, it is clear that about 89% of the water is contributed by surface water sources in the lean season period from November to May. The surface water flow in the Table is the 80% dependable outflow from the regional model simulation and net outflow to Bay of Bengal excluding regional outflows. Groundwater sources contribute about 10% of the total water resources. The balance (1%) is contributed by the standing water sources. The available water resources have been estimated at 205 BCM.

The annual cycle of water from over-abundance to scarcity is a dominant factor of life in Bangladesh. Almost every year, during the monsoons (June to October) more than a quarter of the country is under floods. During the dry months, from November to May, the flow in rivers like Ganges and Brahmaputra reduces significantly, and most of the smaller rivers dry up. This leads to scarcity of fresh water for different uses in the dry months (November to May). The areas under drought during the wet and dry seasons are shown in **Figure 8** (on the following page).

Surface water, an important strategic resource for Bangladesh in the dry season, is the only resource for some 44% of the country (barring some small pockets of groundwater used for domestic and municipal supplies), and can be used to augment all areas where deficits arise. Under the directions of the National Water Policy, however, much more attention is now being given to in-stream demands and the environmental benefits that will come from healthy river systems.

In-country run-off during the dry season is minimal, and by far the most dominant sources of surface water are the Brahmaputra and Ganges Rivers (notwithstanding the locally important inflows on other trans-boundary rivers). Of the two, the dry season flows in the Brahmaputra are substantially greater than those on the Ganges, even after the signing of the 1996 Ganges Water Treaty.

Groundwater in limited quantities is available in only about 56% of the country (the Groundwater Irrigation Thanas or GIT). In other areas, small quantities of available groundwater exist, sufficient only to support a limited amount of domestic and municipal use, but these are easily over-exploited. Other parts of the country, mainly the NE, SE, EH and the southern parts of the SW and SC, rely principally upon surface water to meet all their needs. A comparison of potential demands (WARPO, 2000) on groundwater availability indicates that deficits may arise in both the Southwest and Northwest regions, principally along the western border where recharge tends to be less.

2.4 Water Resources of Nepal

Nepal is endowed with some 6000 rivers and rivulets that carry a substantial amount of water flow. There are two distinct rainy seasons in Nepal - the first from June to September is due to the southwest monsoon, and the second, in winter, is brought about by the western disturbances. Almost 80% of the rainfall is received under the influence of the southwest monsoon. About 64% of precipitation directly contributes to the river flows as surface run-off, and the rest is utilized as snow, recharge of ground storage, or lost as evaporation and transpiration. The snow and the groundwater later appear as base flow during the lean flow periods in the rivers.

The precipitation is the highest (up to 6000 mm per annum) along the southern slopes of the Annapurna Range in central Nepal, and the lowest (less than 250 mm per annum) is in the north-central portion near the Tibetan Plateau. Most of the country receives rainfall in the range of 1500 to 2500 mm per annum. The southern slopes of the Mahabharata range, the Himalayan range, and the eastern two-thirds of the country receive the maximum precipitation. The minimum precipitation falls in the west through the mid-section of the country. Precipitation in the form of snow normally occurs above 3,500 m altitude. The annual average precipitation in the country is around 1,770 mm.

Surface Water Availability

There are nine major and medium river basins in the Nepalese river system, covering a total drainage area of 194,500 km^2, of which 47,290 km^2 are in Tibet, China, or India. A map of Nepal showing the major river basins is shown in **Figure 9.**

The rivers of Nepal can be classified into three categories:

- The major rivers, like the Koshi, Narayani (Gandak), Karnali and Mahakali, originate in the Himalayas and the high mountains, and are snow fed. After flowing through the Terai, they merge with the Ganges in India. These rivers are perennial and carry substantial flow even during the dry season.
- The medium flow rivers, like the Kankai, Kamala, Bagmati, West Rapti and Babai, originate from the middle mountains below the snow line, and are rain-fed. These are also perennial rivers, with contributions from ground water and springs during the dry seasons.
- The minor rivers originating from the Siwalik range or in the Terai are much smaller in size, and carry very little flow during the dry season.

Koshi is the largest river basin, with a drainage area of around 60,400 km^2. However, the Gandak basin, with a drainage area of 34,960 km^2, has the highest surface water availability. The Gandak and Koshi basins account for 24.6% and 23.3% of the total water availability respectively, in Nepal (WRSF, 2000). About three-fourths (74%) of the total annual surface flow occurs in the four monsoon months from June to September. The surface water availability in the country is estimated to be about 225 BCM/year, equivalent to an average flow of 7,130 cubic meters per second (m^3/s).

In Nepal, good potential for groundwater exists only in the Terai region (The southern plains) and the inner valleys and mountainous regions. The annual ground water recharge available for extraction is estimated to range from 6-12 BCM/year (WRSF, 2000).

The magnitude of the average availability of surface and ground water resources of the whole country as expressed above can be very misleading when it comes to its actual utilization. The variations of water resources availability in terms of time and space are considerable. The demands of water for domestic, industrial, irrigation, hydropower generation, and environmental requirements normally does not match temporally or spatially with the available water supply. This may lead to the resource being categorized as "scarce" rather than abundant.

Groundwater Resources

The groundwater resource estimates are mainly available for the Kathmandu Valley, the Inner Terai Valleys like Udayapur, Chitwan, Deukhuri, Dang and Surkhet, and the main Terai. The groundwater estimates of the springs and dug-wells in the hills and mountains have not yet been prepared. Around 1,300 deep tube-wells (DTW) and 50,000 shallow tube-wells (STW) (excluding hand, rower and treadle pumps) have been installed in the country (WRSF, 2000). There have been various estimates of groundwater availability. In the Kathmandu valley, the annual rechargeable estimates vary from 4.75 MCM to 13.7 MCM per annum. In addition, the static reserve is estimated to be anywhere between 21 and 3,250 MCM. The five inner Terai valleys are estimated to have a good groundwater potential. Udayapur and Surkhet have good potential, but their magnitude is yet to be reliably estimated. The estimates in Chitwan, Deukhuri and Dang are about 136 to 421 MCM/annum, 133 to 181 MCM/annum, and 130 to 140 MCM/annum (from shallow tube wells alone), respectively.

The groundwater - rich main Terai can be divided into two hydrogeologically significant units, the Bhabar zone, immediately below the Siwalik range, and the Southern zone extending to the Indian border. The Bhabar Zone, formed by the alluvial and colluvial coarse sediments, is an area considered to be very suitable for groundwater recharge. It is estimated that about 2,760 MCM to 4,430 MCM per annum of groundwater is available in the Bhabar zone (WRSF, 2000). The Southern Zone is laden with thick sediments of the Indo - Gangetic flood plain type. It is estimated that the groundwater available in the southern zone of the Terai is anywhere between 5,800 to 11,600 MCM per annum.

2.5 Water Resources of Pakistan

The rivers in Pakistan originate in the higher altitudes, and derive their flows primarily from snowmelt and monsoon rains. The Indus river basin has already been shown in Figure 3. The rivers of the Indus system can be classified into Western rivers (Indus, Jhelum and Chenab) and the Eastern rivers (Ravi, Beas and Sutlej). The Indus is the main river of Pakistan and northwest India, and in terms of the extent of dependent agriculture and population, this river system can be ranked as one of the most important in the world.

The new international boundary resulting from the partition of India in 1947 cut across the Indus river system. The upper reaches of the main Indus, and its tributaries from the east came to lie in India, with the lower reaches in Pakistan. The Punjab Partition Committee, which was set up to deal with the problems arising out of the partition of the Punjab approved, in December 1947, arrangements to continue release of water until March 1948 in canals cut by the new border.

Under the Indus Water Treaty (1960) between Pakistan and India (Biswas, 1992), worked out with the assistance of the World Bank, the flow of the Western rivers was allocated to Pakistan, whereas India was allocated the flows of the Eastern rivers for its use.

The cardinal principles of irrigation distribution in Pakistan date back to the British Colonial era, when the population was smaller and the investments on development works were probably assigned for short recovery periods. The irrigation distribution was designed to cover the maximum area possible. For perennial canals, the allocation of water at the outlet was designed for a cropping intensity of 25% and 50% for Rabi (winter) and Kharif (summer) cropping respectively. About 210 liters per second (l/s) were allocated for 1000 ha (1.8 mm/day) for this 25% intensity, which was forcing the farmer to leave 75% of the land fallow during the Rabi and 50% during the Kharif seasons for preparation of next season’s crops. The Indus Basin irrigation system in Pakistan is shown in **Figure 10**.

The non-perennial canals were allocated about 1330 l/s for 1000 ha for rice cultivation, which was equivalent to 8.64 mm/day for 100% cultivation in a single season. The operation of the system is still based on a continuously running fixed rotational supply system, which is closed only for one month of winter to de-silt the canals. The supply of canals is also stopped during the peaks of floods so that silt does not enter the canal systems.

Surface water resources

Surface water from rivers is the primary source of water in the country. Infiltration from rivers, canals, watercourses and fields is the main source of ground water, which is secondary resource. The total water resources of Pakistan have been estimated (World Bank, 1990) as 236 BCM, of which surface water accounts for 180 BCM (76.3%). The balance i.e. 56 BCM (23.7%) is from ground water sources.

The mean value of inflows from the Western Rivers into the Indus Basin at the rim stations (that is entering Pakistan) is 165 BCM, with a 20% chance of not exceeding 148 BCM. Of this, approximately 125 BCM are already diverted at canal heads, which is 75% of the average inflow, but more than 85% of the inflow in low flow years. Only 30 per cent of the diverted water reaches the crop roots. The rest is lost in canals and watercourses or during application in the field.

The Indus River System (IRS) is the major source of water in Pakistan. The inflow of Indus and eastern river systems during Kharif and Rabi seasons is given in **Table 9**.

Table 9. Details of water flow in the Indus and Western River systems (BCM)

Source	Kharif	Rabi	Total Annual
Rim Stations			
Indus	65.24	10.07	75.31
Jhelum	21.82	5.45	27.27
Chenab	25.40	4.80	30.20
Swat/Kabul	22.15	4.29	26.44
Hero/Soan	1.48	0.36	1.84
Ravi/Satlej	8.51	1.50	10.01
Direct flow			
Eastern rivers	2.41	0.17	2.58
Swat/Kabul	3.69	1.42	5.11
Tarbela to Taunsa	1.99	0.63	2.62
Total inflow	152.69	28.69	181.38

Note: Period of Record: Indus: 1936-88, Jhelum/Chenab : 1922-88, Ravi/Sutlej: 1966-76, Others : 1966-76
Source: Environment Operations and Strategy Division, Guide to Indus Basin (Model Revised), January 1990, The World Bank and WSIPS (1990) by ACE/Harza et al

Ground water resources

Around 51.3 BCM of groundwater is pumped for irrigation use and for domestic and industrial use in urban and rural areas. Province-wise, the current utilization versus estimates of recharge and 'safe yield' are as follows:

Table 10: Ground water recharge, 'safe yields' and current use

(BCM)

Province	Recharge/Safe yields	Current use
Punjab	49.3	41.9
Sindh	12.3	4.3
NWFP	3.0	2.5
Balochistan	1.1	0.6
Total	65.7	51.3

(Source: ACE/Halcrow, "Exploitation and Regulation of Groundwater", June 2001

Groundwater use is nearing the upper limit in most parts of Pakistan. The groundwater table is falling in most fresh groundwater areas. Most of the unutilised discharge is in areas of saline groundwater and cannot be used. The capacity for additional withdrawal is limited at best to 1.2 to 2.4 BCM. On the other hand, the water table has been declining continuously in certain basins of Balochistan. A number of studies have estimated that the deficit in Quetta sub-basin is about 26 million m^3 per year, and that the aquifer will be exhausted in 20 years.

The main source of the ground water is seepage from the irrigation conveyance system and percolation from the irrigation fields. During the 1970s, when the population of the country was smaller, the concern was to lower the ground water through drainage wells. With the increase in population and a corresponding increase in food demand, the private sector has been investing in pumps to lift ground water to meet the deficiencies of irrigation at critical stages of crop growth. Out of an annual ground water withdrawal of 51 BCM, the private sector is now pumping about 49 BCM, through 516,000 small size tube wells (Economic Survey, 2001a). Pakistan has thus reached a stage where further increase in ground water extraction could lead to serious problems of ground water degradation from salt-water percolation and encroachment.

During the lean season, the ground water is the main source for meeting irrigation and domestic requirements. The hydro-geological conditions are mostly favorable for pumping by tube wells. It has been estimated that 15,500 large capacity tube wells and 516,000 low capacity tube wells are currently installed in Pakistan. The annual ground water utilization increased from 4.1 BCM in 1959 to 51 BCM in 2001. Due to over-exploitation, Pakistan’s ground water resources are almost at the brink of exhaustion and there is an urgent need to conserve this precious resource.

The quality of the ground water is variable. In about 79% of the area in the Punjab and 28% of the area in Sindh, it is suitable for irrigation. However, indiscriminate pumping without proper monitoring and lack of knowledge about the chemistry and hydrodynamics of the aquifers have led to deterioration in ground water quality. In many places, the salinity level of ground water has increased considerably due to over-exploitation of ground water resources.

Outside the Indus Basin and outside the canal command in the Indus Basin, water is even more limited. Ground water depletion is a major issue. In parts of Balochistan, geological fossil water is being mined. For example, in the Quetta Valley, the water table is falling by up to two meters every year, due primarily to competing demands for water from concentrations of orchards and human settlements. Other changes are also reinforcing each other. A five-fold increase in goats and a four-fold growth in the number of sheep since Independence has led to overgrazing and reduced the productivity of rangelands to as little as 15-40% of their potential (Mohammad, 1987). Simultaneously, it has led to the compaction of topsoil that has reduced infiltration capacities.

CHAPTER 3: PRESENT UTILIZATION OF WATER

3.1 Regional Overview

Considering the region as a whole, the total precipitation, the surface flows and dynamic groundwater in each of the four countries of the WASSA project, water for irrigation dominates the scene, followed by domestic and other uses. The countries of the region have a long history of irrigation development. They have learned the lesson that the management of water has to take precedence over attempts to develop more sources of water. An Integrated Water Resources Management Plan is recommended as the cornerstone of sustainable water and land management. A summary of the total water use of surface and ground water, based on the details of various uses discussed in subsequent sections, is given in Table 11 below.

Table 11

Details of present utilization in WASSA countries

	Use	**Quantity in BCM/Year**			
		India[#] (1997- 98)	**Bangladesh**	**Nepal**	**Pakistan**
1	Irrigation	524	27	38	145
2	Domestic	30	5	1	4
3	Industries	30	-	-	2
4	Energy	9	-	-	-
5	Others	36	8	-	7
	Total	**629**	**40**	**39**	**158**

Source: [#] Report of NCIWRDP

From the above Table, it can be inferred that Irrigated agriculture is by far the largest consumptive use sector in the four countries, taking over 86% of water in India (about 524 BCM out of 629 BCM), about 70% in Bangladesh, over 90% in Pakistan, and over 97% in

Nepal (38 BCM out of about 39 BCM). It may be expected to retain its dominance, although with some decline in relative importance over time.

3.2 India

The total water withdrawal and utilization of surface and ground water for all uses - irrigation, domestic, industries, power and evaporation losses in the year 1997-98 - has been estimated by NCIWRDP (WARPO, 2001) to be 629 BCM, with 399 BCM from surface water sources and 230 BCM from ground water sources. Storage projects on rivers constructed and under construction are major contributors to the surface water supply for various uses and are, therefore, explained first before the different individual uses are detailed.

3.2.1 Storage

Storage and river diversion projects have contributed richly to the utilization of surface water flows for various uses. The total storage available in the major and medium -sized projects already completed has been estimated (MOWR, 2001) at 174 BCM. The projects under construction are expected to contribute another 75 BCM. The storage expected from projects under consideration is expected to be the order of 132 BCM. Thus, the likely total storage available will be about 380 BCM.

The largest developed storage is in the Ganga basin, which accounts for a little over 20% of the entire storage capacity available in the country. The percentage of storage capacity vis-à-vis average annual flow exceeds 50% only in the Krishna and Narmada basins. The corresponding figures for the Ganga and Brahmaputra basins are of the order of 16% and 11% respectively. Details on the available water in the various river basins of the country and the live storage situation in various basins are given in **Table 12**.

Table 12:
Utilizable water in various river basins of India (BCM)

Sr. No.	Name of the River Basin	Average annual potential in the river (BCM)	Estimated utilizable flow excluding ground water(BCM)	Live storage			Percentage of likely storage to average annual flow
				Completed projects (BCM)	Ongoing projects (BCM)	Proposed projects (BCM)	
1	Indus (up to border) @	73.31	46.00	13.85	2.45	0.27	22.6
2	a) Ganga	525.02	250.00	36.84	17.12	29.56	15.9
	b) Brahmaputra, Barak & others	585.60	24.00	1.10	2.40	63.85	10.7
3	Godavari	110.54	76.30	19.51	10.65	8.28	34.8
4	Krishna	78.12	58.00	34.48	7.78	0.13	54.3
5	Cauvery	21.36	19.00	7.43	0.39	0.34	38.2
6	Pennar	6.32	6.86	0.38	2.13	-	39.7
7	East flowing rivers from Mahanadi to Godavari and Krishna to Pennar	22.52	-	1.63	1.45	0.86	17.5
8	East flowing rivers between Pennar and Cauvery	16.46	16.73	1.42	0.02	-	8.8
9	Mahanadi	66.88	49.99	8.49	5.39	10.96	37.1
10	Brahamani and Baitarni	28.48	18.30	4.76	0.24	8.72	48.2
11	Subernarekha	12.37	6.81	0.66	1.65	1.59	31.5
12	Sabarmati	3.81	1.93	1.35	0.12	0.09	40.9
13	Mahi	11.02	3.10	4.75	0.36	0.02	46.6
14	West flowing rivers of Kutch, Saurashtra including Luni	15.10	14.98	4.31	0.58	3.14	53.2
15	Narmada	45.64	34.50	6.60	16.72	0.46	52.1
16	Tapi	14.88	14.50	8.53	1.00	1.99	77.4
17	West flowing rivers south of Tapi	200.94	36.21	17.34	4.97	2.54	12.4
18	Iinland drainage of Rajasthan	-	-	-	-	-	-
19	Rivers draining in Myanmar & Bangladesh	31.00	0.31	-	-	-	1.0
20	East flowing rivers South of Cauvery	-	-	-	-	-	-
	Total	**1869.35**	**690.32**	**173.73**	**75.43**	**132.32**	**20.4**

Source: Report of the National Commission on Integrated Water Resources Development (1999).
@ For the Eastern Rivers of Indus in India only

Major states like Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Uttar Pradesh together account for more than 71% of the total live storage capacity of the country. The northeastern states of Arunachal Pradesh, Nagaland & Tripura account for more than 66% of total storage of the projects under consideration (CWC, 1989). Per capita live storage capacity is highest in Himachal Pradesh (2.7 BCM/million), followed by Nagaland, Karnataka, Madhya Pradesh and Maharashtra. These all have higher per capita availability than the national average of 0.291 BCM/million.

The available storage facilities, by state, are given in **Table 13**.

Table 13
Storage capacity in the states of India

Sr. No	Name of State/ Union Territory	Live Storage Capacity (BCM)			
		Completed projects	Projects under construction	Total	Projects under consideration
1	Andhra Pradesh	24.85	7.12	31.97	1.73
2	Arunachal Pradesh	-	-	-	45.50
3	Assam	-	1.05	1.05	1.02
4	Bihar	4.66	4.35	9.01	3.58
5	Goa	0.04	0.67	0.72	-
6	Gujarat	14.92	7.25	22.17	0.26
7	Haryana	-	-	-	-
8	Himachal Pradesh	13.81	0.11	13.92	0.01
9	Jammu & Kashmir	-	-	-	0.10
10	Karnataka	21.56	3.01	24.57	1.95
11	Kerala	4.62	1.62	6.23	8.09
12	Madhya Pradesh	18.58	21.63	40.21	5.17
13	Maharashtra	22.10	12.92	35.01	16.32
14	Manipur	0.40	0.12	0.52	0.51
15	Meghalaya	0.70	-	0.70	-
16	Mizoram	-	-	-	-
17	Nagaland	-	1.22	1.22	21.86
18	Orissa	14.29	3.30	17.59	-
19	Punjab	0.02	2.34	2.37	1.80
20	Rajasthan	8.32	1.59	9.91	-
21	Sikkim	-	-	-	-
22	Tamil Nadu	6.72	0.04	6.76	-
23	Tripura	0.31	-	0.31	20.16
24	Uttar Pradesh	16.35	7.06	23.40	0.17
25	West Bengal	1.48	-	1.48	-
26	A & N Islands				
27	Chandigarh				
28	D & N Haveli				
29	Daman & Diu				
30	Delhi				
31	Lakshadweep				
32	Pondicherry	0.01	-	0.01	-
	Total	173.73	75.42	249.15	132.32

Source: W.M.Directorate, Central Water Commission (CWC)
*Note : * Projects having live storage capacity of 10 Mm^3 and above are included.* An estimated additional live storage capacity of 3 Bm^3 is to be created through medium –sized projects each having a capacity less than 10 Mm^3.*

3.2.2 Irrigation Potential

At the time of independence, India had a total irrigated area of 22.6 million ha, which increased to 88.5 million ha by the year 1995-96. The area irrigated by ground water is of the order of 45.8 million ha, around 52% of the total (Planning Commission, 1999). The total irrigation potential of the country is estimated to be about 140 million ha.

Table 14

Irrigation potential from major, medium and minor projects in Indian states (million ha)

Sr. No	State	Major/ Medium irrigation potential	Minor irrigation potential			Total irrigation potential
			Surface water	Ground water	Total	
1	Andhra Pradesh	5.00	2.30	3.97	6.27	11.27
2	Arunachal Pradesh	0	0.15	0.02	0.17	0.17
3	Assam	0.97	1.00	0.90	1.90	2.87
4	Bihar	6.5	1.90	4.95	6.85	13.35
5	Goa	0.06	0.03	0.03	0.05	0.11
6	Gujarat	3.00	0.35	2.76	3.11	6.11
7	Haryana	3.00	0.05	1.46	1.51	4.51
8	Himachal Pradesh	0.05	0.24	0.07	0.31	0.36
9	Jammu and Kashmir	0.25	0.40	0.71	1.11	1.36
10	Karnataka	2.50	0.90	2.57	3.47	5.97
11	Kerala	1.00	0.80	0.88	1.68	2.68
12	Madhya Pradesh	6.00	2.20	9.73	11.93	17.93
13	Maharashtra	4.10	1.20	3.65	4.85	8.95
14	Manipur	0.14	0.10	0.37	0.47	0.61
15	Meghalaya	0.02	0.09	0.06	0.15	0.17
16	Mizoram	0.0	0.01	-	0.01	0.01
17	Nagaland	0.01	0.08	-	0.08	0.09
18	Orissa	3.60	1.00	4.20	5.20	8.80
19	Punjab	3.00	0.05	2.92	2.97	5.97
20	Rajasthan	2.75	0.60	1.78	2.38	5.13
21	Sikkim	0.02	0.05	-	0.05	0.07
22	Tamil Nadu	1.50	1.20	2.83	4.03	5.53
23	Tripura	0.10	0.10	0.08	0.18	0.28
24	Uttar Pradesh	12.50	1.20	16.8	18.0	30.50
25	West Bengal	2.30	1.30	3.32	4.62	6.92
	Total States	58.37	17.34	64.05	81.39	139.76
	Total (including Interstate &Union Territories)	58.47	17.38	64.05	81.43	139.90

3.2.3 Ground water use

The importance of groundwater in the Indian economy can hardly be over-emphasized. One estimate maintains that ground water resources account for as much as 70-80% of the value of farm produce attributable to irrigation. With agriculture contributing roughly 29% of India's GDP, the health of the Indian economy is clearly tied to the availability of ground water. In addition, ground water also provides 80% of the domestic water supply in rural areas (Planning Commission, 1999), and about half of the urban and industrial water requirements.

The total replenishable ground water potential of the country has been estimated at 430 BCM/year. About 16% of the total potential is required for domestic, industrial and other uses (besides irrigation), leaving a net potential of 360 BCM/year available for irrigation (IWRS, 1997).

At an aggregate level, only about 30% of the annual utilizable groundwater potential is actually exploited. Thus, on average, exploitation of ground water should generally not be a problem in the country. However, the situation is critical in some states because of over-exploitation. The level of groundwater utilization is over 98% in the Punjab. In Haryana, the overall ground water utilization is of the order of 80%. Other states where over-exploitation of ground water is alarmingly high are Gujarat, Rajasthan and Tamil Nadu (IWRS, 1999). In many of the major cities like Delhi, Ahmedabad, and Chennai, over-exploitation of ground water resources is a major problem.

Reasons for high rate of ground water exploitation

- The Green revolution has led to more and more use of ground water to meet the increased irrigation water requirements. Farmers, in order to have higher degree of control over irrigation, prefer to use ground water. The share of groundwater in net irrigated areas rose from 33% in 1965-66 to 52% at present (Planning Commission, 1999). Modern farming technology, which emphasizes high-yielding varieties and greater use of chemical fertilizers, requires a time - bound crop management regime, with assured water supply. Ground water is relied on to provide such supplies.

- Most of the ground water structures in India are privately owned, and are outside the purview of direct regulation by the state. Attempts to regulate ground water extraction through restrictions on credit or electricity have not been very successful.
- There is no law that regulates or restricts the exploitation of ground water. According to the existing law, there are no *de jure* rights to ground water, and the landowner has access to all the ground water underlying the land.

3.2.4 Agriculture in India

The total cultivable area in the country is 184 million ha, which is about 60% of the reporting area. The four states of Madhya Pradesh, Maharashtra, Rajasthan and Uttar Pradesh account for almost 50% of the total cultivable area (Planning Commission, 1999). For the country as a whole, Gross Sown Area (GSA) exceeds Net Sown Area (NSA) by 31%. *(The Net Sown Area is the net cropped area in the year specified. An Area cropped twice or more times in a year is accounted only once. The Gross Sown Area is the sum of areas under all crops, and represents the sum of the Net Sown Area and areas sown more than once.).*

There are wide interstate variations with respect to total cultivable area (TCA) and gross sown area. Among major states, Andhra Pradesh and Rajasthan have total cultivable area exceeding GSA by more than 24% and 33% respectively (Planning Commission, 1999). On the other hand, in states such as Punjab, Haryana, Uttar Pradesh and West Bengal, GSA exceeds NSA by more than 20%. For the country as a whole, GSA exceeds NSA by 31%. Punjab (81%) and West Bengal (59%) are the leading states. The gross irrigated area (GIA) is about 37% of the gross sown area (GSA). The states of Uttar Pradesh, Punjab, Rajasthan and Madhya Pradesh account for half of the net irrigated area (NIA) of the country.

3.2.5 Sources of Irrigation

Water is provided for agriculture through canals, tanks (impoundments), and wells including tube wells. According to the most recent statistics, Groundwater supplied about 54% of the total irrigated area, followed by canals (33%) and tanks (6%) (Planning Commission, 1999). The balance (7%) was irrigated by other sources.

3.2.6. Cropping pattern

India has reached a plateau as far as the land under agriculture is concerned that is expected to remain more or less constant in the near future. On the other hand, the increasing population and changing lifestyles will lead to increasing pressure on available land for housing, industrial development, infrastructure development, etc. During the last two decades the net sown area has not changed much, i.e. it has fluctuated within a narrow range of 140-143 million ha. The gross cropped area, however, has increased from 166 million ha to 188 million ha (Planning Commission, 1999). The cropping intensity has thus increased from 118% in 1970 to about 134% in 1995.

The area under food grains has declined from 75% in 1970 to about 65% in 1995. The important aspect of this is that the absolute area allotted to food grains has remained almost unchanged and most of the increase in the cropped area has been for the non-food grain crops.

Another important feature has been that the area under wheat and rice has increased at the expense of coarser cereals. The combined area under rice and wheat has increased from 56 million ha in 1970 to about 69 million ha in 1995. The combined production of rice and wheat during the period increased from 66 million tonnes to 148 million tonnes, while that of coarse cereals remained constant at around 30 million tonnes. As a result, the share of rice and wheat in the total food grain production increased from 61% to 77% during the said period.

During the last 30 years, India's population has increased from 551 million to more than 1,000 million. As a result, the per capita availability of food grain area during the period declined from 0.23 ha in 1971 to 0.13 ha in the year 2000. The food grain production during the period increased from 108 million tonnes in 1970 to 192 million tonnes. The average food grain production per hectare of area increased from 0.87 t/ha to 1.55 t/ha. The per capita production of food grain during the period increased from 196 kg to 210 kg during the same period (GOI, NCIWRDP, 1999). The details of the growth in population and food grain production are summarized in **Table 15**.

Table 15
Growth in population and food grains production

Year	Population (million)	Per capita		Food grain production/ha of food grain area (tonnes/ha)
		Area under food grain (ha)	Food grain production (kg)	
1971	551	0.23	196	0.87
1981	689	0.18	189	1.02
1991	852	0.15	207	1.38
1995	916	0.14	210	1.55

3.2.7. Growth in Irrigation Facilities

During the last 50 years, there has been a substantial increase in the irrigated area. The NIA has increased from 20.9 million ha in 1950-51 to 51.5 million ha in 1993-94 (GOI, NCIWRDP, 1999). Likewise, the gross irrigated area has increased from 22.6 million ha to 68.4 million ha during the corresponding period. The contribution of surface water to net irrigated area during the last three decades declined from 62% to 46%, with a corresponding increase in the contribution of ground water sources from 38% to 54%. The share of food grain area irrigated in the GIA available during the last 30 year period declined from 79% to 69%, with a corresponding increase in the area under non-food grains from 21% to 31%, which implies that most of the increase in irrigation intensity has been for non food grain crops. The growth of irrigation facilities in the country during the last 50 years is given in **Table 16**.

Table 16:
Growth of irrigation facilities during the last 50 years (million ha)

	Area sown			**Irrigated**		
Year	**Net Area Sown**	**Gross Area Sown**	**Area Sown more than once**	**Net Irrigated Area**	**Gross Irrigated Area**	**Area Irrigated more than once**
1950-51	118.8	131.9	13.1	20.9	22.6	1.7
1960-61	133.2	152.8	19.6	24.7	28.0	3.3
1970-71	140.3	165.8	25.5	31.1	38.2	7.1
1980-81	140.0	176.8	36.8	42.0	53.8	11.8
1990-91	142.2	185.9	43.7	47.8	62.5	14.7
1993-94	142.1	186.4	44.3	51.5	68.4	16.9

Source: Ministry of Agriculture, Directorate of Economics & Statistics

3.3 Bangladesh

3.3.1 Agriculture in Bangladesh: An Overview

With a population density of 813 persons/km^2, land is a very scarce resource in the country. Of the total area of 14.7 million ha, cultivable land in Bangladesh amounts to around 8.5 million ha. The variation in land use pattern for Bangladesh over a period of the last twenty years is given in **Table 17**.

Table 17: Land Use in Bangladesh

Unit: Thousand ha

Year	Forest	Not Cultivable land	Cultivable land	Fallow land	Net cropped area	Area sown more than once	Total cropped area
1975-76	2,201	2,680	268	644	8,486	3,528	12,014
1980-81	2,192	2,716	251	568	8,563	3,528	13,161
1985-86	2,119	2,921	271	404	8,766	4,775	13,540
1990-91	1,899	3,221	584	963	8,174	5,681	14,035
1996-97	2,157	3,918	524	390	7,852	5,944	13,796

Source: Bangladesh Bureau of Statistics (BBS), Agricultural Statistical Yearbook- 1998.

It can be seen from Table 17 that agriculture is the major occupation in Bangladesh, with almost two-thirds of the country's total area used for that purpose. The area under agriculture has remained more or less constant during the last 15-20 years, as shown in **Table 18**. However, the area being sown more than once is steadily increasing (BBS, 1998). The cropping intensity increased from 153.7% in 1980-81 to 175.7% in 1996-97.

Table 18

Trends in cropping intensity in Bangladesh

Year	Total Land area (Million ha)	Net Sown area (Million ha)	Total cropped area (Million ha)	Cropping intensity (%)
1980-81	14.3	8.56	13.2	153.7
1985-86	14.5	8.77	13.5	154.5
1990-91	14.8	8.17	14.0	171.7
1995-96	14.8	7.80	13.5	173.2
1996-97	14.8	7.85	13.8	175.7

Source: Bangladesh Bureau of Statistics (BBS) Yearbook – 1998.

Rice is the major crop of Bangladesh, and the percentage of area under rice cultivation is steadily increasing. This is essential to feed the increasing population. As the Bangladesh Bureau of Statistics (BBS) data indicate, the area under rice in 1980-81 was 78.3% of the total cropped area, and increased to 82.8% in 1995-96. A large part of the increase in cropping intensity is due to the increase in area under rice cultivation.

The situation in Bangladesh is quite similar to that in India, in the sense that the per capita area under food grains is steadily decreasing due to the growth in population. However, unlike India, the improvement in the yields of farm produce in Bangladesh is not enough to feed the increasing population. At present, sufficient data on the yield of various farm produce is not available, but it is clear that the increase in yield in the last two decades has not been sufficient to meet the requirements of the increasing population. Thus Bangladesh faces a shortage of food grains even in normal years. To improve the level of food security in the coming years, Bangladesh needs to significantly improve its agricultural production, either by increasing cropping intensity or by improving agricultural productivity.

3.3.2. Water Utilization for Irrigation and Other Uses

In general, water shortages do not occur during the monsoon season from May to November. In the early part of this season, rainfall can be variable, which is significant to those many farmers who plant *aman*[1] at this time of the year. Supplementary irrigation is practiced by few farmers, although there is potential to expand this. Many of the public sector's surface water irrigation schemes were originally designed to promote both early and late monsoon crops, rather than the now popular dry season *boro*[1] *crop*.

(Note 1: The three cropping seasons in Bangladesh are boro, an irrigated, dry-season crop that is transplanted in February; aus, a rain-fed crop that is direct seeded or transplanted in the pre-monsoon period; and aman, the most widely planted season, in which rice is transplanted (T.aman) at the onset of the monsoon in July)

The main issue during the monsoon season is excess of water. Most of Bangladesh is located within the floodplains of three great rivers --- the Brahmaputra, Ganges and Meghna, but only 8 per cent of the total catchment area lies within Bangladesh. River flows have huge seasonal variations, with the combined flow of the Ganges and Brahmaputra typically increasing from less than 10,000m^3/s early in the year to a peak of 80,000 - 140,000m^3/s in late August or early September (WARPO, 2001). These high flows, along with (i) high internal rainfall, (ii) the general low elevation of the country and (iii) inadequate drainage, result in widespread inundation each year.

Consumptive demands for water include evaporation from forests, water bodies, charland, urban and rural environments, rain-fed and irrigated agriculture, as well as the needs of water supply and sanitation. In-stream demands include the overlapping requirements for salinity and pollution control, navigation and fisheries.

Consumptive demands represent 44% of the total water demand and in-stream demands the balance of 56% (WARPO, 2001). Agricultural demands, the focus of previous studies, amounts to only 32 per cent of the total demand. At present, only about half the area is irrigated, but much of the remaining agricultural land is classified as unsuitable for irrigation. Thus the existing demands are already 85-90% of the future potential demand.

Ground-water irrigation has caused seasonal water levels to decline. Increased seasonal drawdown is of significance both to rural water supply planning, and to the types of technologies required for irrigation. However, in those areas where irrigation is already highly developed, this means a small change from current levels.

The irrigation intensity in Bangladesh is low compared to that in India and Pakistan. In the year 1985-86, the irrigated area was only 5.2%, increasing to 28.6% in 1998-99 (BBS, May 2000). During the last 20 years, the area irrigated by surface water sources has remained more or less constant. The increase in irrigated area has been achieved mainly by utilizing ground water resources. The trend of area irrigated by surface and ground water resources in Bangladesh in the last two decades is given in **Table 19**.

Table 19
Area irrigated by surface and ground water in Bangladesh

Year	Surface water	Ground water	Total Area

	Area ('000 ha)	**Percentage of total irrigated area**	**Area ('000 ha)**	**Percentage of total irrigated area**	**('000 ha)**
1982-83	903	59.2	622	40.8	1525
1983-84	850	52.8	760	47.2	1610
1984-85	865	48.8	907	50.2	1772
1985-86	834	47.9	906	52.1	1740
1986-87	867	47.1	973	52.9	1840
1987-88	949	46.0	1115	54.0	2064
1988-89	1043	43.8	1288	56.2	2381
1989-90	1139	44.2	1437	55.8	2576
1990-91	1246	44.7	1543	55.3	2789
1991-92	1018	37.0	1736	63.0	2754
1992-93	1033	34.9	1928	65.1	2961
1993-94	1034	35.2	1904	64.8	2938
1994-95	1014	30.7	2291	69.3	3305
1995-96	1151	30.9	2574	69.1	3725
1996-97	1090	29.0	2672	71.0	3762
1997-98	1123	29.3	2710	70.7	3833

Source: National Minor Irrigation Census (NMIC), Report of 1997-98, May-1999.

The major mode of irrigation in Bangladesh is shallow tube wells (STW), which at present accounts for about 57% of the irrigated area. Another 13% of the irrigated area meets its water requirements from deep tube wells (DTW). The trend in area irrigated by various sources over the last few years is given in **Table 20.**

Table 20:
Increase in irrigated area by different water modes

Season	% of irrigated area by irrigation source						% by water source		Area irrigated by ground water sources ('000 ha)	Area irrigated by surface water sources ('000 ha)	Total Area Irrigated ('000 ha)
	STW	DTW	Manual	LLP	Trad	Major Canal	Ground Water	Surface Water			
1982-83	24.4	15.4	1.1	22.1	26.6	10.5	40.9	59.1	622	903	1525
1983-84	29.8	16.3	1.0	21.2	23.1	8.5	47.1	52.9	760	860	1610
1984-85	33.1	16.2	0.9	19.8	21.7	8.3	50.2	48.8	890	882	1772
1985-86	33.7	17.5	0.9	20.5	18.1	9.4	52.1	47.9	907	833	1740
1986-87	34.7	17.3	0.9	21.0	17.7	8.4	52.9	47.1	973	867	1840
1987-88	36.5	16.7	0.8	19.5	21.0	5.6	54.0	46.0	1115	949	2064
1988-89	39.5	16.0	0.7	20.3	16.4	7.1	56.2	43.8	1333	1043	2381
1989-90	40.3	14.9	0.6	18.8	18.6	6.8	55.8	44.2	1437	1139	2576
1990-91	40.8	13.8	0.7	19.4	18.8	6.5	55.3	44.7	1542	1247	2789
1991-92	46.1	16.2	0.7	18.7	11.8	6.5	63.0	37.0	1735	1019	2754
1992-93	49.0	15.4	0.8	17.5	11.4	6.1	65.1	34.9	1928	1033	2961
1993-94	49.8	14.0	1.0	16.5	12.5	6.2	64.8	35.2	1904	1034	2938
1994-95	52.4	16.1	0.8	17.2	8.0	5.5	69.3	30.7	2290	1015	3305
1995-96	53.4	14.4	1.3	15.9	6.0	9.5	69.1	30.9	2574	1171	3725
1996-97	57.4	12.6	1.0	15.2	4.9	8.9	71.0	29.0	2671	1091	3762
1997-98	56.9	12.1	1.7	16.2	5.2	7.8	70.7	29.3	2710	1123	3833

***Source**: National Minor Irrigation Census (NMIC) Report of 1997-98, May-1999*

It can be seen from Table 20 that the percentage of area irrigated by surface water sources has been steadily decreasing during the last 20 years. About 59% of the area under irrigation in 1982-83 met its requirements from surface water sources, but at present it amounts to less than 30%. In terms of the area irrigated by surface water sources, there has been an increase from 0.9 million ha in 1982-83 to 1.12 million ha in 1997-98. In 1990-91, the area irrigated by surface water sources was 1.25 million ha which was the highest during the above-mentioned period.

The total irrigated area has increased from 1.53 million ha in 1982-83 to 3.83 million ha in 1997-98, i.e. an increase of 2.3 million ha. The increase in total irrigated area is mainly due to the increase in the area irrigated by ground water sources. The area irrigated by ground water sources was 0.62 million ha in 1982-83, increasing to 2.71 million ha in 1997-98.

Thus ground water sources account for almost 91% of the increase in irrigated area. The area irrigated by the shallow tube wells has accounted for most of this increase. This is bound to have some adverse impacts on the ground water balance in areas with high ground water extraction. At present, about 3.4 million ha of area in Bangladesh has depth to water table between 9-25 m below ground level (bgl). Likewise, in another 0.35 million ha, the ground water level is more than 25 m below ground level. In these areas, ground water should be used judiciously. The details are given in Table 21.

Table 21
Details of ground water level in Bangladesh

Depth (m bgl)	Area (million ha)
< 7	2.00
7-9	3.31
9-25	3.40
> 25	0.35
Total	9.06

At present, four `thanas’ in various districts have been identified as having high groundwater exploitation areas. These are:

Thana	District	Area (ha)
Gopalpur	Tangali	44,982
Gabtali	Bogra	41,522
Adamdighi	Bogra	21,626
Dupchanchia	Bogra	17,301
Total		125,431

The trend in area under irrigation for major food crops is given in **Table 22** (NMIC, 1997-98 and BBS Yearbooks).

Table 22:
Trend in area under irrigation for major food grain crops

Crop	Area Cultivated (million ha)			
	1980-81	1984-85	1987-88	1997-98
Rice				
Aus	3.11	2.94	3.04	1.66
Aman	6.04	5.71	5.90	5.60
Boro	1.16	2.94	1.74	2.66
HYV	NA	2.78	NA	4.97
Total rice	10.31	10.23	10.68	9.93
Wheat	0.59	NA	0.73	0.75

Note: NA means Data Not Available

It can be seen from Table 22 that the total area being irrigated under rice and wheat has not shown significant variation since 1980-81. However, for rice, the area under irrigation is increasing for high yield varieties (HYV) at the expense of coarser varieties.

Irrigation Water Requirements

Preliminary estimates indicate that the total amount of water available, on an annual basis, in Bangladesh is of the order of 1,370 BCM, of which 1350 BCM is surface water and the balance (20 BCM) is from ground water sources. This amount of water is however not utilizable as it includes 1010 BCM of cross-boarder inflow during floods, and 340 BCM are generated within the country from rainfall. The present water demand for meeting irrigation requirements, during the 7-month period (the dry period) from November to May, as estimated by WARPO (WARPO, 2001) is 34.4 BCM/yr., which is nearly 72% of the total water requirements.

Drinking water requirement

The present population of Bangladesh is about 129 million. The rural and urban populations are 102 million and 27 million respectively. Assuming the per capita water consumption of 100 and 150 lpcd for rural and urban population, the total annual domestic water requirement works out to about 5.2 BCM/year.

Other requirements

Apart from irrigation and domestic use, the other major requirements include water for environment, fisheries, and forests. The estimates of WARPO (2001) for various types of water needs in the different regions of Bangladesh are shown in **Table 23**.

Table 23: Summary of present water needs

Region	Present water demand in Mm^3 (for Nov-May)							
	Env	**Fisheries**	**Forest**	**Irrigable**	**Rainfed**	**Domestic, Commercial & Industrial**	**In-stream**	**Total**
SW	43	764	320	6949	157	186	7258	15676
SC	19	137	185	3379	55	111	18144	22030
NW	127	439	447	11858	420	311	1016	14619
NC	40	134	355	3863	127	331	3538	8389
NE	23	112	288	4309	172	138	1379	6420
SE	23	133	167	2340	38	142	1016	3859
EH	34	179	2028	1676	63	111	653	4744
RE							18144	18144
Total	309	1897	3790	34374	1032	1331	51148	93881

Source: State of Water Resource system, 2001 (unpublished), WARPO

3.3.3 Present total water requirements

The total water requirement at present in Bangladesh has been estimated at 54.5 BCM/year. The details are given in **Table 24**.

Table 24
Summary of Present water requirements in Bangladesh

Sector	**Quantity (BCM/year)**
Irrigation	34.40*
Domestic, commercial and industrial	1.33
Others	7.03
Instream	51.15
Total	93.91

Source: State of Water Resource system, 2001, WARPO
** For Nov-May only.*

3.4 Nepal

3.4.1 Agricultural aspects

There are three distinct and parallel ecological zones in Nepal, namely:

- The southern Terai plains;
- The medium sized hills;
- The northern mountains.

About 20% of the total area is under agriculture, and another 7% is suitable for agriculture but is not being used for that purpose. The land use pattern of Nepal is outlined in **Table 25**.

Table 25:

Land Use in Nepal

Land use category	Area (million ha)
Agricultural land: cultivated	2.97 (20.1)
Agricultural land: uncultivated	0.99 (6.7)
Forest (including shrubs)	6.31 (42.8)
Pastures	1.76 (11.9)
Others	2.73 (18.5)
Total	14.75 (100.0)

Note: These data are from 1979 and may not reflect the current position. For example, the latest (1998) forest cover estimate is 29% of the total area (NPC, 1998). Figures in brackets indicate percentages.
Source: Agriculture Statistics Division (ASD), Ministry of Agriculture, 1998.

The Terai region accounts for nearly 52% of the gross cropped area. Paddy is the major crop in Nepal, as it accounts for nearly 37% of the total cropped area. The other major crops are maize and wheat and account for 19.5% and 15.5% of the total cropped area respectively. The agricultural statistics of Nepal are summarized in **Table 26** (Ministry of Agriculture, 1998/99).

Table 26. Agricultural Statistics for Nepal

Crop	**Area (million ha)**	**Production (million tonnes)**	**Yield (tonnes/ha)**
Paddy	1.514	3.710	2.45
Maize	0.802	1.346	1.68
Wheat	0.641	1.086	1.69
Millet	0.264	0.291	1.10
Barley	0.032	0.032	1.00
Potato	0.118	1.091	9.25
Oil seed	0.190	0.120	0.63
Sugarcane	0.054	1.972	36.52
Pulses	0.308	0.229	0.74
Tobacco	0.004	0.004	1.00
Fruits	0.045	0.456	10.13
Vegetables	0.140	1.343	9.59
Total	4.112	11.680	

3.4.2 Present water requirements

Water is required for meeting various demands, i.e., drinking water, sanitation and other domestic needs, industrial uses, irrigation, environmental and eco-system preservation, recreation purposes, hydro-power generation, river navigation, etc. About a third of the population still does not have access to safe drinking water, and only 25% of the population has proper sanitation facilities. The population growth rate is about 2.4% per year, which implies a doubling of the population every 20-30 years.

Consumptive Water Demand

Non-Agricultural Uses

The demand for water supply and sanitation is based on the size of the population, which is expected to grow from about 23 million at present to about 40 million during the next 30 years (WECS, 2000). The average consumption for rural water supply is taken to be 60 liters per capita per day (lpcd). The livestock requirement is estimated as 20% of the domestic demand in rural sector. Thus, rural water supply can be taken as (60 + 12) 72 lpcd.

The per capita consumption in the urban areas is estimated to be 200 lpcd (including losses). Data on industrial demand is scarce, and is assumed to be 10% of the urban demand. Thus the per capita water supply for urban population works out to (200 + 20) 220 lpd. Of the present population, about 17.5 million are living in rural areas and the remaining 6 million in urban areas. The present domestic water requirement in rural and urban areas is estimated to be 0.46 BCM/year and 0.48 BCM/year respectively. Thus, the total non-agricultural water requirement is about 0.94 BCM/year.

Most of the domestic and industrial water demand is met by local sources, i.e. from small streams and springs in the hills and mountains, and from groundwater in the Terai. The rural and urban water demand comes out to be a very small fraction as compared to the irrigation demand. The available resources in most cases do meet the water supply and sanitation demand, except in some major urban centers like the Kathmandu valley. The water demand in the Kathmandu valley at present is estimated to be 78 MCM/year. There is a major shortage of water during the dry flow months of March, April and May. Groundwater is supplementing the surface water flow in the valley.

There are 300 DTW and more than 1,000 shallow tube wells extracting about 23 MCM/year of ground water in the Kathmandu Valley (WRSF Consortium, 2000). The annual rechargeable groundwater, according to the most optimistic estimate, is of the order of 14 MCM per year. Thus the Kathmandu valley is likely to face a severe problem of depletion in the ground water table. Similarly, other urban centers of the country too could face a similar situation, unless proper planning of towns and industrial locations is carried out.

Irrigation

The total cultivable land in Nepal is 2.64 million ha of which 1.77 million ha (72%) is irrigable. There is a possibility of bringing another 0.41 million ha of land under irrigation. Thus the total irrigable land would be (1.77 + 0.41) 2.18 million ha. At present, the area under irrigation is 1.10 million ha, which is roughly half of the total irrigable area. The area with irrigation facility throughout the year is only 0.45 million ha (WRSF Consortium, 2000).

About 75% of the total irrigated area is under Farmer Managed Irrigation System (FMIS) and the balance is under Agency Managed Irrigation System (AMIS). The status of irrigation development and management in Nepal is given in Table-27.

Table 27:

Status of Irrigation Development in Nepal – 1999/2000

Region	**Cultivated Area ('000 ha)**	**Irrigable Area ('000 ha)**	**Irrigated Area ('000 ha)**	**Irrigated as % of Cultivated**	**Year Round Irrigated Area ('000 ha)**	**Year Round Irrigated as % of Irrigated**	**Year Round Irrigated as % of Cultivated**
Terai	1,360	1,338	889	65%	368	41%	27%
Hills	1,054	369	167	16%	66	39%	6%
Mountains	227	60	48	21%	18	38%	8%
Total	**2,642**	**1,766**	**1,104**	**42%**	**452**	**41%**	**17%**
Maximum Possible				**67%**		**100%**	**67%**

Source: WECS, 2002

A significant portion of the irrigable area in the Terai is yet to be irrigated or to undertake year-round irrigation. The overall efficiency of irrigation water delivery is low (35-40%). The present cropping patterns are of two types - one with monsoon (seasonal) irrigation, and the other with year-round irrigation. There is also variation with the physiographic regions (Valleys and slopes of the hills and mountains and the Terai), and with the part of the country (East or West). While planning for the future, options for high intensity cropping patterns requiring more water but with better yields could also be explored.

Irrigation requirements

The present irrigation requirements are estimated at 24.3 BCM/year. The details are given in **Table 28**.

Table 28:

Present irrigation requirements

Unit: BCM

Basin	**Demand**		
	Monsoon	**Non-monsoon**	**Total**
Koshi	3.00	1.65	4.65
Gandaki	2.82	1.52	4.34
Karnali	2.19	0.79	2.98
Mahakali	0.24	0.22	0.46
Kankai	0.24	0.22	0.46
Kamala	0.50	0.26	0.76
Bagmati	0.79	0.48	1.27
West Rapti	0.22	0.13	0.35
Babai	1.56	0.60	2.16
Others	4.02	2.80	6.82
Total	15.59	8.66	24.25

Note: ***** *Monsoon period (June to October)*

** *Non-monsoon period (November to May)*

Source : *WRSF Consortium (2000).*

Non-consumptive Water Use

Hydropower

The use of water in hydropower is non-consumptive. There is no power station in the Mahakali or Karnali river basins. The Koshi and Gandak river basins have been primarily used for hydropower generation. Except for Kulekhani I and II and Jhimruk hydropower stations, all the other existing, and all seven hydro-power stations under construction, are in either Kosi or Gandak river basins (**Table 29**).

Table 29:

Hydropower Projects (existing and under construction)

River Basin	**Name of the Hydropower Project**	**Capacity (MW)**
Bagmati	Kulekhani I	60.0
	Kulekhani II	32.0
Rapti	Jhimruk	12.3
Kosi	Panauti	2.4
	Sunkosi	10.5
	Indrawati *	5.0
	Khimti	60.0
	Bhotekosi	36.0
Kankai	Puwa	6.2
Gandaki	Trisuli	24.0
	Devighat	14.1
	Gandak	15.0
	Marsyangdi	69.0
	Andhikhola	5.1
	Chilime *	20.0
	Kali Gandaki A *	144.0
	Modi	14.0
	Total	**529.6**

*Note : * Under construction.* Source: (NEA, 2001a)

Apart from these, about 11.5 MW of power is being generated from small rivers. The Kulekhani reservoir is the only seasonal storage reservoir project in the Nepali power system. Utilization of water resources of Mahakali and Karnali Basins for hydropower generation has not started yet. The total hydropower potential of the country is estimated to be 83,000 MW, of which 43,000 is said to be economically viable. Some of the important reservoir type projects (multi-purpose and single purpose) under planning or construction, together with their estimated capacity and energy generation, are presented in **Table 30** (WRSF Consortium, 2000).

Table 30
Major Hydropower Projects (Reservoir Type)

Basin	**Name**	**Installed Capacity (MW)**	**Energy (GWh)**
Kankai	Mailoop 2	60	245
Kosi	Dudh Kosi 1	300	1,706
	Tama Koshi 3	330	1,472
Bagmati	Kulekhani	92	254
	BMPP*	140	831
Gandaki	Kali Gandaki 2	660	3,071
	Burhi Gandaki	600	2,602
	Andhi Khola	141	547
West Rapti	Naumure	225	843
Karnali	Chisapani	10,800	20,956
	West Seti	720	3,300
Mahakali	Pancheswar	6,480	10,681

*Note : *BMPP: Bagmati Multi-purpose Project*

Other uses

The other uses of water, e.g. flow requirements for environmental reasons, recreation, navigation, flood control, low flow augmentation, religious and cultural requirements, and legal requirements of minimum downstream flows in the rivers etc are all very important in assessing the supply and demand scenarios of water resources. Some of these requirements like the minimum flow requirements are difficult to quantify. It is also a common practice to take these requirements as constraints to be met while planning and developing the water resources projects for purposes of water supply, irrigation and hydropower.

3.4.3 Total Present water requirements

The present water requirement is given in Table 31

Table 31
Present water requirements in Nepal

Sector	Quantity (BCM/year)
Irrigation	24.3
Non - Irrigation	0.9
Total	25.2

3.5 Pakistan

3.5.1 Irrigation and Storage

Pakistan has a total area of 88 million hectares, of which 22 million hectares is under agriculture. Out of the total cultivable land, about 18 million hectares is irrigated and the balance is rain fed or Barani (Economic Survey, 2001d). It is classified under the following categories.

a) Full or partially controlled irrigation schemes covering an area of 14.3 M.ha., of which the Indus Basin Irrigation System (IBIS) is by far the largest system (14.0 M.ha);
b) Spate irrigation (1.4 M.ha), called Rod Kohi in NWFP and Punjab, and Bandat in Balochistan;
c) The Sailaba irrigation or flood recession cropping areas (1.2 M.ha).

Apart from the above, water harvesting, called Khushaba, has been attempted in some areas.

Several reservoirs have been built (52 with a height exceeding 15 m) to store water for various purposes. Three major reservoirs have a total storage capacity of the order of 16.3 BCM, which not only feed large irrigation systems but also generate hydropower. The details (Mohtadullah, 1992) are given in **Table 32**.

Table 32:
Depletion of Live Storage in Major Reservoirs of Pakistan (BCM)

Name/year of commission	Original	2000	2010
Mangla/1967	19.4	15.8	14.4
Chashma/1971			
Tarbela/1976			

Source: Pakistan National Water Sector Profile, Halcrow, 2002

The Indus Basin Irrigation System (IBIS) is the fifth largest irrigation system in the world, and is reported to be the largest contiguous system. It comprises 2 big storage reservoirs, 19 large riverhead works, 43 canal systems measuring 58,000 km, and 1.6 million km of watercourses and field irrigation channels. The average delivery efficiency from the canal head to the root zone is only 35-40% (Lowdermilk, 1978). Another 10-15% is lost due to improper irrigation practices. Thus, a total of 38 BCM/year of water is wasted during irrigation. This not only reduces the water available for irrigation, but also contributes to water-logging.

The reuse of irrigation water is minimal in Pakistan, as the return flows are negligible. Agricultural productivity has been severely affected as a result of water-logging. The Indus River system carries around 33 million tonnes of salt, which flows through its waters; only about 8 million tonnes of salt flows into the sea. The balance remains on land, which contributes to increases in areas affected by soil salinization.

3.5.2. Water Use for Irrigation

Water availability for irrigation has ranged between 116 and 160 BCM/year during the last decade (Economic Survey, 2001a), of which around two-thirds is utilized during Kharif and the remainder during Rabi [2]. The average water utilization in the various provinces of Pakistan is given in **Table 33**. The Indus Irrigation system of Pakistan, the largest irrigation system in the world, is shown earlier in Figure 10.
(Note: 2. Kharif and rabi are the names of crop seasons commonly used in South Asia).

Table 33

Surface water utilization for irrigation in the Indus Basin, Pakistan

Province	**Water utilization (1976-2000) BCM**
Punjab	66.3
Sindh	55.6
NWFP	4.4
Balochistan	1.5
Total	127.9

(Source: WAPDA)

It is clear from Table 33 that the water allocation for Punjab and Sindh is approximately the same. In the past, there have been internal conflicts on water sharing between the two provinces. Sindh, being a lower riparian state claims that it is not receiving its fair share of the water as the upper riparian, Punjab, is consuming more than its share. An agreement reached between the provinces on the apportionment of the Indus waters, replacing the much older agreement, releases the provincial canal systems operation from the need to be in operation all the time so as to protect or establish future rights. A formula for sharing the surplus river flows forms a part of the new agreement.

3.5.3 Domestic use

The domestic water requirement at present in Pakistan is estimated at 3.5 BCM/year, on the basis of an average per capita water demand of 70 liters per day (lpd). Various sources are being used for meeting domestic water demand, e.g. piped supply, hand-pumps, wells, and river or canal systems. Information on the share of water supplied by the various sources (GoP, 1980) is given in **Table 34**.

Table 34:
Sources of water for meeting domestic needs
(Numbers indicate %)

Source	Punjab	Sindh	NWFP	Balochistan
Piped supply	43	80	58	69
Hand pumps	48	15	4	-
Wells	6	2	35	22
Surface water resources	3	3	3	9

It is clear from Table 34 that a large quantity of water is supplied through unorganized sectors, mainly through hand pumps and wells. There is no law restricting ground water use and location of pumps, and therefore the exact quantity of the water use in domestic sectors through wells and tube wells cannot be estimated. In many cases it has been seen that the wells are not properly spaced to sustain withdrawal. Moreover, in certain areas, the unorganized withdrawal may exceed the recharge capacity by several times and therefore is not sustainable on a long-term basis. In addition, when the water is supplied by individual entrepreneurs through wells and pumps, there is little control over the quality of the water supply. In most parts of the world, and especially in South Asia, the wells are extremely susceptible to fecal contamination, which often severely affects the health of the consumers.

It is important that the water supply sector be substantially reorganized. The unorganized supply sector may have to be replaced by more organized sectors, both private and government, to ensure uniformity in quantity and quality of supply. The water supply sector is to be linked with sewage collection, conveyance and treatment systems, to avoid large-scale water pollution of water bodies. This implies that a lot of thought and investment may have to be provided in the water supply sector in Pakistan, especially for the provinces of Punjab and Sindh.

3.5.4. Industrial Use

The water requirement of the industrial sector at present is quite low. About 1% of surface water and 5% of ground water sources is utilized by the industrial sector. Cities such as Karachi, Lahore, Faisalabad, Multan and Sialkot, are the prime industrial areas and consume a large part of the water used by industries. At present the industrial water demand in Pakistan is of the order of 1.8 BCM/year (Gill, 2000).

3.5.5 Total water demand

The total water demand in Pakistan at present is estimated to be about 158 BCM/year. The details are given in **Table 35**.

Table 35: Estimated present water requirement of Pakistan (BCM/year)

S. No.	**Sector**	**Quantity**
1.	Irrigation	144.8
2.	Domestic	3.5
3.	Industrial	1.8
4.	Others*	7.5
	Total (rounded)	157.6

Note: ***** *Assuming 5% of the total demand of other three sectors*
Sources: Gill, 2000 and Agriculture Statistics of Pakistan, 1999- 2000.

CHAPTER 4: DEMAND PROJECTIONS: WATER REQUIRMENTS IN THE YEAR 2025

4.1 General

The demand for water encompasses many uses - both consumptive and non consumptive - with the consumptive use for irrigation dominating the scene. An estimate of present water use has been made in the previous section, but for projections of future requirements, it is necessary to estimate other parameters such as population growth and the corresponding requirements for food, domestic water needs, and industrial demand.

4.2 India: Water Requirements

For the country as a whole, India is endowed with enough water to provide for a comfortable balance between "resource" and "requirement" at present. In specific parts of the country, though, there are shortages during some parts of the year.

The historical projections of water demand are by those by the Irrigation Commission in 1972 (GOI, NCIWRDP, 1999), the National Agriculture Commission in 1976, the Central Water Commission and the Central Ground Water Board in recent years. The latest studies are by the NCIWRDP (1999), the IWP (GWP SASTAC, 2000) and the IWRS (1999). The norms adopted and the projections made up to 2025 by these agencies are briefly discussed here, with suggestions for changes wherever required.

4.2.1 Population projections

The projections made for 2000 AD and for 2025 AD by different agencies are given in **Table 36** below.

Table 36: Population Projections (in millions)

Organization/Agency	2000	2025	Remarks
Irrigation Commission (1972)	900		
National Commission on Agriculture (1976)	936	-	
NCIWRDP1999 Low variant of United Nations 1994 revision High variant of Visaria and Visaria 1996	 1,014 995	 1,286 1333	
Indian Water Resources Society	1,022	1,392	Middle variant of UN projections
India Water Partnership (Growth Rate)	-	-	1.62% till 2001 1.57% till 2006 1.5% till 2025

The high variant figure of Visaria and Visaria (GOI, NCIWRDP, 1999) for 2025 is likely to be the most reliable, as it generally matches the percentage projections suggested by IWP over the figures of 2000. For this population projection of 1333 million for 2025, and assuming a food grain consumption level of 218 kg per capita per year against the present level of 200 kg, the food grain requirement would be 290 million tons by 2025.

4.2.2 Irrigation area and water requirement projections

With net sown area remaining constant at about 143 M.ha, the possibility of increased food production from this area is only through increase in cropping intensity. The gross cropped area has registered an increase from 131.9 M. ha. to 186.4 M.ha. in 1990-91 (Planning Commission, 1999). A cropping intensity of 130 % has been registered in 1992-93. The increase in gross cropped area is attributed to irrigation with gross irrigated area of 68.4 M.ha in 1992-93 (surface water accounting for 45%). The NCIWRDP has assumed a cropping intensity of 140 -142% by 2025 while the IWP assumes this figure as 145%. This would place the Gross Command Area (GCA) at 202-204 M.ha as per NCIWRDP and 210 M.ha by IWP. As per IWP, the area under food grains is reported to be almost stable at an average of 124 M.ha and is expected to remain at the same figure even by 2025. However, the NCIWRDP has assumed the food crop area as a constant percentage of 70% of irrigated area and 66% of unirrigated area. The latter assumption is unfortunate. It is not appropriate to allow non-food crops to dominate irrigated agriculture, since irrigation infrastructure has been created at an enormous cost to the exchequer with the express intent of growing food crops. They therefore should cover at least 80 % of the irrigated area.

The ultimate irrigation potential is estimated to be 140 M.ha, out of which 76 M.ha. would be from surface water and 64 M.ha. would be from ground water sources (IWRS, 2002). The surface water irrigation has expanded from 16 million ha to an estimated 45 million ha in 1996 from major, medium, and minor projects.

Overall, the expansion of ground water use in the period 1951-1996 has seen a seven-fold increase in irrigated area i.e., from 6.5 M.ha in 1951 to 44.3 M.ha in 1996 (estimated to be 53 M.ha by March 2000). The ultimate irrigation potential assessed for development from dynamic recharge is 64.2 M.ha (GOI, NCIWRDP, 1999). The present water use and demand projections are made based on average use of 0.7m for surface irrigation and 0.52 m for ground water use (both IWP and NCIWRDP). In working out these norms, the NCIWRDP has assumed present irrigation efficiency of 35 to 40% for surface water and 65-70% for ground water.

For estimation of future food grain requirements in the year 2025, the following scenarios have been considered:

Scenario-D1: Continuation of the current trend (3% growth in per capita income/ year); Business As Usual (BAU)

Scenario-D2: Using 1987-88 data as base, all the population is above the poverty line;

Scenario-D3: A poverty reduction scenario in which every malnourished person is well fed.

The utilizable water resources in the country as mentioned earlier in Chapter 1 have been estimated as 1,086 BCM/year. The estimated water demand for the three scenarios is given in **Table 37**.

Table 37
Total demand for irrigation water

Year/ Scenario	Total irrigated area (million ha)	Irrigation by surface water sources (million ha)	Irrigation ground Water Sources (million ha)	Surface water requirement (BCM/year)	Ground water requirement (BCM/year)	Total water requirement (BCM/year)	Percentage of total utilizable water resources (%)
1997-98	71	33	39	399	230	629	58
2025							
Scn, D 1	118	65	53	455	275.6	730.6	67
Scn. D2	130	72	58	504	301.6	805.6	74
Scn. D3	140	77	63	539	327.6	866.6	80

Source: NCIWRDP Report-2000 & IWP 2000 Vision Report

The projections made by IWP for the three demand projection scenarios, for food grain and non-food grain production, are 731 (D1), 806 (D2) and 867 (D3) BCM for 2025. The NCIWRDP projections under two scenarios of high demand and low demand put the demand at 784 BCM and 843 BCM respectively. As per WASSA projections, the demand has been worked out, assuming a base year utilization of 629 BCM for 1997-98, for the same three scenarios as done by IWP. Scenario 1, i.e., continuation of the current trend of 3% growth in per capita income per year is considered a likely scenario for 2025. For this scenario, the estimated water requirement is about 730 BCM (67% of the utilizable water resources), with a total irrigation area projection of 118 million ha (65 million ha under surface water and 53 million under ground water). With this scenario, the water available for other uses would be 356 BCM.

The food grain production would be 280 million tonnes under Scenario 1, assuming average food grain yields of 3.4 tonne/ha and 1.25 tonne/ha for irrigated and unirrigated areas respectively. This is based on the assumption of an annual growth rate of 1% over the current national average figures of 2.4 tonne/ha and 1.0 tonne/ha for irrigated and unirrigated areas respectively.

4.2.3 Domestic water requirements

The estimates for domestic water supply for rural and urban areas have been made by NCIWRDP on the usage norms of 200 lpcd for urban and 100 lpcd for domestic uses with population figure of 1392 million for 2025 (55% urban and 45% rural population). Based on these norms, the water requirements have been estimated as 77 BCM, with 50 BCM for urban areas and 27 BCM for rural areas, for the year 2025. However, for the present coverage of 86.7% urban and 90.6% of rural population the use rate norms are considerably less than the norms adopted for estimating the future projections. In this context, it would be appropriate to briefly refer to the various norms prescribed by different agencies in the country for this vital sector.

- The Manual on Water Supply and Treatment of the Ministry of Urban Affairs and Employment (1993) has prescribed a minimum of 70 to 100 lpcd for domestic needs of urban areas, with non-domestic uses varying from 25 to 100 lpcd, depending on their size and economic importance. These figures have been further revised recently with a norm of 70 lpcd for towns with piped water supply but without sewerage system, and 135 lpcd for towns with piped water supply and sewerage system. For metropolitan and mega cities, the norm recommended is 150 lpcd. It is however, assumed that the unaccounted for water (UFW) would be limited to 15 %, but in practice this is stated to be around 30%;
- The Bureau of Indian Standards (1983) has, in its code IS: 1172 -1983, suggested a minimum of 135 lpcd for all residences with flushing system. The National Building Code also recommends the same norms;
- The Rajeev Gandhi National Drinking Water Mission, launched in 1986, has set the norms for rural areas a supply of 40 lpcd in all areas for human beings, and additional 30 lpcd in desert areas for live stock within accessible reach (GOI, NCIWRDP, 1999);
- The Planning Commission in the Ninth Plan strategy has sought to attain universal coverage in no source villages or habitations, partially covered villages or habitations (less than 10 lpcd), other partially covered villages (11-40 lpcd), and water quality problem villages/habitations. The existing norms are to supply 40

lpcd, 250 persons per HP/PSP and distance norm of 1.6km. Once the coverage is achieved as per the present norms, this would be liberalized to a service level of 55 lpcd and one HP/PSP for every 150 persons as also distance norm of 0.5 km. However, in the case of isolated SC/ST habitations there are no restrictions. Drinking water requirement for cattle are proposed to be an additional 30 lpcd;

- IWP has addressed this requirement for two scenarios, viz., Scenario I - Business-as-Usual (many of the current problems will continue), and Scenario II - Sustainable Water World (most problems will be addressed). Under both scenarios, 100 % coverage is envisaged. In Scenario I, the norms for rural and urban supply are 40-70 lpcd & 100-150 lpcd respectively. In Scenario II, the norms for rural and urban supply are 100 & 200 lpcd respectively. The demand projected for 2025 is 30 - 50 BCM for Scenario I & 70-80 BCM under Scenario II for different population projections and per capita norms.

Apart from the above norms, it should be noted that the consumptive use is only about 20% of the gross demand (urban) and the balance would get back into the river system for other uses. What is clear from these explanations is that domestic water supply projection for 2025 is on the high side. Water conservation and reuse of wastewater from the system, however, need to be addressed. This demand constitutes less than 7- 8% of the total utilizable water resources. This generally conforms to the percentage demand derived by model studies carried out by VIKSAT (Dinesh et al, 1999) for the Sabaramti basin, the most water stressed basin in India, as discussed in Annex 1.

4.2.4 Industrial water demand

The water demand for major industries varies widely. The Ministry of Industries has prescribed norms for 13 major industries --- sugar, chemical and petro-chemical, fertilizer, paper, textiles, coal, cement, building (including bricks), steel, small scale industries, food processing, non-ferrous metals & chemicals, and automobiles (GOI, NCIWRDP, 1999). The Central Pollution Control Board (CPCB) has also prescribed standards for water use and wastewater generated for 17 categories of industries. Industries when set up will also create an accompanying demand for domestic supply to cater to the needs of new concentrations of workers and their colonies. Based on these norms the water consumption has been estimated by NCIWRDP, for 1996-97, as 22 BCM including small - scale industries, out of which 3.9 BCM is waste water generation (about 40% of which is estimated to be toxic).

The demand projection made by IWP for 2025 is 120 BCM, which is 11 % of the total utilizable water resources in the country. It should also be noted that the consumptive use in this sector is also about 20% of the demand, which calls for vigorous recycling and reusing technological solutions in accordance with the CPCB notified standards for waste water generation. The demand for industrial use could be easily met from the utilizable water resources in the country but it poses a serious environmental challenge due to pollution, which needs to be addressed with great degree of enforceable rules and regulations.

4.2.5 Other Uses

Other uses of water cover ecology, navigation, recreation, evaporation, and energy. The ecology aspects cover mainly maintaining minimum flows in the rivers to preserve water quality, abate pollution, maintain the river regime, riparian and flood plain processes, and the river ecosystem (e,g, bio-diversity aspects of fish breeding, water fowl habitat and food, triggers for prawn movement in estuaries and endangered species of fish) or other public necessities such as bathing, and drinking water for cattle. This requirement is due to the adverse effect created by over - extraction of ground water, diversion of all flows by diversion structures and storage reservoirs without consideration of downstream flows, municipal and industrial effluents degrading the quality of river water, non-point pollution such as return flows from irrigated agriculture affecting the quality of river water, and direct pumping from the river that reduces the non-monsoon flows or totally dries up the rivers/streams.

To maintain a minimum flow in the river, more storage will be needed in the reservoirs. This flow, as flushing and dilution flows, is also important to ensure water quality goals in regulated systems where the natural regime has been substantially altered and the downstream effects of land uses lead to potential water quality problems. The NCIWRDP has estimated this requirement to be 10 BCM. (For the first time, such a provision has been made in the treaty signed with Nepal on the Mahakali River and the Upper Yamuna Agreement signed by the states to restore the ecology of the river regime and to abate pollution). The other important requirement for environment is for afforestation to restore and increase India's forest cover. This would need a large quantity of water. The NCIWRDP estimates that this would be met mostly from precipitation and soil moisture. Hence, no separate water requirement is projected for this purpose.

The demand for navigation is to maintain design depth and width of navigation. The need arises when the river is dammed, thereby reducing the river flows in the river, or when water is diverted specifically to maintain navigability of a river channel and/or a port during the lean flow season or to maintain an exclusive navigable channel section of the major rivers, which have been declared as national Waterways. No norm can be prescribed for this purpose. Their requirements are only to be planned and managed through operational mechanisms to suit other demands. However, on the example of exclusive diversion of the Ganga lean season flows through the feeder canal to maintain the navigability of the Bhagirathi River and the Calcutta port, NCIWRDP (1999) has suggested a provision of 10 BCM for 2025.

The energy and power sector uses a substantial quantity of water. NCIWRDP has estimated the percentage contributions of thermal, hydro and nuclear power stations as 73, 24 & 3% of installed capacity respectively. Consumptive and non-consumptive uses of all these sectors have been estimated either as per prescribed norms (for coal fired stations) or existing scales of use. The projections have been made for two scenarios --- low and high demand scenarios at 19 BCM & 63 BCM respectively for 2025.

The water requirement to compensate evaporation losses from reservoir surface has been estimated by NCIWRDP on the norm of 15% of live storage capacity of major and medium reservoirs and 25 % of capacity of minor reservoirs. This requirement works out to 50 BCM for 2025. The total demand of water requirements for other uses is 89 BCM and 133 BCM for low and high demand respectively.

4.2.6 Total Water Requirements

The total water requirements for the year 2025 for various uses are given below:

Use	Demand (BCM)
Irrigation	730
Domestic supply	77
Industry	120
Other uses	133
Total	**1,060**

The final demand scenario suggested by this project (WASSA) is summarized in Box 1. Considering the country as a whole, the total precipitation, the surface flows and dynamic groundwater, India is endowed with enough water to provide a comfortable balance between “resource” and “requirement” up to the year 2025.

A schematic diagram depicting the complete scenario of demand vis-à-vis the present situation is shown in **Figure 11**.

Box1: Final Assessment of Water Demand in India in 2025

Population:	1333 million for 2025
Food grain requirement:	*290* million tons (assuming a food grain consumption level per capita of 218 kilograms per year against present level of 200 kilograms)
Irrigation:	Net sown area -143 M.ha Ultimate irrigation potential 140 M.ha - 76 M.ha (54 %) - surface water; 64 M.ha. (46%) - ground water source Water use average delta - 0.70m for surface irrigation and 0.52 m for ground water use Scenario D1 - Continuation of current trend - 3% growth in per capita income per year - Business -As - Usual scenario Estimated Irrigation water requirement - 730 BCM (67% of the utilizable water resources) Total irrigation area - 118 million ha (65 million ha under surface water and 53 million under ground water) Food grain production 280 million tonnes; assuming average food grain yield of 3.4 tonne/ha and 1.25 tonne/ha for irrigated and unirrigated areas respectively, with an annual growth rate of 1% over the current national average figures of 2.4 tonne/ha and 1.0 tonne/ha for irrigated and unirrigated areas respectively. The gap can be bridged by improved irrigation efficiency.
Domestic Supply:	Present water use 30 BCM (1997-98) i.e. 3 % of utilizable water Usage norms of 200 lpcd for urban and 100 lpcd for domestic uses – Population - 1392 million – Higher Projection -Water requirements - 77 BCM, with 50 BCM for urban areas and 27 BCM for rural areas (80% of this will be return flow into the system) Consumptive use - about 20% of the gross demand (urban) Demand - less than 7-8% of the total utilizable water resources.
Industrial water demand:	*Present water use 30 BCM, demand for 2025* -120 BCM - only 11 % of the total utilizable water resources Consumptive use - about 20% of the demand
Other Uses:	Minimum flow in the rivers (for environment, flushing and dilution) -10 BCM Navigation -10 BCM, to Compensate evaporation losses - 50 BCM, Energy or power sector - 63 BCM - Higher demand - Total -133 BCM
Total Water Demand:	***1060 BCM***

A study of this scenario disaggregated by basin, however, gives a grim picture in respect of a few basins but indicates a large scope for development in major basins such as the Ganga, the Brahmaputra and some of the west flowing rivers. The Godavari and Mahanadi Rivers in the east have sufficient surplus, which would need to be developed.

4.3 Bangladesh - Water Requirements

4.3.1 Irrigation water requirement

The Ganges basin is much more developed than the Brahmaputra, and in the future it is more likely that increasing demands will be strongly apparent in the former. Studies have been undertaken to make use of the flows secured under the Ganges Treaty to restore the environment and develop areas commanded by the Ganges. The Brahmaputra, on the other hand, represents more of a long-term strategic reserve of dry season water resources, notwithstanding the high costs associated with controlling and distributing these to deficit areas.

With the above perspective, the Water Resources Planning Organization (WARPO) has estimated (WARPO, June 2000) that in the year 2025 the total area under agriculture is expected to be of the order of 19.7 million ha. The irrigation water requirement is expected to be of the order of 34.3 BCM/year. The details of the area under agriculture in each hydrological region are given in **Table 38**, and for irrigation water requirements in **Table 39**.

Table 38

Projected Distribution of Arable Land in 2025 (Mha)

Crop Types	Monsoon	Early Dry	Late Dry	Total Area
Local rice	2.68	0.00	0.00	2.68
HYV Aman	2.68	0.00	0.00	2.68
HYV Boro	0.00	3.49	1.87	5.36
Wheat	0.00	1.48	0.00	1.48
Other Crops	0.62	1.45	0.12	2.19
Permanent	0.45	0.45	0.45	0.45
Existing Crops (sub total)	6.43	6.87	2.44	14.84
Potential new crops	0.44	0.00	4.43	4.87
Total	6.87	6.87	6.87	19.71
Existing crops/Total (%)	94	100	36	75

Source: DDS, WARPO Report, August 2000

Table 39
Dry Season Net Water Demand (2025) For Agriculture

Hydrological Region	Water requirement in Agriculture (BCM)
NE	3.34
NC	4.32
NW	11.84
SW	6.30
SC	3.01
SE	2.72
EH	1.48
RE	1.28
Total	34.29

Source: WARPO topic no.-7, Land and Water Resources, June 2000

4.3.2 Domestic water requirement

The total population of Bangladesh in the year 2025 is expected to be of the order of 181 million (WARPO, 2000). Details of the estimate are given in **Table 40**. The rural and urban populations are likely to represent 60% and 40% respectively of this total. The total domestic water requirements are expected to be of the order of 9 .1 BCM/year.

Table 40
Projected population of Bangladesh in the year 2025

Unit: million

Division	**Rural**	**Urban**	**Total**
Barisal	7.9	2.4	10.3
Chittagong	20.4	13.5	33.9
Dhaka	29.5	35.5	65.1
Khulna	13.1	6.2	19.4
Rajsahi	29.1	13.5	42.6
Sylhet	7.6	2.2	9.8
Total	107.6	73.3	181.1

The Water Resources and Planning Organization (WARPO) have estimated the net water demand for the year 2025 for domestic, commercial and industrial uses in the year 2025 as 0.01435 BCM/day. The annual water requirements work out to 5.24 BCM/year, which seems to be on the low side. The details are given in **Table 41**.

Table 41:
Water for domestic, commercial and industrial uses in 2025

Unit: MCM/day

Use	**NE**	**NC**	**NW**	***SW***	**SC**	**SE**	**EH**	**RE**	**Total**
Domestic	2.03	7.89	4.79	2.84	1.53	1.94	2.25	0.85	24.12
Commercial	0.30	1.18	0.72	0.43	0.23	0.29	0.34	0.13	3.62
Industry	0.47	1.82	1.10	0.65	0.35	0.45	0.52	0.20	5.55
Total (gross)	2.80	10.89	6.60	3.91	2.11	2.68	3.11	1.18	33.29
Return flow	1.56	6.20	3.76	2.23	1.20	1.53	1.77	0.67	18.94
Total (net)	1.21	4.70	2.85	1.69	0.91	1.16	1.34	0.51	14.35

Source: WARPO topic no.-7, Land and Water Resources.

4.3.3. Other Uses

As mentioned earlier, the water requirement for other uses can be taken as 25% of the total demand. Thus, the water requirement for other uses in the year 2025 works out to 9.0 BCM/year.

4.3.4. Total water requirements

The total water requirements in Bangladesh in the year 2025 have been estimated as 46 BCM/year. The details are given in **Table 42**.

Table 42:

Summary of water requirements in Bangladesh in the year 2025

(For Nov-May only)

Consumptive Demands (BCM)	
Domestic and industrial	3
Agriculture	34
Forestry and other land	9
Water bodies etc	2
Non-consumptive Demands (BCM)	
Fish migration/navigation	61
Dilution	2
Net salinity control	48
Total consumptive	49
Total non-consumptive needs	112
Total demand	161

Source: WARPO topic no.-7, Land and Water Resources, June 2000.

It should be appreciated that because of the huge amount of cross-border inflow from outside Bangladesh and severe scarcity of water during the dry months it is wise to calculate the supply and demand of water for the country on a month-to-month basis. This has also been done. Since the critical month of water scarcity is usually March/ April, water demand and gap for the month of March around 2025 has been shown in the **Table 43** below, taking other parameters more or less as they apply today.

Table 43:

Water Demand and Gap in Bangladesh, 2025 (Projected for March only)

Water Availability (MCM)		**Water Requirement (MCM)**		**Water Surplus/Deficit (MCM)**
Ground water	**4163**	**Consumptive demand**		**22713 - 29019 = (-) 6306**
Surface water	18550	Agriculture	8910	
		Domestic and Industrial	431	
		Forest	1876	
		Water bodies	1622	
		Non-consumptive demand		
		Fishing/Navigation	8777	
		Dilution	336	
		Salinity	7067	
Total	**22713**		**29019**	

Source: WARPO, Land and Water Resources, June 2000 (computed)

From the above it is seen that there would be a severe shortage of water in the month of March, only if both consumptive and non-consumptive uses are taken into account. However, consumptive uses for agriculture, domestic and industrial water use, forest and bodies estimated as 12,839 MCM are more than met from the available 22,713 MCM for the month of March. However, it should be noted that non-consumptive demand is also important for preserving the ecological health of the water bodies, and for averting major environmental disasters.

4.4 Nepal: Water Requirements

4.4.1 Irrigation requirements

The future irrigation requirements in the year 2025 have been estimated as 58 BCM/year, against the water availability of 237 BCM/year (equal to about 12 BCM/year of groundwater and 225 BCM/year of surface water). The basin - wise irrigation requirements and water availability are summarized in **Table 44**. Although in terms of gross water availability, Nepal seems to be well off, a few basins, namely Karnali, Kankai, Kamala, Bagmati and Babai would face water shortages in non-monsoon months. The Kamala river basin is likely to face a water shortage even in the monsoon months. This could lead to severe water scarcity in these basins, leading to increased pressure on ground water resources.

Table 44
Irrigation water requirements and water availability for the River basins in the year 2025

Unit : BCM

Basin	Irrigation requirement			Water availability		
	MS	Non MS	Total	MS	Non MS	Total
Koshi	5.64	6.10	11.74	35.45	8.90	44.36
Gandaki	4.69	2.73	7.42	42.01	8.33	50.34
Karnali	5.70	4.73	10.42	35.26	8.71	43.97
Mahakali	2.87	2.25	5.12	13.54	4.51	18.04
Kankai	1.16	1.59	2.76	1.61	0.29	1.91
Kamala	2.12	2.75	4.86	2.02	0.31	2.33
Bagmati	1.60	2.25	3.85	3.77	0.60	4.37
West Rapti	0.67	0.42	1.10	2.55	0.60	3.16
Babai	2.17	1.43	3.60	2.41	0.35	2.75
Others	4.19	2.91	7.10	45.06	7.90	52.96
Total	31	27	58	184	41	225

Note : ***** *MS : Monsoon period (June to October)*
***** *Non-MS : Non-monsoon period (November to May)*
Source : *WRSF Consortium, December 2000.*

4.4.2. Non-irrigation requirements

The population in the year 2025 is estimated to be about 38.2 million, of which the rural and urban population is likely to be 25.9 million (67.8%) and 12.3 million (32.2%) respectively (WRSF Consortium, 2000). Assuming per capita water consumption of 100 lpcd and 220 lpcd for rural and urban population, the total water requirements work out to 1.67 BCM/year. The details are given in **Table 45**.

Table 45:
Non-irrigation water requirements in the year 2025

Use	**Quantity (BCM/year)**
Domestic requirement (rural)	0.57
Domestic requirement (urban)	0.90
Industrial*	0.09
Livestock**	0.11
Total	1.67

Note **: *** *10% of urban domestic water requirement*
****** *20% of rural domestic water requirement*

4.4.3 Total water requirements

The total water requirements in Nepal in the year 2025 have been estimated as 60 BCM/year (Tables 44 and 45). Of this amount, the irrigation requirements are 58 BCM/year, and the remainder consists of non-irrigation requirements.

4.4.4 Demand for Hydropower

Nepal's ambitious vision is to integrate development in hydropower sector with the rest of the economy (Irrigation, Transportation, Industry and Rural development) to achieve the ultimate goal of a modern Nepal. Hence, this sector is crucial to Nepal's demand projections and is discussed in this WASSA project study.

Only 18% of the population of Nepal is served with an electricity connection of which only 5% are in rural areas (NEA, 2001a). A major disincentive to the use of electricity for agricultural use of surface and ground water is the very high tariff charged for electricity use. The tariff of electricity in Nepal is the highest in South Asia; from 3.3 US cents per kWh in 1991 it has increased to more than 8 US cents per kWh (World Bank, 2001).

Further, the system loss of the electricity generated is about 28%, with the Katmandu valley recording a 35% loss.

Presently, the Nepal power system has inadequate supplies of electricity, and the deficit is likely to continue for a few more years. After the completion of the Chilime, Kali Gandaki A, and Indrawati power plants, the system will have a surplus of up to 35 MW in 2001/02 in peak capacity (**Table 46**). However, the situation will reverse back to deficit if the next project in line i.e. Middle Marsyangdi does not come on line in 2003/04. It is unlikely that the project could start generation in 2003/04. If no other hydropower is commissioned during that period, the system will once again move to a deficit situation of about 38 MW. Even after the Middle Marsyangdi comes on line in 2004/05, there will be a deficit in supply of about 14 MW. This scenario is valid for an average demand growth of 7.8 % over the forecast period.

Table 46: Power Supply and Demand Balance

Operating Hydro Projects	**Installed Capacity**	**Peaking Capacity**	**1999/00**	**2000/01**	**2001/02**	**2002/03**	**2003/04**	**2004/05**
Kulekhani I & II	92	92						
Trishuli Devighat	38	32						
Marsyangdi	69	69						
Sunkosi	10	6						
Gandak	15	10						
Andhi Khola	5	4						
Jhimruk	12	7						
Others	5	4						
Total:	246	224	224	224	224	224	224	224
Kosi	10	10	10	10	10	10	10	10
Tanakpur	8	8	8	8	8	8	8	8
Operating Thermal Power								
Duhabi	39	22						
Hetauda	9	8						
Others	3	2						
Total:	51	32	32	32	32	32	32	32
Projects under Construction:								
Puwa	6	2	2	2	2	2	2	2
Modi	14	5		5	5	5	5	5
Chilime	20	20			20	20	20	20
Khimti I	60	23		23	23	23	23	23
Kali Gandaki “A”	144	144			144	144	144	144
Bhote Koshi	36	16		16	16	16	16	16
Indrawati	5	3				3	3	3
Middle Marsyangdi	70	70						70
Peaking Capacity	355	283	276	320	484	487	487	557
Peak Demand			369	408	449	482	525	571
(Deficit)/Surplus			**(93)**	**(88)**	**35**	**5**	**(38)**	**(14)**

Source: WRSF Consortium (2000).

The above analysis is mainly based on the comparison of the peak demand and the peak capacity of the power system. This is only half the story as far as the power demand is concerned. Apart from the capacity (MW), the electricity demand and supply in terms of GWh also needs to be met. Nepal's power system as depicted above shows a deficit in terms of the peak demand but the situation in terms of electricity is quite different. There is normally a surplus of electricity in the wet season where the run-of-river projects like Khimti start generating in its full capacity up to 60 MW as compared to only 23 MW in the dry but high demand period (NEA, 2001b). This type of situation of capacity shortages in the dry season and energy surpluses in the wet season is quite relevant in pure hydropower systems with predominance of run-of-river type projects. A solution to such cases is to have an optimal mix of various types of hydropower projects i.e. run-of-river, peaking run-of-river and seasonal storage projects and/or coordination and optimal mix between hydro and thermal projects.

Hence, with the projects under construction and those committed, the peak deficit in dry season and possible energy surplus in the wet season will continue unless suitable projects are developed. The addition of Upper Modi with capacity of 14 MW can more or less balance the system in 2004/05. The above gives an idea of the supply and demand of power or hydropower, as it is a hydro dominated power system, in the coming few years.

With projected GDP growth rates of 6.5-8.0% (moderate to high) for the 2000-2025 period, the growth in the demand for electricity is expected to increase by an order of magnitude (WRSF, 2000) by 2025. To achieve this electricity growth, Nepal is considering putting in place the following:

- The small and micro-hydro development will be increasingly planned and implemented to envisage energy inputs at reduced tariff for use in lifting or extraction of ground water for irrigation and for operation of rural agro-based industries, since the national grid would not be able to reach the remote rural areas. It is presumed that smaller scale projects (50-200MW run of the river types) can be funded with lesser risk. India would be the market for some of the additional electricity that might be generated. If India turns down the offer of additional electricity purchases, Nepal could always absorb this smaller magnitude of power into her own system. It is also believed that the medium-scale projects handled within the market discipline and under corporate cultural practices would assure both the Indian Government and the Indian customer that the security of their supplies would not be jeopardized;
- Mechanisms are to be established to bring down the cost of the electricity to enable integration of hydropower sector development with other productive sectors, particularly in the rural areas;
- Routing of electricity through the “third party access” to the grid. This will help the private sector to wheel electricity from a remotely located power house to an

industry located elsewhere, at a nominal routing charge. This would facilitate operation of power plants at higher load factors, and thus produce cheaper electricity. This will also encourage private sector investments not only in hydro schemes of all sizes, but also in energy intensive industries;

- Building up institutional capacity so that the existing organizations such as the Ministry of Water Resources, and the National Electricity Authority (NEA) are reorganized into several institutions such as a) Transmission Authority, b) Power Sector Developer, and c) Management Unit for the distribution system;
- Electrical tariff being an inhibiting factor at present in its extensive use for allied sectors of development, it is proposed to develop a transparent and fair system of fixation of electrical tariff and control of the cost of production of energy by the private sector;
- To involve local expertise in the development of power projects;
- Enhance cost competitiveness and reliability of electricity supply not only to encourage increased use within Nepal for economic development but also to make it reasonably relevant for export to India;
- To take up multipurpose storage projects on several medium rivers like Bagmati, Kankai, Karnali, Sun Kosi-Kamla diversion, West Rapti, and the Beri-Babai diversion. To pursue building of major multipurpose projects such as the Pancheswar High Dam on Mahakali, Karnali high dam on the Karnali river, and Kosi high dam on the Kosi river;
- To enable power export to India, to create a power export infrastructure through cross - border transmission lines.

4.5 Pakistan - Water Requirements

4.5.1 Irrigation requirements

Pakistan is projected to have a population of 207 million by the year 2025. Assuming current land and water productivity, Pakistan would require 47.9 million hectares of cropland and 304 BCM water for irrigation. The basis for estimation and details of total land and irrigation water requirements in the year 2025 are given in **Table 47**.

Table 47: Estimate of irrigation water requirements in the year 2025

Crop	Yearly consumption (kg/capita)	Total requirements (million tonnes)	Crop delta (m)	Yield (t/ha)	Requirements	
					Land (million ha)	Water (BCM)
Wheat	138	28.56	0.50	2.10	13.60	68.00
Rice	23	4.76	1.17	1.83	2.60	30.43
Maize	10	2.07	1.00	0.60	3.45	34.50
Pulses	7	1.45	0.37	0.58	2.50	9.25
Other grains	5	1.04	0.30	0.52	2.00	6.00
Fruits	59	12.21	2.00	12.00	1.02	20.35
Vegetables	45	9.32	1.00	7.50	1.24	12.43
Sugarcane	338	69.97	1.30	46.90	1.49	19.40
Oil seeds	68	14.08	0.40	1.00	14.08	56.32
Cotton	17	3.52	0.80	0.60	5.87	46.93
Total		**146.98**			**47.85**	**303.60**

4.5.2. Domestic requirements

The population of Pakistan is expected to reach 207 million by the year 2025. About 50% of the projected population would be living in urban areas. Considering the increasing level of globalization, improvement in lifestyles, and removal of trade barriers, the water requirements are bound to increase. We have assumed per capita daily water demand at 100 lpcd and 220 lpcd for the rural and urban population respectively. Using the assumptions discussed above, the total water requirement for the domestic sector works out to about 12.2 BCM per year.

4.5.3. Industrial Requirements

At present, the industrial water demand is 1.75 BCM/year, which is about half of the total water requirement of the domestic sector. In the absence of data on industrial water requirements in the year 2025, using a similar assumption, i.e. 50% of domestic water requirement, the projected industrial water requirement in the year 2025 has been taken as 6.1 BCM/year.

4.5.4 Other Uses

In the absence of data on water requirements for other uses including commercial, livestock, and ecology, a figure of 5% of the total water requirement for other sectors has been taken. Thus, the water requirement for other uses has been assumed as 16.1 BCM/year.

4.5.5. Total Water Demand

The total water demand in the year 2025 is estimated at 338 BCM/year, as shown in **Table 48**.

Table 48
Total water demand in Pakistan in the year 2025

S. No.	**Sector**	**Demand (BCM/year)**
1.	Irrigation	303.6
2.	Domestic	12.1
3.	Industrial	6.1
4.	Others*	16.1
	Total	337.9

Note: *** *Assuming 5% of the total demand of the other three sectors.*

4.5.6. Water Availability in the Year 2025

Surface water is a renewal but finite, while ground water is a secondary resource derived from surface water infiltration. Pakistan has reached the limits of surface and ground water abstraction, and water availability in 2025 will not exceed by much the current availability of 236 BCM. Thus there will be a “shortfall” of around 100 BCM against the extrapolated demand. The critical life support and other services provided by water will have to be met by increasing productivity and conservation.

CHAPTER 5: DEMAND - SUPPLY GAPS

5.1 The Aggregate Gaps

The demand-supply gap for each of the four WASSA countries discussed in the earlier sections is summarized below in Table 49.

Table 49
Water "Requirements" and Gaps (in BCM) in the WASSA countries, 2025

Country	Total Water Required	Projected Water Availability	Projected Water Surplus /deficit (Gap)
India	1,060	1,086	(+) 26
Pakistan	335	236	(-)102*
Bangladesh	48	1,181	(+)1,133
Nepal	60	237	(+)177

** Includes flows at rim stations*

Note: The above figures exclude non- consumptive uses and rain fed agriculture use for the sake of maintaining uniformity with all four countries of the region

5.2 Case Studies: Gap Analyses

Before identifying approaches to meeting the projected demand-supply gap for the time frame of 2025, it is useful to examine what options are available, and what approaches have been taken in other parts of the world to address such situations. In this context, case studies of demand-supply gap analysis, one in the most water stressed basin of the Sabarmati on the west Coast of India, a study of the large urban centres of China and Denver, and one in the Indus basin in Pakistan are presented in **Annexes 1, 2 & 3** respectively. In Bangladesh, the NWMP has also identified the key constraints and addressed the Plan to tackle the issues of concern. The key findings of the studies that are relevant to meeting the demand -supply gap in the fours countries of the region are discussed below.

5.2.1 Sabarmati Case study

An analysis (Dinesh et al, 1999) of the scarce conditions in the Sabarmati basin, which is the most water - stressed basin now in India, was attempted by the Vikram Sarabhai Centre for Development Interaction (VIKSAT) situated at Ahmedabad, India. The broad details of this study are given in **Annex 1**, since it provides many approaches that could be adopted for other basins in the country to meet the supply - demand gap.

In this study, the Water Evaluation and Planning (WEAP) modeling system has been adopted to evaluate local water management options. Alternatives analyzed are: i) local recharge using excess runoff within the basin, ii) adoption of efficient water use practices and reduced conveyance losses, iii) conjunctive management using imported water supplies, and iv) a combination of efficient water use and local recharge activities. The studies show that:

a) The gap between demand and supply can be bridged only marginally by local recharge - less than 1% by 2020 and 2050;
b) Interventions of efficient water use technologies of drips, sprinklers, and efficient conveyance system in the fields, and in the domestic and industrial sectors, could reduce the gap between supply and demand by 324 MCM and 1,005 MCM in 2020 and 2050 respectively, i.e. roughly one-third of the gap projected for 2020, and more than half that for 2050; and
c) Recharge of surplus monsoon flows diverted from the Sardar Sarovar reservoir (Narmada Canal) would increase by 157 BCM and 156 BCM by 2020 and 2050 respectively - a significant contribution to reducing water scarcity.

The WEAP model studies indicate the most effective avenues for addressing water scarcity options that require changes in water use as a) the level of individual users (that is, adoption of efficient water use technologies and practices); b) the level of systems (that is, improved conveyance system); and c) the level of regions (that is, aquifers for conjunctive management).

In the final analysis, it has been inferred that a combination approach, namely, demand side management allied with conjunctive management of locally available and imported surface and ground water supplies, has the best prospect for maximizing the potential to address water scarcity problems on a sustainable basis. It has been observed that the existing organizations dealing with water need to receive greater involvement of all the stakeholders throughout the planning, implementing and monitoring stages.

5.2.2 North China Case study

Another example of a gap analysis was the one carried out by the State Science and Technology Commission of China (SSTCC), in cooperation with the East-West Center (EWC), in 1985-1987. It was a joint study of water management options in the growing North China Plain cities of Beijing and Tianjin, using a demand-supply gap analysis with a short-term time horizon of one year. The methodology used was a refinement and adaptation to Asian developing nation conditions of one developed for Denver in the early 1980s by Milliken and Taylor (1981). A more recent gap-oriented analysis was of the Jordan by Aaron Wolf (1995). These approaches contain some features, including definition of supply, means of comparing approaches and incorporation of uncertainty that may be worth considering in defining future approaches. The summary of this study is provided in **Annex 2**.

While the general approach of these studies can provide guidance to the WASSA study, it is important to note some differences at the specific level. One is *scope*. A limiting feature of two of these studies (Denver and Beijing) is that they are designed for urban areas, not entire countries, where agricultural uses dominate and industrial uses are often quite insignificant, at least in terms of quantity. Hence the quantities of water involved are much more modest and, presumably, more capable of planned management. The administrative boundaries of Chinese cities include a significant rural hinterland, but options considered in Beijing centered on the reduction of irrigation water use for reallocation to urban uses rather than ensuring food security. It should be noted, however, that it was possible in Beijing to reduce irrigation water use and farmed area while maintaining or even increasing farm output and incomes, and increasing total farmer income even more through greater off-farm employment alternatives. Only after a drastic decline in farm labor in the middle 1990s did grain output begin to decline.

Where the water economy is dominated by agriculture, as in the WASSA countries, the kind of gap analysis used for urban and semi-urban areas, or even the Jordan valley, may understate the importance of high value water uses outside of irrigation, especially when food security arguments are used to continue to claim priority for irrigated agriculture. Of course, this “non-urban bias” would be mitigated by appropriate benefit-cost analysis or, as in the WASSA reports, by common sense. The *range of alternatives* that need to be covered in the WASSA region is probably broader with more complex inter-linkages in the national and basin contexts. Complexities are likely to multiply when the four-country area is viewed as a single region. At the same time, the *institutional infrastructure* for certain policies, especially those aimed at demand management, is likely to be more highly developed in urban areas such as Denver and Beijing, or in countries such as Israel. These two factors make effective action more challenging in the WASSA region, but no less necessary.

5.2.3 Pakistan case study

An Indus Basin model that forecasts *Rabi* (winter) water demand over time (1993 – 2017) against anticipated supplies has been developed by Qutub (1992). With no water development or conservation, an increasing shortfall is demonstrated that varies as a function of the rate of depletion of the Tarbela reservoir. The model then sequentially introduces a range of water conservation and development options along with their costs. These are a) Land leveling and forming, b) Watercourse renovation, c) Lining of distributaries d) Canal earthwork rehabilitation, e) Lining of canals passing through saline tracts, f) Watershed protection, and g) Construction of a large new storage.

The model then allows posing the question whether the first six water saving activities can compensate for the increase in water demand and decrease in dry season water availability if they were to receive water sector funding that would otherwise go toward a large storage reservoir. The broad findings are as follows:

Watercourse renovation is one of the most cost-effective programs but will still fall short of the additional *rabi* demand and, as such, other conjunctive programs are required. The lining of distributaries is the next most cost-effective program. Because land leveling or forming has to be repeated every three to five years, it is not a particularly cost-effective option. Progressive farmers may see it as an adjunct program for private initiative. Limiting *rabi* shortages to current levels requires – in addition to on-going programs – the lining of “saline” canals at an additional cost or the construction of interceptor drains along the main canals or demand side management, entailing research and extension of low water using crops, and varieties. The construction of a large storage dam alone will not stop *rabi* water shortages. It is not a standalone option when considered over a 25 years timeframe.

One major limitation of the model is that it treats the Indus irrigated plains as a single entity suffering current and increasing *rabi* water shortages. It ignores the possibility of simultaneous water shortages and surpluses in certain agro-ecological zones and their constituent fresh and saline groundwater sub-zones. This defect could be overcome by working with the much the more detailed (2500 equations) Indus Basin Model (Revised) of the World Bank and WAPDA (World Bank, 1990)). Awareness of a such a low-cost “win-win” solution based on water trading between agro-ecological zones would however need foresight and political will to implement.

5.2.4 Bangladesh Policy Planning Study

In Bangladesh, committing to the NWMP, with a time schedule, is expected to remove uncertainties in meeting demand supply gaps. The main policy gap is the absence of a land use, or physical planning, policy. In addition to its implications for agriculture, not least as regards brackish water aquaculture, the lack of such a policy has a very tangible effect on urban issues in the water sector, particularly for those who are entrusted with preparing detailed water services plans. A key element of this will be the provision of bulk water supply and mains sewerage. These are discrete and major investments, which can be far more efficiently planned with a clear understanding of where the urban population will be situated, and in what densities. In the absence of this information, the National Water

Management Plan had, therefore, to take a broad-brush approach to this issue. It is certainly to be hoped that this policy gap will be filled by the time of the first NWMP update.

There are three areas of prediction that are important – the first of which is a demographic trend. These predict estimates of future demand for water, directly in the case of water supply and sanitation services, and indirectly in terms of food production requirements and the demand for irrigation. In general, these do not affect short-term decisions and therefore their precision, in the context of a rolling plan, is not a matter of substantial importance now. However, it does affect bulk water supply provisions. The plan, as now cast, foresees investment in this area in 10-year blocks.

The second prediction is of economic growth. This is important primarily as it will affect the ability of the government to fund the wide range of programs envisaged over the next twenty-five years and beyond. There are two considerations to this. Firstly, the plan, in line with policy, envisages the opening up of new financing sources. Provided the government is successful in doing this, the new sources will reduce the dependence of development investment upon direct government funding. The second consideration is that, given the imperative of providing adequate water supply and sanitation services (which are the areas most appropriate for the new sources of capital funding), the other major investments envisaged are essentially those related to the development and management of the main river systems. By inference, therefore, the impact of lower economic growth is most likely to be reflected in a slowing of investment in the Main River sub-sector.

The third important area of prediction is what happens to agriculture over the next 25 years. It is evident that total rice production (the biggest water consumer) essentially follows domestic demand, and that an increasing population will drive this up. Given also a trend towards diminishing land available to agriculture, and a marked downward trend in agricultural land per capita, the pressure to increase agricultural production will be considerable. At issue is the extent to which this increased production will come from intensification through irrigation, as continues to happen today, or through internal yield increases through improved crops, husbandry and crop inputs.

The conversion to HYV, which also has been a major success over the last twenty years, is coming towards an end. There is a genuine debate over the potential for a second “green revolution” on the back of new varieties now being tested in Bangladesh. The plan assumes that all the area that can be irrigated will eventually become irrigated, which may be an overestimate, but at least on this basis removes dry season water as a constraint to agriculture. Clearly the situation needs to be monitored for future plan updates, as it may have a bearing on the efficacy of long-term public sector investments in irrigation.

5.3 Gap analysis

Despite their limitations, the above case studies have some possible lessons for the current WASSA gap analyses. These include (1) The definition of supply; (2) The treatment of uncertainty; and (3) The comparison of alternatives within a common frame.

5.3.1 Definition of supply

The supply could be defined as 'making water available on demand at a cost for services rendered'. The presentation of a gap, as in Table 49, is only an indicator based on total projected water availability within a nation’s borders, regardless of whether it can be tapped or not with current projects and programs, and is therefore of limited utility. It does provide a sort of upper limit to supply development initiatives, but, taken at face value, it indicates that there is no overall 2025 gap (defined as excess demand) likely in any of the four countries except Pakistan. The water requirement presented places India’s demand on the brink of an absolute gap, but not quite there. Therefore, if we look at the national aggregate level, using total potential supply, it seems that little needs to be done!

Tthe subsequent analyses in the WASSA reports do not rest on this implication. Large areas within nations, especially India (notably the basins of the East flowing rivers of Cauvery, Pennar and Pennar and Kanyakumari in the south, the west flowing rivers of Sabarmati in Gujarat, and Saurashtra and Kutch rivers including Luni in southern

Rajasthan, where per capita annual water supply is below 1000 cu.m. and in many if not most urban areas throughout the region), are already at this limit. Others, such as Bangladesh, are at risk from seasonal shortages at critical demand periods, especially for agriculture. Still others suffer gaps due to the lack of conveyance, storage and treatment facilities rather than the absence of accessible water.

The water demand and supply on a national aggregate basis show a surplus situation in Nepal. However, the temporal and spatial variations of the available water supply and demand cause imbalances or "gaps" between demand and supply in the form of both deficits and surpluses of available water resources. The pattern of demand for irrigation or hydro-power on a daily or seasonal basis may not be according to the pattern of supply. One other important factor in identifying the gaps is also the occurrence of extreme events -- either very high flows or floods, or very low flows or droughts. These extreme conditions, quite natural in the hydrological cycles, can be a cause for great concerns to human needs. Measures to cope with such extreme events have to be made.

As irrigation is the major consumptive demand, we could categorize the various river basins into two categories -- surplus and dry basins. The "surplus basins" are the ones where the overall average supply exceeds the potential demand (mainly consumptive uses). Koshi, Gandaki, Karnali and Mahakali can be said to be the surplus basins. The "dry basins" are the ones where the average supply barely meets the potential demand of the basin. Kankai, Kamala, Bagmati, Westi Rapti, and Babai fall under this category. However, due to the temporal and spatial variations of supply and demand, these basins may be considered self-sufficient only with some flow regulating structure like storage reservoirs, groundwater supplement, and/or interbasin transfer. Even in the "surplus" basins, any meaningful water resources utilization without regulating storage reservoirs would be limited. A case in point is the fact that 85% of Nepal's estimated hydropower potential would have to come from multipurpose storage projects.

5.3.2 Specific Gaps

This section briefly considers some specific “gaps,” or pressing needs, as identified in the WASSA studies and Water Visions Reports.

Gap in agricultural production

Irrigated agriculture is by far the largest consumptive use sector in the four countries, taking over 80% of the water in India (about 501 BCM out of 690 BCM), over 90% in Bangladesh and Pakistan, and over 96% in Nepal at present (24 BCM out of 25 BCM). It may be expected to retain its dominance, although with some decline in relative importance over time.

A critical issue, and one that is difficult to resolve, is whether and to what degree agricultural water use should continue to increase, especially if the amount demanded as against realistic needs in countries or areas within countries begins to approach the limit of sustainable supply level. Fortunately that is not the case, at least within the WASSA time frame up to 2025. Arguments in favor of continued increase center upon increases in population, often accompanied by increases in living standards, especially for the poor (a key element of the India Water Vision); a view that increased application of water to irrigation, especially by expanding the area under irrigation, are essential to increasing food production; and an assertion of the need to maintain food security at a national level. Arguments against continued increases in agricultural water use question one or more of these elements, especially the assumptions that more food needs more water (not true generally in recent years), and that food security should play a dominant role in policy. They also point to the technical and economic inefficiencies of current water use applications in agriculture, and to the potential for using technical, economic or institutional measures to improve farm output based mostly or entirely on possible increases in yield per unit water applied.

Returns from irrigation.

It is clear that yields on irrigated land are much higher than those from dry land. For example, in India, it is estimated (IWP, July 1999) that irrigated agriculture, with almost

50% of the Gross Cropped Area (GCA), produces more than 75% of the total food grains and about 95% of the non-food grain output of the country. Nonetheless, food production has increased to meet local demand in most highly irrigated countries in recent years without a commensurate expansion in the area brought under irrigation – via new agronomic practices, seeds, and higher multiple cropping ratios.

It is an open question as to whether this trend will or can continue—in economic jargon, whether technical change is endogenous (will change in response to demand) or exogenous (depends primarily on factors other than demand). Of particular concern is the effect of non-point source residuals of yield-enhancing farm chemicals and fertilizer on the *quality* of drainage water subsequently used for non-agricultural uses, including storage in reservoirs and lakes.

There are certainly indications that water use efficiency could be increased considerably, although measures of inefficiency are often presented in technical rather than economic or basin terms – e.g., water lost from a canal system through evaporation and seepage. Sometimes, the cost of improving the technical efficiency of water delivery, e.g., via lining, may not be economically worthwhile, and by reducing reusable seepage into groundwater, it may not increase the total delivery efficiency as much as projected (Secler, 1996). From an institutional perspective, of course, improving project efficiency may make it easier to monitor, control and assess payment for water delivery.

Food security

Food security is much - used but rarely well-defined concept. It could mean national self-sufficiency in food grains, or at least that grain production should keep pace with population and income growth (possibly involving greater indirect consumption of food grains). Or it could refer to achieving a balance between exports and imports of foodstuffs. It might mean reducing national exposure to possible predations by large international grain trading corporations. Or it might, but rarely does, consist in minimizing the total risk of domestic and international price and production fluctuations over time.

A common assumption is that food security should be considered at the national level. It may also be useful to look at it from the standpoint of the interest groups (stakeholders) affected. For whom is food security to be ensured? Is it for the non-producing consumer, the subsistence farmer, or the commercial farmer? From a producers' point of view, especially those who operate on world markets, a big problem is the secular decline in the real price for grain over the past quarter century.

It is necessary to see what irrigation water is actually used for. If food security is a thinly disguised cover for continuing subsidies of cheap water to local elites to produce subsidized commercial crops or non-agricultural produce, it should not be a basis for policy. For example, in Pakistan, a significant portion of irrigation water goes to sugar production. If water and production subsidies are propping this up, the best policy to ensure greater food production may be to remove those subsidies. On the other hand, where food security focuses unduly on grain, it may inhibit diversification (as in China before 1979).

Gap in water quality

As noted previously, for most countries, the greatest gap in terms of need may be in terms of quality rather than quantity. This applies particularly to drinking water and sanitation, both rural and urban**.** Since other studies have been undertaken on water quality in South Asia, the WASSA project did not address this issue.

Gap in electricity demand and supply

In some places, the greatest developmental needs may be in non-consumptive uses of water. This applies in particular to Nepal, where the development of hydropower is a necessity in view of the limited alternatives such as thermal power. There are important international implications associated with Nepal's development of hydropower, and these are discussed in the WASSA project volume on "Water-related Conflicts between Countries".

Gap in human resources

It is widely agreed that the human element is a principal factor in inefficiency, although it is hard to quantify. Aspects include inadequate training, poor and/or unstable pay to water delivery and maintenance professionals, susceptibility to bribery or threat, and the lack of organized user groups with the capacity to distribute water, pay bills, and negotiate with higher levels. Some of these gaps can be addressed with education and awareness training, but many of them stem from more fundamental governance problems that have accumulated over the years.

Gap in the legal framework

Property and user rights in South Asia are often unclear. Laws or administrative rules and habits may inhibit voluntary transfers from low value uses of water to high value ones. They may place obstacles in the way of water user organizations and the financial self-sufficiency of water distributors. Sometimes adequate laws are in place, but their implementation is inadequate. This is often noted and much criticized, but the root causes are rarely (but increasingly) analyzed. Related gaps are in “governance” and institutional reform, including greater participation. Often citations of these gaps appear to be at a very general, almost rhetorical level, with little attention to the costs (including transaction and transition costs) and feasibility of change, or how specifically to carry it out.

CHAPTER 6: APPROACHES TO MEETING THE DEMAND-SUPPLY GAPS

6.1 General

There is a general tendency to overestimate future demand. This is a natural reflection of a "no regret" syndrome typical of most planners. Nonetheless, some river basins in India are clearly headed towards a gap between "demand" and "resource" in the next two decades unless action is taken. This is directly attributable to the large spatial variation in rainfall across the country. The temporal variation further exacerbates the gap in some of these basins. However, the situation is manageable if surface and ground water are handled as a unitary resource and managed scientifically.

In Pakistan, which is experiencing the fastest rate of population growth among the countries of South Asia and is also the most water-stressed country among them, renewable water resources have been exploited to the limit while remaining a largely agrarian economy. The country will have to adapt to water scarcity in the coming decades. Technical innovations in the water sector and related innovations in governance are essential for meeting the needs of the people and ensuring the security of their livelihoods. These innovations could also ease the transition to a sustainable industrial economy.

Given the above context, and the analysis of a few specific gaps discussed in the previous chapter, what is really critical is the "gap" between "demand" and "supply" at the consumer level. This gap has more to do with administering water than with its availability as a natural resource, at least in the WASSA time frame (up to 2025). The specific approaches towards reduction of this gap could be broadly categorized under a four level strategy envisaged to achieve sustainable development. These are discussed below:

- Governance & Institutional innovations that enable the new technologies to be widely adopted and applied - Integrated Water Resource Management (IWRM), private sector participation, and investments.
- Increasing the efficiency of water use in all sectors, particularly irrigated agriculture and domestic & Industrial water supply, including technology

improvements and participatory management. These would be at the micro- (farmed field, household), meso- (distributary, watercourse) and macro- (river basin, canal command, and urban district) scales. Measures to improve efficiency include: Introducing economic incentives, Operation and Maintenance (O&M) funding and related policies, revenue generation, storages (Surface water - major & minor, Ground water), Diversion schemes, Ran-fed agriculture, Renovation and Modernization of Projects, and the conjunctive use of surface and ground water;

- Knowledge of innovations that enable the institutional reforms to happen such as sprinkler and drip irrigation, and Interbasin water transfers;
- Reinforcement of the values for conservation and for community rights and responsibilities that drive the acquisition and application of knowledge, such as watershed management, catchment area treatment and soil conservation, and defined systems of water rights;

6.2 Governance - Integrated Water Resource Management (IWRM)

Assessment of the gaps should be carried out on the basis of river basins so that options for meeting the gaps can be rationally and optimally evaluated. In water resources planning and management, river basins are normally treated as fundamental planning units because water and land resources of a river basin are inter-related and form a unit. River basin planning and management thus recognizes the existence of water use conflicts and trade-offs and hence ensures that the inter-sectoral (among various sectors like irrigation, water supply, hydropower, flood control, recreation, and environmental requirements) and inter-regional (upstream-downstream or one basin and another) allocations of water resources are optimal and rational.

The past approach of mono-disciplinary and single resources manner of development has to be replaced by a holistic and integrated approach for achieving the demand targets for the future. It could also be termed “unified management” as it focuses on integrated and comprehensive management of the resource itself e.g. integration of surface water and ground water, water quality and water quantity, resource issues, and economic and social issues. It is, therefore, essential that to foster better coordination amongst the myriad organizations dealing with water in the country and to achieve pragmatic allocation of water amongst various uses, river basin organizations (RBOs) would be a solution at state, interstate, and riparian countries levels. This will ensure that fast and optimum development takes place to meet the projections made for 2025.

6.2.1 Integrated Water Resource Management (IWRM)

The Indian National Water Policy has been evolved on the basic paradigm that "Water is a scarce and precious national resource to be planned, developed and conserved as such, and on an integrated and environmentally sound basis, keeping in view the needs of the states concerned".

The global consensus for management is also for an integrated approach of the precious and scarce resources of water and is defined as follows:

“IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.”

For IWRM to be successful, integrated river basin Planning and Management (IRBPM) is an essential prerequisite.

6.2.2 Integrated River Basin Planning and Management (IRBPM)

In the **Indian** context, the above definition of the IWRM or the RBO plan could be modified to incorporate the functions of management as follows:

“ A truly integrated, holistic macro & micro planning policy for a basin or a sub-basin would involve multi disciplinary & inter-disciplinary planning concepts and approaches for the basin or sub-basin, marrying approach & actions for land use and water use, harmonizing diverse water use on the demand side and integrating all ‘development’ from local rain water-harvesting and micro water shed development to ‘mega projects’ (and surface water and ground water) on the supply side, while at the same time fully internalizing environmental, ecological, human and social concerns, and fully associating the people concerned (‘Stake holders’) at all stages.”

Given that the river basins in India are divided by political boundaries, IRBPM may not be in the offing soon, not at least until political maturity transcends short-term concerns about electoral gains. Notwithstanding this man-maintained hurdle, there is absolutely no reason why every state cannot put into practice IRBPM and IWRM within its own political boundaries of a basin.

India's Ministry of Water Resources has taken the initiative of making this a policy issue in their National Water Policy Documents. In the document "Vision for Integrated water Resources Development and Management" released recently by the MOWR (MOWR, 2003) an "Action Plan" to implement it has been suggested. The suggested action envisages helping each major state to establish Basin Organization for a basin falling within the state. The Ministry also recognizes that what is most essential is to create trust among the states so that they do not see it as an infringement of their rights.

In **Bangladesh**, at present, there are no Authorities in the country dealing with water in an integrated basin approach. The government is in the process of evolving a suitable strategy to achieve this goal.

The National Water Resources Strategy of **Nepal** recently approved by His Majesty's Government of Nepal (WECS, 2002) has recognized and advocated the need of a "holistic, systematic approach, honoring, respecting and adhering to the principles of integrated water resources management". River basins are therefore treated as fundamental planning units in water resources planning and management for rational decision-making. The present institutional structure of HMGN for the development of water resources is at the following levels:

1. Government councils and commissions;
2. Government ministries, departments, institutes and corporations;
3. Local level.

It is recognized in **Pakistan** that there is an urgent need for integrated water resources development to ward off famine conditions beyond the year 2025.The Government of Pakistan is taking major decisions in bringing about change in the institutional framework in water sector development. In order to improve the social services and management of the natural resources and the environment, the following main reforms have been identified:

a. Redefining the roles of the public and private sectors to remove the public sector from areas and tasks that can more efficiently be performed by the private sector;
b. Restricting public expenditure and getting key public sector institutions to perform their functions in an efficient and cost effective manner;
c. Capacity building of institutions to make them ready for newly defined roles;
d. Formulating of a comprehensive national water policy to provide an appropriate framework for water resources management; and
e. Introduction of basic legislation to regulate fresh ground water.

Since there are no specific sub-basin organizations under the Indus basin, the need for RBO is yet to be defined and debated. However, the need to take up a massive national drainage program based on a basin concept is on the anvil. The current institutional reforms in the Water and Power Development Authority (WAPDA), the provinces and the coordination agencies are all project specific and do not address the basin concept.

With increasing complexity and uncertainty, sectoral laws and departmental structures in Pakistan are considered no longer sufficient to resolve conflicts. In the future, the promotion of organized co-operation between actors is needed, if planning is to be able to deal with growing uncertainties. Therefore, horizontal structures will become more important than vertical structures, and decentralized decision-making more important than centralized decision-making. The following are some important criteria to consider when promoting new horizontal structures.

- Plans and decision-making should take place at the lowest possible level. Complexities and uncertainties of implementation can only be understood by looking from a small or from the bottom-up/end-user perspective;
- To handle actor conflicts, legal arrangements should be made to establish places of dialogue;
- Provision should be made either by laws, contracts, or incentives to enable horizontal structures to take decisions; and
- Provisions should be made so that decisions taken by horizontal structures are followed up and implemented.

It is, therefore, advocated that water-centered education and training, from examples through the Global and Pakistan Water Partnerships, could help remove professional blinkers. Learning and sharing the use of integrated water management tools would be central to this effort.

6.2.3 River Basin Organizations

India's experience in this field is highly relevant to the region and is therefore being elaborated in detail. India launched the Basin approach of management as early as 1948 through an Act of the Parliament to set up the Damodar Valley Corporation (DVC). The success story of DVC'S river basin approach was not replicated in other river basins even though a specific Act, called the River Boards Act, 1956 was promulgated to address interstate management issues.

The main reason for the lack of a follow up is that the states, who had the unquestioned right over the subject of water, would not easily relent from their perceived rights of their share of water in the interstate river basins. This resulted in innumerable water disputes on almost all the interstate river basins in the country, and necessitated the enactment of the Interstate Water Disputes Act, 1956 under which tribunals were set up to adjudicate on the water disputes in the interstate river basins. However, the tribunals have been set up sparingly, and for only five interstate river basins. One of these, the Ravi-Beas tribunal, is yet to give its award, while the Krishna Tribunal Award's validity has expired leading to fresh disputes.

The legal changes required in the Constitution and the approach to resolving interstate water issues have been discussed in detail in another Volume in the WASSA project Reports, that deals with water sharing conflicts within countries. However, since water has historically been subject under the jurisdiction of the states, any changes in the constitutional provisions to bring in significant changes to set up RBOs within the control of the central government may be difficult.

Even though the River Board Act is a statute, its use for the purpose of basin planning of interstate rivers has not materialized due to Act being advisory. Consequently, no river boards have been established so far. Some bodies have been established (either to deal with specific projects on interstate rivers, or for the preparation of the master plans) through executive actions (e.g. the Bansagar Control Board, the Upper Yamuna River Board, the Ganga Flood Control Commission) or through specific legislation by Parliament independent of River Boards Act (e.g. the Betwa Board, the Brahmaputra Board). Even these Boards could be set up only with the consent of the concerned states.

The need for RBOs for interstate rivers has been extensively discussed at the government, non-government and political levels in the country. While there is no disagreement on the need for RBOs, the doubts are mainly related to their powers and functions. The political level Parliamentary Consultative Committee Reddy (1997) has drawn up comprehensive lists of desirable functions and powers of the RBOs. These are:

I. To cause hydrological and geo-hydrological data to be collected by various agencies and to complete and analyze, for each basin, these data and to determine from time to time the volume of water flowing in the main river and its tributaries during a year, taking into account withdrawals for various uses;

II. To prepare basin plans, i.e. to prepare and keep up-to-date a comprehensive plan for water and related development within the basin, aiming at optimal use of surface and ground waters;

III. To serve as the principal coordinating agency for plans for water and related land development;

IV. To develop ground water management policies and schedules for integrated operation of the surface and ground water systems;

V. To develop river management policies to regulate the flow in river channels from time to time;

VI. To oversee plans for catchment area treatment, watershed management, rehabilitation of affected population and for the water-related aspects of conservation of the environment;

VII. To have overall coordination and direction in respect of measures undertaken in the interstate river valleys for the purpose of:

    - Conservation, control and optimum utilization of the water resources of the interstate river;
    - Promotion and integrated operation of projects for various uses like irrigation, water supply, industries, hydroelectric power, flood control, navigation, recreation and fisheries;
    - Promotion of measures for the prevention of water-logging and salinity;
    - Promotion of measures necessary for conservation and upgrading the quality of the surface and ground water;

- Other matters as may be required.

VIII. To monitor the progress of major projects to ensure that due regard is given to safety of structures and environmental protection measures;

IX. To formulate regulations for water management, including development of cropping pattern, integrated operation of reservoirs and water budgeting in the river basin;

X. Any other matter that is supplemental, incidental or consequential to any of the above functions.

The powers to be provided to such RBOs and their organizational structure were also defined. It was strongly suggested that the RBO be established and maintained by the Government of India, and operated with the cooperation of the basin state governments. A Review Authority at the Ministers' level was also suggested. However, the prelude to the above recommendations of the Consultative Committee introduces a politico-legal situation that cannot be wished away or bypassed. The preface says: "An equitable distribution of water resources between various users bristles with difficulties, but due weightage has to be given to each of the various priorities/considerations in apportioning shares. Economic development and activities including agricultural, industrial and urban development should be planned in the river basin with due regard to the interstate awards/agreements and water availability. In other words, a water zoning of the basin and socio-economic activities should be guided and regulated by RBOs in accordance with such zoning."

In the light of the above, the issues regarding changes required in Article 262 of the constitution and Interstate Water Disputes Act have been elaborately discussed in the WASSA volume dealing with water sharing conflicts within countries. After detailed analysis of all issues, it has been suggested that river basin organizations should be set up for ensuring integrated development of river basins. This could be better done under a separate Act in consonance with the revision of the ISWD Act, which shall take cognizance of the Stakeholders participation."

Keeping in view the recommendations of the Consultative Committee, a phased process is suggested for the RBOs to achieve integrated basin development. These phases comprise a legal and regulatory framework, state level and interstate organizations, and implementation and monitoring. Such RBOs could also be involved with negotiation of Interstate water disputes, before the dispute is referred to the tribunal for adjudication. There could be no bar on the Union Government setting up multi-disciplinary RBOs by an executive order. To start with, RBOs may collect and analyze data and prepare plans for integrated river basin development for optimal utilization of the water with appropriate sectoral allocations. In the next phase, RBOs could assist the tribunals, and finally they could be authorized to monitor the implementation of development plans by the State RBOs. An organizational structure based on this process in enclosed at **Figure 12**, which fully takes note of the Consultative Committee's recommendations.

There are several major river boards or commissions existing in the states and at the central government level, which are at present functioning as single purpose or multipurpose organizations, either for planning or regulation or monitoring or implementation. Some of these organizations can be modified with a few structural changes and enabling laws to function as river basin authorities.

Given the country's present political system, adjudication by tribunals appears to be still the best mechanism for solving interstate water sharing conflicts. The mechanism can be streamlined, as already discussed in an earlier section. Beyond the adjudication mechanism, every state shall have to organize state level RBOs for effective IWRM if the water vision 2025 has to have even a modicum chance of success. The recently approved (MOWR, 2002) revised National Water Policy 2002, states, "The scope and powers of River Basin organizations shall be decided by the basin states themselves."

The format considered for India may also be quite useful for the formulation of RBOs in other countries of the region, For example:

a) A Mahakali River Commission/Organization (Indo-Nepal joint Board) or Kosi River Basin Organization/Authority or Gandak River Basin Authority or Organization, in Nepal;
b) A Ganges Basin Authority in Bangladesh; and
c) An Upper Indus Basin organization and a Lower Indus Basin organization in Pakistan.

The International Network of Basin Organizations (INBO) was created in May 1994 with 134 member organizations in 51 countries with the following objectives:

- To build national, regional and international links between existing, incipient and embryo River Basin Organizations or between administration preparing reforms based on river basin management;
- To increase understanding on river basin management including possible organizational design, management tools and process leading to their definition and implementation;
- To support processes engaged in basins where there is a felt need for improvement of water resources management;
- To support dialog and collaboration between river basin organizations and the civil society.

The Global Water Partnership (GWP), an independent network, has also taken the international initiative in this field. GWP is open to national governments, research and non-profit organizations, NGO’s, UN agencies, multilateral banks, private companies, and other stakeholders involved in water resources management. Out of the nine regional outlets of GWP, the South Asia outlet called the South Asia Technical Advisory Committee (SASTAC) has identified Sri Lanka as the nodal country in the Region to take the lead in RBM. SASTAC has designated Mahaweli of Sri Lanka as the co-coordinating Agency for setting up and managing the network SASNET-RBO.

Following this, a Regional Workshop on Sustainable River Basin Management held in Colombo in July 2000 reached consensus on a set of recommendations for promoting RBM and RBO in South Asia as a means to achieve IWRM in the medium to long term. The International Conference on Sustainable Development of Water Resources, held in New Delhi in November 2000, elaborated further and reaffirmed South Asia's interest in RBM. In the Delhi Declaration of the Conference, the emphasis on River Basin Organization has the following suggestions.

- There is need for creation of river basin organizations (RBO). States should be encouraged to form river basin organizations and the affected people should be associated with these boards. In the course of time, the water users associations could also be integrated with river basin organizations;
- Five phases of action might be taken for the development of river basin organizations. These comprise of legal and regularity framework, state level and inter-state organizations and implementation and monitoring plan;
- There is no single model for RBO, which can be applied in all types of situations. Instead, a range of models may be developed to suit specific situations;
- To start with, in some cases, instead of the entire basin, it may be advisable to look into a compact part as a pilot area, so that the integration of social, technical and environmental aspects can become feasible;
- Projects pertaining to inter - basin transfer of water should be entrusted to river basin organizations.

Partner RBM organizations (Bangladesh, India, Nepal, Pakistan and Sri Lanka) met in Sri Lanka in January 2002 to review the policy of implementation of river basin organizations in the region and see how to help it. The Mahaweli Authority of Sri Lanka (a public body in the process of evolving from a development project authority to a river basin organization) has agreed to be the pilot site for basin management in the region and to serve as host of the SASNET-RBO secretariat. This meeting has evolved a work plan of three and half years in line with the Action Plan (AP) being developed by GWP and INBO.

Each country in South Asia will identify 2 basins initially to develop partnerships and management systems.

6.3 Efficient water use

The major water use in India is for agriculture, accounting for nearly 83% of consumptive water use -irrigation dominating the scene. Domestic water use accounts for nearly 7-8% (GOI, NICWRDP, 1999). Both these sectors waste water and need very effective water use efficiency techniques, if the demand and supply gaps are to be met along with the creation of new infrastructure. These are discussed below.

6.3.1 Irrigation and agriculture sectors

Inefficiency of management and operation of the irrigation system is well recognized in India. The productivity of Indian agriculture is low with irrigated yields ranging from around 1.5 tons/ha to 3 tons/ha of cereal crops, as compared to an achievable target of 4 tons/ha. The major thrust, therefore, is to increase irrigation water efficiency i.e. to maximize the value per unit of water than per unit of land, since the land for irrigation is limited. Water use efficiency could be defined as the increase in the water content at the root zone following irrigation, expressed as a fraction of the total quantity of water applied to the irrigated area. In simple terms, it could be defined as the ratio of volume of water delivered to the volume of water received. It is estimated that the present irrigation efficiency is between 35% and 40% in all four countries of the region (Planning Commission, 1999). Improving irrigation efficiency is at the top of any future Vision to achieve food production to match the population growth.

It is estimated that with a 10% increase in the present level of water use efficiency in irrigation projects in India, an additional 14 M.ha. area could be brought under irrigation from the existing irrigation capacities (Planning Commission, 1999). Hence one of the basic approaches to meet the supply demand gap is to increase irrigation efficiencies not only in existing projects but also planning & attaining it in new schemes taken up for implementation. This is also possible in the existing projects through modernization and upgrading to realize optimum benefits on the one hand and mitigate the significant side effects like water-logging on the other.

In Bangladesh, increasing dry-season water scarcity is a distinct possibility. Hence, efforts to raise water-use-efficiency – especially in irrigation – should be an essential demand management approach. The National Water Policy (MOWR, 2002) lays special emphasis on measures to increase efficiency of water use in irrigation. Such measures could include drainage water recycling, rotational irrigation, adoption of water-conserving crop technology, conjunctive use of surface and ground water, and better management of canals to reduce wastage. For household use, the practice of the simple, but effective, means of rainwater harvesting may be encouraged as an indigenous conservation measures.

Some of the major problems in Pakistan include delayed sowing, unleveled fields, poor cultural practices, and the use of conventional technologies in rice growing areas and the cotton belt. Eliminating some of these constraints causing low water productivity can result in a considerable reduction in water wastage. It is anticipated that a considerable amount of water can be saved with the introduction of mechanical transplantation (for rice cultivation), promotion of zero tillage technology (for wheat cultivation in paddy areas to curtail time dependent yield losses, furrow-bed-irrigation system (for cotton/row crops cultivation), and introduction of precision land leveling facilities. An additional benefit would be increased productivity. With the combination of mechanical rice transplanting and laser land leveling technologies, it is possible to transplant seedlings at a uniform spacing on zero leveled fields, and thus obtain optimum plant population per unit of land (Gill, 2000).

A study carried out by the ICID (MOWR, 2001) from data available for 29 countries has identified the following as the reasons for low values of irrigation efficiencies, which is true for all the four countries addressed in the WASSA project:

- Excessive losses in conveyance and distribution systems due to leakage, seepage, improper operation and evaporation;

- Under the present system, inequity and indiscipline prevail; The upper reaches of rivers take a larger share and the shortages are passed on to the lower reaches. The methods of allocation and distribution are causative factors in this situation;
- The inadequate communication system in operation, inadequate monitoring and evaluation, and the creation of ponds in water channels aggravate the problem;
- Participatory irrigation management is lacking.

6.3.2. Approaches to improving Irrigation efficiency

The factors to be considered for improving irrigation efficiency can be divided into physical aspects, agronomic aspects, and socio- economic aspects.

a. Physical aspects

The physical aspects would involve:

- Maintenance of distribution network: Lining of canals has contributed to increases in irrigation efficiency and in area under irrigation. In Pakistan, it has been estimated that about 30% of water could be saved annually by lining the watercourses. India also has a similar experience;
- Experience also dictates that lining be limited to a few problem reaches. The advantages of lining need proper evaluation in the context of total surface and ground water system performance. The extent of conveyance losses and their contributions to ground water from different components of canal distribution systems (main canal, distributaries & field channels) are different. Hence the cost effectiveness of lining of various components, individually and in combinations, needs careful assessment for deciding the extent of the lining. Consideration must be given to energy saving, saving in cost of additional ground water facilities, and ease of maintenance. An important factor is the possibility of transferring wet season water from dry season use through pore pressure storage etc., by adopting selective lining practices;
- Remove control structures like cross - regulators and head regulators in the secondary system, and replace them with proportionate distribution systems (volumetric distribution of flow). This will ensure that any reduction in the flow

in the main canal will automatically be taken care of and there will be proportionate reduction in the secondary system;

- The reservoir operation schedule should be dovetailed to match the water demand in the command area when two or more reservoirs are to be operated in tandem;
- On-farm development under the command area development program for improved water distribution through the construction of field channels below the outlets in the distributaries is essential;
- Field to field irrigation in basins results in considerable loss of water by way of surface evaporation, which could be avoided by practicing channel to field irrigation through adopting a common irrigator;
- Adopting rotational water supply based on the water demand of crops and on water availability can increase the equity of water distribution as well as the efficiency of its use at the farm level;
- Conjunctive use of surface water and ground water would provide increased efficiency of water resources and also provide additional water, increase the intensity of irrigation, and enhance the availability of water in the lower reaches of rivers. This topic is elaborated later in the chapter.
- An important bio-technological advance in recent years that is relevant to water conservation relates to developments in saline agriculture. The use of halophytes to reclaim salinity afflicted land, and the development of salt-tolerant varieties of staple crops, can help contain the threat to food production posed by rising levels of salts on the surface and in the soil profile. Research in Pakistan and elsewhere has demonstrated that it is economically feasible to grow fodder on saline drainage water and even on seawater.
- The reuse of surface and subsurface drainage water, depending on the quality, is feasible for direct use for irrigation, blending with canal water, cyclic or rotational, saline agriculture forestry system and solar evaporators, & aquaculture. Similarly, saline water can be pumped from the saline aquifers and blended with fresh water for use. There are also certain tolerant crops that allow use of saline waters to varying degree can be used. Its management and

disposal requires an understanding of the drainage characteristics of the water and the matching of those characteristics to the environmental protection needs of the re-use at the disposal area. Based on extensive research carried out by leading research stations in India in these fields, this type of use has gained support in many parts of the country. These applications are also relevant to Pakistan's situation.

- *Demand based management*: Crops require water at critical stages in their growth, not once every week or once every two weeks. For wheat, in descending order of priority, water is needed at the tillering (plowing of agricultural land), jointing, booting and grain development stages, with the greatest loss of yield occurring through water stress at the earlier stages of plant development. Introducing automation, where on-demand irrigation is possible and human intervention is avoidable in the irrigation system, would save precious water by quickly responding to sudden change in demand. Efforts initiated in India to introduce this system in the major irrigation systems of Bhakra Beas, Tungabhadra, Jayakwadi, Rajasthan canal, Chambal canal, Jayakwadi, Majelgaon and Sardar Sarovar should be pursued vigorously. In Pakistan, by 2020 or thereabouts, for the first time in the history of the Indus Civilization, there would be enough computational power and information transmission capacity to indent for river water on the basis of crop needs in each of its 40 million farm fields (Qutub and Nickum, forthcoming). The National Commission on Agriculture (1988) of Pakistan has assessed that when water is available to the farmer on demand, yields improve dramatically, up to 89 percent for sugarcane, 41 percent for wheat, and 53 percent for Irri Rice. The institutions and the farmers’ level of knowledge would need to be built up over the next two decades to enable the use of this technical capacity.

b. Agronomic practices

The agronomic practices that would improve irrigation efficiency and which can be achieved only with farmers' participation in water management and crop husbandry, are the following:

- Identification of appropriate crop combinations in various systems, especially of cereals, pulses, and oil seeds. The cropping pattern should be changed from water-intensive crops to less water-demanding crops. Drought resistant crops and salinity resistant crops are other options;
- Precision leveling of agriculture fields to curtail irrigation application losses. The laser land leveling technique adopted in Pakistan is reported to have saved a significant (20-25%) amount of irrigation water by ensuring uniform application of seed and fertilizer and help in better and uniform seed germination. Laser land leveling facilities are available countrywide and farmers have seen its advantages. Similar techniques can be adopted in other countries of the region wherever suitable;
- Adopt mechanical rice transplantation as it saves labor, lessens plant stress, ensures timely planting, attains optimum spacing and plant density, and increases productivity. The technology is under pilot testing in Pakistan for its countrywide replication;
- The bed furrow system of Irrigation is practiced in Pakistan as it provides better water efficiency than can be achieved using drip irrigation. The bed and furrow system of irrigation for cotton and other row crops has many benefits over conventional basin irrigation methods. It reduces overall energy requirements, saves a considerable amount of irrigation water, reduces changes of plant submergence due to excessive rain or over - irrigation, and enhances fertilizer use efficiency;
- Adopting irrigation scheduling based on water demand of crops in command of all irrigation projects;
- Optimum fertilizer use to be suitably matched with crop and water management practices;

- Adoption of appropriate irrigation methods such as drip, sprinkler or channel to field irrigation based on cost effectiveness;
- Mulching, a simple effective practice at the field level, could reduce surface evaporation.

c. Socio-economic aspects - Devolving Water Management to Farmers

The Socio-economic aspects of irrigation management have three significant components, which are all dependent on the farmers and devolving water management to Farmers' Organizations. These are:

1) Participatory Irrigation Management

India has accepted and adopted Participatory Irrigation Management (PIM) for better management of its irrigation systems. In the existing system of management, all the responsibilities of planning, construction, operation and maintenance of the irrigation system rests with the state Irrigation Department. The Irrigation Act or Canal and Drainage Act, and the relevant 'Rules' under the Act, which are sacrosanct as they are legal, dictate the opening of canal, frequency of supply, distribution of water among farmers, operation and maintenance of the systems, water rights and water charges, and penalties.

According to the prevailing rules, each individual farmer has to deal with the government except that mutual co-operation is sought in the case of water distribution under 'warabandis' being followed in several states. The system does not provide for collective efforts in self-governance by the users/ beneficiaries. This has contributed to low efficiency in the irrigation system, almost total involvement in maintenance of field water courses by the government agencies, and lack of institutional interface between the technical staff and farmers. The NWP has laid stress on "the necessity of involving the farmers in irrigation water management." The planners have now recognized it all over the country. The concept of "participatory irrigation management" (PIM) has emerged in which the farmers through their organizations that are called 'water user associations' (WUAs) could take over the authority and responsibility for irrigation management below an agreed point.

In the recent past, there has been more emphasis on farmer-managed irrigation in Nepal as compared to agency-managed irrigation. Participatory management and turnover of irrigation systems to the farmer have proved to be effective because communities have the incentive to perform their responsibilities effectively. The recommendations of a recent study by the International Water Management Institute (IWMI) on the Nepal Water Management Transfer, given below, are very relevant and need to be adopted:

- Further support is required for sustainable and productive self-management of irrigation at management transfer sites;
- Based on the needs of the individual systems, selective and responsive support in the form of training, facilitation and technical advice is required by the WUAs;
- More effective support systems are necessary to deliver services required by farmers and WUAs;
- Thoughtful effort, taking into consideration the views of stakeholders, is required to improve policies and regulations to create a more enabling environment for WUAs.

2) Water User Associations (WUA)

Farmers associations are formed so that bulk irrigation water at distributary head could be supplied to them and the association itself is also authorized to collect the revenue from individual farmers using this water. This process can also reduce the overall expenditure on O&M. This approach can make the governmental agencies more responsive to the farmers' problems in water management, as well as deliver more equitable supplies to individual farmers. Thus the formation of WUAs offers considerable scope as a part of policy package to improve the present situation. The package should also include autonomy to a farmer to utilize the water purchased by him in any manner. With this, the role of the government department would be limited to promotion and technical assistance to the farmers association.

Each state government should, therefore, prepare a detailed package of turnover of the system to the farmers under the control of the WUAs, with due consideration of the socio-economic situation in each region. Simultaneously, the states should also ensure that the main system is operated and maintained properly to ensure proper water supply to the farmers associations. Farmers' participation should be made obligatory at the outlet and minor level and gradually expanded to form canal and project level committees.

At the present stage, in India, under the command area development programs of several interstate, WUAs have been formed but their coverage is limited (about 15 % of the total area under irrigation) and their functioning in the past was far from satisfactory. This situation was recognized, extensively debated in various fora in which the farmers also participated, and corrective steps have been taken to make them effective. The present overall consensus is for a "covenant" to ensure that the WUAs become very effective instruments of a process of a dynamic change in the socio-economic facet of irrigation water management. WUA's success is assured if human factors, administrative and financial factors along with scope for higher return are assured. Sustainability can be achieved if the level of productivity, which in turn improves the income of farmers, is maintained through the participatory process. It has now made significant progress with the central government, with the World Bank playing a catalytic role.

The legal bottlenecks in promoting the involvement of farmers have been removed and certain basic policy measures have been introduced in the states. As a result, there are 23,626 WUAs (up to end of India's Ninth Plan, in 2002), covering about 9 M.ha, functioning successfully in 14 states of the country. The pace of establishing these WUAs is to be further accelerated during the Tenth Plan (2002-2007) to cover an additional irrigation service area of 10 M. ha.

In the irrigated areas of Pakistan, since the Canal and Drainage Act (1873) - the principal legislation for irrigation in the Punjab province, and the Sindh Irrigation Act (1879) in Sindh - had no scope for formal legal mode of organizing water users to improve water use efficiency, an ordinance was promulgated in 1981 to give effect to this change. The provincial (1982) Water User Association Ordinances, which provided for such associations at the watercourse level initially, and recent further modifications in the form of provincial Irrigation and Drainage Acts (1997), envisage Farmers Organizations managing distributaries as well. On the other hand, co-operatives have failed. Executive members have misappropriated funds, and most co-operative banks have gone bankrupt. Similarly, most Water Users' Associations set up by the provincial On-Farm Water Management departments have ceased to function after the renovation of their watercourse. However, it should be noted that, whereas in NWFP, most of the OFWM clientele are small farmers, farmers contribution is taken up-front and 96 per cent of the due amount has been recovered (Halcrow, 1996). On the other hand, in Sindh, the target group is mainly large farmers and only 20 per cent of the amounts due have been recovered.

The great successes of the rural support programs, (such as the Aga Khan Rural Support Program and Thardeep Rural Support Program) have taken place in resource-extensive frontiers (such as northern mountains and deserts), where there is a tradition of social and economic co-operation. In irrigated croplands, much of the focus of the RSPs has been on forming small homogenous interest groups for savings and loans. Such interest groups tend to externalize both power issues and environmental concerns.

Yet the scenario of community managed irrigation water is not just a dream in Pakistan. The International Irrigation Management Institute (IIMI) has demonstrated in pilot experiments in Sindh and Punjab that Farmer Organizations are capable of taking over distributary management with collective benefit. Similarly, PIEDAR is engaged in an interesting experiment with community - based organizations on a distributary of the Haveli Canal, Punjab. In this case, 48 watercourse associations have banded together to form an apex organization (PIEDAR, 2002). They are learning water measurement, dispute resolution, record keeping and other related skills before seeking to take over distributary management from the Punjab Irrigation Department.

3) Women's participation

The position women hold in society as providers and users of water and trustees of the vital environment needs due recognition through suitable institutional arrangements in the water resources sector. The ultimate challenge in the water sector's gender dimension is to attain and ensure equal access to both genders in the allocation and use of water resources.

In India, women's participation as labor is almost 50% in agriculture, irrigation, horticulture, fish culture, and construction activities of irrigation projects (World Bank, 1998). On an average, Indian rural women spend at least 4 hours a day to fetch water for the family. Gender awareness in irrigation management should form part of water resources planning. Water resources managers should therefore take into account the women's requirements seriously and their approach should be target based. Irrigation schemes should accommodate women farmer's requirements. They should be involved in planning, budgeting and conducting of irrigation. Women who have the knack of managing the household with limited resources can effectively use the same capability in water conservation. Women should be trained in ways of improving water use efficiency and relevant technologies. NGOs can play an important role in engaging women in irrigation.

In Bangladesh also the close association between women and water use is recognized, but they enjoy little or no role in decision making in water management. Even though women constitute 49% of the population, they are virtually absent in public sector departments that deal with water. Further, their views, needs and perceptions are not recognized and considered in planning the location of water collecting points, designing the water pumps, and organizing community management operations of water facilities. According to a survey carried out in 1995-96, of the total 56 million labor force, only 21.3 million are female (BBS, 1998). Women are generally pushed into the unskilled labor force. Recognizing the fact that women have traditionally displayed a strong sense of understanding of the conservation strategy of natural resources, the National Action Plan (GoB, 1997) drawn up by the government outlines a range of activities to promote gender equality, including greater involvement of women in water management. In specific terms, the activity and programs proposed are:

- Policy formulation to address women's role in irrigation and water management;

- Initiation of proposals for the Law Ministry for amendment of laws with respect to property and inheritance rights in order to establish women's legal access to water bodies;
- Ensuring women's involvement in wetland conservation programs; and
- Involving local government bodies where women have a mandatory representation in water quality monitoring and waste disposal.

In Pakistan, women are the invisible gender. While they are given responsibility at the household level, they are confined and their voice is seldom heard. Women's participation in decision-making in many programs related to water has remained more on paper than in practice. The operation and maintenance of the water supply schemes in villages is the responsibility of men, but the schemes are not functioning since men have little interest in them and assume that women will get the water from somewhere or other. Pakistani society, therefore, needs to transform the male ethos into a cooperative effort with women to meet the future challenges in the water sector or any other sector of development.

6.3.2 Domestic water supply

The World Bank (1999) has noted that providing consumers with increased access to efficient, sustainable water and sanitation services is a challenge. This can be achieved by transforming under - performing public sector agencies into vibrant and responsive organizations and developing the capacity of local governments and community institutions to be key players to provide efficient and sustainable water supply and sanitation services (WSS). The vital and creative NGOs and small-scale private sector must be transformed from a fragmented response to the failures of existing institutions into a key partner to large scale public and private agencies and small scale local governments and community institutions.

Water audit involving water supply and usage study, process study, water systems audit, discharge analysis, operational cost analysis and a final report with analysis and recommendations, whether it is domestic water supply or industrial water supply, should be increasingly adopted in the countries of the region.

Water supply should be made 100% reliable with high quality assurance in both urban and rural conglomerates in all the countries of the region. The approaches in this regard are discussed below.

A. Urban water supply

There have to be limits on consumption when working out allocation, and the treatment of effluents should be made a condition of allocation. The amount of effluent is large in urban areas, and it should be reused, after treatment, for industries and irrigated agriculture. This would facilitate releasing corresponding amounts of water for other sectors (such as irrigated agriculture) and also reduce the pollution load in receiving watercourses.

The distribution efficiency needs to be improved, since the water not accounted for (UFW) is reported (World Bank, 1998) to be in the range of 30-50%. In areas of intermittent supplies, which is mostly the case in urban water supply, the losses are classified as follows:

- When losses are at about 5% to 7%, the situation is considered to be satisfactory;
- A loss of 10% to 20 % is considered unsatisfactory and action is advisable; and
- When the loss exceeds 20%, remedial actions are essential.

Where the water supply is available round the clock, the above percentages could be increased by 5%.

This lost water is a waste of money spent on pumping, treating and distributing the water; it causes investments in developing new sources of water that could be postponed or avoided if all the water were supplied to consumers. It creates environmental nuisances around points of leakage. This could be reduced by management techniques such as leak detection and pipe repair programs used extensively in all cities and towns along with improved monitoring and metering. The cost of saving a cubic meter of water is usually much less than the marginal cost to provide a cubic meter of water from alternative sources. A few key strategies applicable to the region are:

- Over - exploitation of ground water must be avoided to maintain quality and to control water-pumping costs. Appropriate legislation and its effective implementation should form an integral part of any strategy for ground water exploitation. Ground water legislation should be effectively implemented;
- Drinking water and sanitation activities should be taken up as an integrated program, because in the absence of such a linkage, sanitation activities tend to be overlooked;
- Alternative strategies, new technologies, cheaper methodologies, as also mechanisms like rain - water harvesting, need to be pursued in a big way to provide alternatives to present practices;
- New strategies would need to be developed for 100% recovery of operating and maintenance (O&M) costs in the first instance and the capital costs in later stages, with subsidy in pricing adopted more sparingly;
- Urban local bodies should be strengthened adequately and made responsible at least for O&M of the systems;
- Timely action should be taken for rehabilitation of systems for their longevity so that investments on replacement costs could be reduced;
- Human resources development in this sector needs due attention, particularly for those involved in O&M activity.

Indian perspective

The strategies stated above are uniformly applicable to India. In recent years, the Private sector is increasingly getting involved in funding this infrastructure, with the active support of state governments and local bodies. The involvement can take place in diverse ways. To cite a few examples:

- The implementation of specific projects as in the case of Pune water supply and sewerage project;

- To meet industrial and domestic water demands as in the case of the Tirupur Municipal areas and 31 wayside villages (with cost recovery through levy of water charges and user charges); contracting of operation and maintenance of pumping stations. (The Chennai Service contracts for 75 pumping stations);
- The maintenance of water supply system as done recently for the New Mumbai areas;
- The maintenance of tertiary treatment plants as in Mumbai, and
- The bulk production, treatment and supply of drinking water to cities as in the case of Bangalore city.

Bangladesh perspective

In urban areas, the water supply situation is becoming increasingly critical due to the growth of the urban population at the rate of 6% per annum (Ahmad, 2000). In Dhaka, where the present population is about 9 million, about 70% of the households have access to piped water. The population is likely to double by 2025, resulting in an increase in the demand for domestic water from the present 1,420 million liters to 2660 million liters. The situation in Chittagong, the second largest city in Bangladesh, is more critical. Only 38% of the households have piped water supply at present. The urban population, which now comprises 20% to the total, is likely to increase to 53% by 2025, thus putting the urban water supply situation in a highly critical situation. The strategy for ensuring adequate and safe drinking water to the urban areas also has to address the situation of arsenic intrusion in ground water. The urban water planners have a very serious situation that has to be addressed immediately.

Nepal's Perspective

Since the water supply and sanitation demand is a very small fraction of the water demand in all the basins, it does not pose any problems in meeting the demand at the macro level. However, shortages at the micro level, especially in the urban areas as in the case of the Kathmandu Valley, emphasize the need for expanding the present national coverage to include the whole population. In the case of urban centers and municipalities, bigger systems can be implemented to take advantage of economies of scale.

Water Supply in the Kathmandu Valley

The currently available water supply in the valley is not able to meet the present level of demand. In addition, the current level of groundwater extraction (about 23.4 MCM/year) is way above even the most optimistic estimate of 13.7 MCM/year of groundwater recharge in the valley (WRSF Consortium, 2000). This is an alarming situation for the capital and the surrounding districts of the valley. Although better management and loss reduction of the present supply could make some improvements in the situation, a few major interventions are essential to meet the present and future demands of the valley. The Melamchi interbasin transfer project to be implemented soon will provide 170 million liters/day (MLD) (1.96 m^3/s) in the first phase (2006) and will ultimately withdraw 510 MLD (5.9 m^3/s) by the third phase in 2026. Other options under consideration are rainwater harvesting and the construction of storage ponds in the foothills surrounding the valley. The feasibility of the latter option has not yet been verified. The Melamchi project, for now, seems to be the preferred option for implementation.

Pakistan's perspective

Overall, a small proportion of the surface and groundwater is used in urban and industrial sectors in Pakistan. However, the volumes are significant in certain urban areas. Moreover, water use is growing rapidly. Water conservation and re-cycling is a priority for dry-land cities like Karachi and Quetta where water is conveyed from a long distance or pumped from great depth. For cities located in the fertile agriculture zones, water treatment before disposal to canal or drain is the priority. According to a World Bank country report (1994), 35% is the most frequently quoted figure for losses in the urban supply system due to leakage, illegal retail connection and abstraction from the system. The control of excessive water losses and demand side management should become priority tasks. A comprehensive program for repair of leakages is warranted.

B. Rural water supply

Gradual adoption of demand - responsive and sustainable approaches in the rural water and sanitation sector is essential to achieve 100% coverage by 2025. Most of the needs are met from ground water. With more and more water being extracted for use in irrigation, it is becoming increasingly difficult to meet this demand. One option is to place selective controls on ground water extraction. The other option is to enact laws for transferable water rights or temporary acquisition in addition to controls on ever-extraction. Community organizations have convinced the users to pay for the services from public stand posts and convert these public taps into community-metered taps. The level of service has generally been efficient, with 24-hour service, and the percentage of leakage and wastage has been kept below 10%.

Water quality concerns have serious implications in rural water supply programs, particularly the arsenic, fluoride, manganese, iron levels and other heavy metals, as well as salinity in ground water to varying degrees in some state of the countries. The hydro - geochemical characteristics of ground water vary considerably. The serious ramifications of this problem necessitate an integrated approach in specific terms to undertake ground water pollution monitoring and alleviation programs. It is essential to identify the contaminating solutes, their source, and dispersal as well as the type of pollution they generate. Technology innovations developed and tested in this regard should be implemented.

Environmental sanitation is an issue generally neglected in rural areas. This needs to be remedied with adequate wastewater disposal programs.

Indian situation

Reliance on ground water, up to 90% of drinking water for the rural population, has caused scarcity in the availability of this supply since the annual withdrawal exceeds the recharge. A survey carried out by the Rajeev Gandhi Mission in one third of the habitations has revealed that seasonal or permanent fall in the groundwater table has taken place (GOI, NCIWRDP, 1998). This has serious social, financial and institutional implications that need to be addressed. Ground water legislation for its equitable and judicious use is therefore an immediate need. The enabling laws envisaged to rectify the situation are:

a) To record the site of domestic water supply wells, and to prevent any new ground water structure within 500 m radius from such a well; and
b) In years of deficient rainfall, ground water extraction should not be permitted for any other purpose than for domestic use.

Watershed management and water harvesting would further increase ground water availability to meet rural drinking water needs.

Peoples' awareness programs on the scarce nature of water resources and the need for quality protection would no doubt play a facilitating role in the functioning of the water supply schemes. In this effort, the technical considerations should not be overlooked in the selection of sites in villages.

Bangladesh’s situation

Water supply coverage in rural areas is almost 97%, with 20 households (about 105 people) covered by one tube well. Hand tube pulls are supplemented as drinking water sources by deep tube wells or Tara pumps. Arsenic contamination of ground water (high level of over 0.05 mg/l) in 59 districts out a total of 64 districts has necessitated examining the possibilities of providing safe drinking water from surface water sources in both rural and urban areas. The government of Bangladesh has also launched a four year program called the "Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP)", with World Bank and Swiss funding, to provide arsenic free water supply to urban and rural communities. The project envisages:

- Identifying the causes of arsenic contamination;
- Determining alternate sources of water supply;
- Building awareness of the arsenic hazard; and
- Preparing detailed proposals for a national program for arsenic mitigation.

Nepal's situation

As the villages and settlements in Nepal are spread across the country, small scale community participatory approach should be taken in increasing the present coverage of safe drinking water and sanitation to 100% of the population. Community management of water supply systems in Dhulikhel and Kakarbhitta (serving 15,000 people), with a water users committee taking over the role of operation and maintenance after initial financial support for three years in a declining manner, has led to the following positive lessons (WRSF Consortium, 2000e) :

- The community organizations could convince the users to pay for the services from public stand posts, and converted these public taps into community metered ones;
- The level of service has been efficient with round the clock operation and the percentage of leakage and wastage has been kept below 10%;
- The user committee made a decision to levy the water tariff at a rate even higher than the one set by the Nepal Water Supply Corporation (NWSC) - the national public water utility.

6.3.3 Industrial water

The overriding need for total management of water for industries is accentuated by the following:

a) Municipal supplies are limited, with the priority for domestic uses;
b) Conventional ground water use has resulted in overdrawing of the resource;
c) The water table is declining rapidly; and
d) Water quality is deteriorating at a high rate.

Industry is in a better position to respond to these issues as it has the necessary resources and technology. A pyramidal approach, involving the four elements of water audit, rain water harvesting, water technologies, and water outsourcing, is increasingly becoming the latest tool to meet the increasing needs of industry as well as for domestic water supplies. The rising water scarcity, coupled with increasing environmental concerns on effluent quality and the increasing cost of water, have led industry managers to look more closely at ways to enhance the efficiency of water efficiency use.

The Indian scene

In India, the need for conservation, evolving water saving systems and designs, and the recycling of water have now become accepted policy approaches in planning for industrial water supply. With only twenty percent of the water supply used in industries, the importance of ensuring the quality of the effluents discharged by the industries into the remaining 80% has assumed enforceable legal environmental concerns (GOI, NCIWRDP, 1998). Consequently, the Central Pollution Control Board (CPCB) has stipulated that every industry should have its own treatment plant. The CPCB has also announced wastewater generation standards for various categories of industries under the Environmental (Protection) Rules of 1986.

Water efficiency makes good business sense when water is scarce and expensive. The industrial, commercial and institutional sectors are allies in helping rural and urban water supply entities save water and, consequently, funds. With increasing demand for water, industries have to adopt technological development in processing and methods for reusing water. This will reduce the volume of polluted water released by the industry and its cascading impact on the downstream users. Recycling of wastewater also facilitates recovery of certain commercially viable by-products. Treated effluents can be economically used for irrigation, in inland towns, and in arid and semi arid areas where suitable lands are available in the neighborhood of the industries discharging effluents. This, however, calls for the use of appropriate methods and levels of treatment.

Well known technologies of treatment in use include the up flow, anaerobic sludge blanket, biogas generation from waste, use of oxygen bleaching to replace chlorine in pulp and paper industry, and the use of cartridges for treatment of electroplating wastes. Adoption of membrane technology is an asset to industry to meet the expanding fresh and clean water requirements and complicated effluent water treatment problems. It operates at ambient temperature and offers one - step separation of all dissolved and suspended constituents at the molecular and ionic levels, without any need for the addition of chemicals. These help in resource conservation, waste minimization, and recovery and reuse of wastes to the extent possible. They improve the financial viability of the industry and reduce possible conflicts with the public interest. It would, therefore be prudent to mandate the recycling and reuse of wastewater in certain industries.

ISO 14000 prescribes the adoption of conventional methods of conservation, reduction at source, and waste management through waste minimization. It provides for a voluntary framework for improved environmental performance going beyond the traditional command and control approach, which merely compels compliance with statutory laws and regulations. It not only gives the procedures for dealing with environmental performances, but also provides direct cost savings through process efficiency gains, with a crucial focus on waste, energy and materials management. Since all industries are eager to get ISO certification, they are likely to comply with the procedures prescribed for water management.

There is a need to review the existing system of subsidies and tax structure on investment in pollution control, water conservation and water recycling. The concepts of "Polluter Pays" to introduce a punitive tax, and the “Polluter gets punished" would result in greater compliance of effluent treatment by industries.

The Common Effluent Treatment Plant (CETP) is an important scheme for assisting in the setting up of common facilities of clusters of small-scale units for treatment and disposal of solid liquid and gaseous waste generated by small-scale units located in industrial estates or clusters. This scheme has been successfully implemented in a few states like Andhra Pradesh, Maharashtra and Tamil Nadu. The cost of such schemes is shared by the central government, the state government, industries, and with loan assistance from the Banks. This program should continue to be supported after proper evaluation of existing systems in different states. The Pollution Control Board in Tamil Nadu, has introduced the pollution tax based on a classification of the industries according to their pollution potential into "Red", "Orange" and "Green" and by their gross fixed assets, as a proxy for the pollution amount, within each class of industries. The effectiveness of the novel fee structure adopted for the different "colored" industries could be evaluated and suitably adopted in other regions of the country.

The economic instruments introduced through government policies under planned development, in addition to regulatory mechanisms, embody increases in charges on water consumption, duty concessions on import of certain pollution control equipment, and accelerated depreciation on pollution abatement equipment. These instruments should find wider application.

The Government of India has also promoted a scheme for development and adoption of clean technology including waste reuse and recycling for small-scale industries. Under this scheme, research and development is linked with diffusion and adoption of pollution prevention measures.

The Environment Statement, as a part of the environment audit, is a mandatory requirement to be submitted by the polluting units to the state Pollution Control Boards. This enables the units to take a comprehensive look at the industrial operations and facilitates an understanding of material flows and focuses on those areas where waste reduction, and consequently saving in input costs, is possible. In the context of water conservation, water auditing is very relevant.

The Bangladesh scene

Certain industries in Bangladesh have provisions for water supply installed *in situ* from surface or ground water sources and these industries tend to pollute water by discharging untreated effluents. Increasing salinity in surface and ground water in the southwestern region has also become a serious constraint on industrial growth. The ability of some industries to use river water for cooling has been constrained and large quantities of fresh water are imported by barge for industrial use. Fresh water flow, therefore, must be increased to push the salinity front south, and dilute the effluents if a sustainable water ecosystem is to be ensured for industrial development. Since the water demand will increase substantially by 2025, the National Water Policy recommendations to introduce zoning regulations to tackle the effluent discharge problem need to be established urgently, and enforced for industrial location, to enhance fresh water availability.

The Pakistan scene

It is observed that industrial use in Pakistan is inefficient both technically in terms of wastage and economically in terms of production per unit water used. Industry is the prime source of persistent and toxic effluents that are polluting water bodies across the country. The contamination of groundwater by heavy metals and some synthetic chemicals persists for centuries, severely restricting the range of future uses. There is a need to maintain the quality of water bodies at least in the prime agriculture lands of the country, by treating effluents before disposal into natural drains and rivers. The reuse of effluents after proper treatment may also be a part of the solution to the water scarcity problem in the industrial sector.

Al-Abid Silk Mills, Sindh Industrial and Trading Estate (SITE), Karachi has recently installed automatic shut down valves for its process water. As carefully documented by its in-house research team, the payback period for this substantial investment has been a phenomenally short 4 to 5 weeks (NEC, 2000). The question arises why other mills do not follow the same water conservation practices.

There is no shortage of technical solutions to the treatment of most types of industrial effluent. For example, 97 percent chrome recovery from leather factory effluents has been successfully demonstrated (NEC, 2001) on a pilot scale in Korangi, Karachi. Combined effluent treatment plants are being installed in Korangi and in Kasur.

The need now is to scale up to achieve complete coverage of effluent streams from all the seven leather production clusters in Pakistan. The next priorities should be waste streams from paper and board (with large loads of COD), sugar (large loading of BOD), and caustic soda (microchip technology) because of its dangerous discharges of mercury to river sediments.

The Nepal scene

The Water quality in the country has deteriorated mainly due to industrial pollution. The volume of effluents generated by most industries is not large, but the concentration of pollutants is remarkably high (WRSF Consortium, 2000). It has been a major concern in Kathmandu due to rapid unplanned urbanization and lack of proper facilities. The water quality of surface drains has deteriorated and ground water sources polluted. The approaches pursued to control and discourage pollution of water, both surface and ground water, are:

- Formulate laws to reduce pollution of water;
- Develop a mechanism for “User and polluter pays" principle so that the price reflects the investment cost of development of water resource systems;
- Encourage new technology;
- Train users for optimum use of water and discourage them from pollution of watercourses.

6.4 Conjunctive use of surface and ground water sources

“Conjunctive use” connotes a planned intermix of irrigation water supply by surface and ground water sources, so that such supplies dovetail smoothly in improving the area under irrigation, both in terms of quality of irrigation supply as well as its extent. It does not necessarily mean the mixing of surface and ground water before using on land for irrigation. Integration of the use of water from two sources on land may involve different levels of time and space integration. Its objective is to increase water availability, control of water-logging and salinity, provide better regulation of combined systems, afford higher flexibility in supply, permit use of inferior quality water, and provide reduction in capital costs as well as operating costs for achieving sustainable irrigation.

India

In India, the past practice of intensive surface irrigation has given rise to land degradation and an alarming rise in the water table. This has resulted in related problems of water-logging and salinity/alkalinity in the affected areas. Inadequate surface and subsurface drainage provisions, poor maintenance of the systems, and improper management in irrigated command have compounded the problems. The land affected due to these reasons is estimated to be about 6 M.ha; 2.7 M.ha affected by water logging, 3.06 M.ha affected by soil salinity, and 0.24 M.ha affected by alkalinity (Planning Commission, 1999). Conjunctive use of surface and ground water is an accepted solution for removing the water-logging problem, which will enhance the yield from such lands. There is large scope for such usage in alluvial plains, particularly in the Gangetic plain, the coastal areas of Orissa and Andhra Pradesh, the Brahmaputra valley, the Cauvery delta, and parts of the Narmada basin.

Bangladesh

In the case of Bangladesh, there is a need for the balanced use of surface and groundwater resources, since the dry season scarcity of water is a major impediment which adversely affects drinking and domestic water supply, fisheries, forestry navigation, irrigation, industries and above all the natural environment in large areas. Farmers are already practicing conjunctive use by irrigating with stored surface water until January and with shallow tube wells thereafter, and this practice should be encouraged everywhere, including areas such as the GK project.

There are a number of parts of the country where groundwater is not available. Surface water can be developed in some places. In most such instances, the existing surface supplies are already fully utilized, and expanding supplies requires transfer from an alternative source, normally the main river system. The investment is risky if the source is not guaranteed. The Ganges Water Treaty secures an opportunity to make use of the Ganges flows in the GDA.

Conjunctive use can be encouraged wherever surface water supplies can be augmented relatively cheaply and the aquifer is usable, by pricing irrigation supply so that farmers use it in *addition to,* rather than *instead of*, groundwater.

In Bangladesh, ground water is a major source of irrigation (68.5%). The arsenic problem exists in 92% of the districts, including those in the Southwestern, South - central and Southeastern regions. Since these regions have a major share of the present irrigation of 4 million ha, their over-dependence on ground water is considered very risky. A balanced conjunctive use of surface and ground water is now being advocated as a pragmatic approach.

Nepal

The groundwater potential, especially in the Terai and inner valleys of Nepal, is substantial. Conjunctive use of ground and surface water can help in mitigating the gaps.

Pakistan

In Pakistan, conjunctive use of groundwater has been instrumental in the intensification of agriculture and raising crop yields over the past 20 years. However, due to overexploitation of groundwater resources, the sustainability of irrigated agriculture is threatened in some of the areas. This situation needs to be checked urgently and addressed properly. A detailed study needs to be undertaken to examine these issues and to evaluate alternate strategies for more effective groundwater use. Moreover, a legal framework and legislation are required to control overexploitation of fresh groundwater resources.

Conjunctive use Plan

Four strategies are suggested for evolving conjunctive use plans, which are applicable to all the four countries under study. These are:

a) Conjunctive use in space – Earmark separate parts of command for permanent surface and ground water use;

b) Conjunctive use in time – Allocate surface and ground water in time, so that in a particular season only surface water is used, and in other season only ground water is used;

c) Conjunctive use in space and time - Combination of approaches (a) & (b) above - space and time integration in which,

- Part of the command area relies permanently on surface water;
- Part of command area relies permanently on ground water; and
- Part of the command area is supplied with surface water in one season (Kharif or monsoon season) and ground water in another season (rabi or summer season);
- Conjunctive use by annual regime – This is a variation of approach (c) in which both ground water and surface water are used, intra - annual regime of the uses vary from year to year in order to take advantage of the more stable regime of ground water. This could involve the ground water partly for carryover purposes. Also, it may require larger uses of surface water in years of surplus surface flows.

The design of the distribution network could be both separate and distinct or could be common. In a common network, the ground water would be pumped into the surface water network and distributed through the lower elements by the surface water network. In such cases either the surface or ground water can be physically mixed or certain rotations can be imposed on surface water and others on ground water.

The Indian Ministry of Water Resources has drawn up draft guidelines for this purpose, which could be widely adopted. It is imperative that all out efforts are made to fully utilize this approach as it will not only increase irrigation potential but also mitigate the problem of water-logging.

6.5 Renovation and Modernization of Projects

In India, the modernization of irrigation and drainage systems for increasing the effective irrigation area is an essential need, not only in the context of meeting the food grain demands projected for 2025 but also in view of the present resource constraints. It is estimated (MOWR, 2001) that about 21 M. ha of irrigated area from major and medium irrigation projects of the pre-plan period and those completed twenty-five years ago require renovation, upgrading, or restoration to a substantial degree. These are areas that have gone out of irrigation, either partly or fully due to deterioration in the performance of the system. It is estimated that the total investment requirements for this renovation and modernization program would be in the range of Rs. 20 to 30 billion over a period of 20 years (MOWR, 2001). Such modernization works have been taken up under planned development, as ERM (Extension, Modernization & Renovation) schemes, for which the World Bank is also providing funds under the program of Water Resources Consolidation Projects (WRCP). The program covers engineering, agronomic and management aspects as described below:

- Review of cropping patterns and crop calendar vis-à-vis the soil conditions in the command, and their suitability for different crops to avoid excessive losses in the distribution system and field channels;
- Re-appraisal of the irrigation water requirements and the frequency of the water application;
- Use of ground water under consumptive use to the extent possible;
- Improvement of the drainage conditions in the command area;
- Modifications to canal structures and construction of new structures as necessary;
- Adequate on - farm development;
- Proper water management;
- Satisfactory maintenance of the system;
- Strengthening of participatory irrigation management and irrigation management transfer.

Such projects have to be continued with large investments because of the obvious benefits they can provide.

In Nepal, the rehabilitation and extension of existing irrigation schemes is emphasized over starting new projects.

6.6 Technology in Irrigation

Sprinkler and drip irrigation are modern methods of irrigation advocated for adoption in India because of their demonstrated water application efficiency of 90-95%, resulting in the saving of water and also in increased production. However, the cost of installation of these systems is estimated to vary from Rs.15,000 per ha to Rs. 40,000 per ha over and above the basic cost of delivering water to a location (Planning Commission, 2001). Thus their application is now restricted to high value cash crops or fruit crops. They are therefore adopted by farmers individually or in a cooperative way, independently or integrated with surface irrigation system, wherever government subsidies are available for such systems. Their adoption on a wider scale has to be envisaged in the planned development programs in the country.

While all the modern systems of sprinklers are well known and also manufactured within the country, at present their use is reported in only about 700,000 ha, mostly in the drought prone states. This has been possible due to a heavy subsidy provided by the government to popularize this system. In respect of drip irrigation, also called micro irrigation, the use is limited to fruit crops and the government subsidy regime is in place to encourage use of this practice. Its use covers about 200,000 ha of fruit and vegetable crops (MOWR, 2001). There is a need to extend these systems, since alternatives such as storage reservoirs and interbasin transfers are no less expensive but have bleak prospects in the near future.

In Pakistan, inefficient traditional methods of irrigation, such as furrow, basin, and border are used. Both the drip and sprinkler methods that have much higher irrigation efficiency can be used in places where irrigation tube-wells are installed. The efficiency of drip and sprinkler systems is of the order of about 80%, as compared to the traditional irrigation systems with efficiency of around 30%. Thus, if even 15-20% of the present area under irrigation were brought under drip and sprinkler systems, it would reduce the water deficit by approximately 40-50 BCM/year, which is a substantial amount. However, these systems are costlier, and would require governmental assistance on a large scale if they were to be widely adopted. However, considering the benefits involved, this aspect needs to be accorded the highest priority.

Sprinkler, drip and trickle irrigation have good prospects in the hills and mountains of Nepal, where water may be scarce due to its transfer cost from the source to the fields. These techniques are more suitable for growing cash crops like vegetables and high value herbs.

6.7 Economic Incentives & Pricing

India's National Water Policy states the approach to this issue very concisely: "Water rates should be such as to convey the scarcity value of the resource to the users and to foster the motivation for economy in water use. They should be adequate to cover the annual maintenance and operation charges and part of the fixed costs. Efforts should be made to reach this ideal over a period, while ensuring the assured and timely supplies of irrigation water. The water rates for surface water and ground water should be rationalized with due regard to interests of small and marginal farmers." With this declared national approach, the issue is examined and addressed in retrospect and in the context of the future. The GWP in identifying needs to bridging the gaps has suggested to "integrate service development with the local consumer economy to generate enterprise and employment surrounding water services and wares", which covers all sectors of water resources development. The concept of water pricing and cost recovery would, therefore, need to focus on the principal issues of:

a) Water allocation between competing uses;
b) Cropping patterns;
c) Generation of additional revenue which could be used to operate and maintain projects;
d) Environmental impacts;
e) Income distribution; and
f) Water management.

Before India attained independence, the emphasis in irrigation projects was commercial and accordingly the water rates charged were adequate to meet the working expenses and the interest on the capital invested. The basic concept adopted was to evaluate economic viability of the project on the basis of financial return, which *inter-alia* decided the water rates. However, since independence, the focus shifted to considering irrigation projects as a necessity for net output to the national economy. Even though the evaluation procedures for clearance of schemes were continued with more guidelines, the emphasis on the benefit-cost ratio remained as the sole criterion for the approval of projects. This ended in most state governments failing to increase the water rates periodically, resulting in inadequate allocation to operation and maintenance needs of completed projects.

Further, no definite norms were followed for individual projects. The rates charged on area basis varying from crop to crop, season to season, state to state, and even project to project, are just sufficient to meet the salaries of the staff engaged on the system for operation and maintenance. This has caused poor maintenance of completed works, resulting in inefficient water use. Consequently, a progressive deterioration of completed works has occurred. In the past, several commissions and committees have examined this issue and given recommendations. The most important of these are the recommendations of the Irrigation Commission in 1972 (Ministry of Irrigation and Power, 1972) and the Vaidyanathan Committee in 1992 (GOI, NCIWRDP, 1998). The analysis and recommendations of the latter have been the more comprehensive.

While the Irrigation Commission linked the rate structure with the value of gross product of irrigated hectare irrespective of working expenses, the Vidyanathan Committee linked the rates with O&M costs and part of the capital cost without reference to the value of the product. A combination of these two approaches would ensure a rate that would be adequate to cover annual O&M costs and also cover a part of the productivity gains of the farmers.

The latest analysis carried out by the NCIWRDP (1998) indicates that the annual revenue receipts have been low, while the working expenses have been very high, both in major and medium irrigation projects and in minor irrigation schemes; with the gap widening from year to year due to water rates remaining more or less stagnant. The factors listed for low revenue receipts in surface water supplies for irrigation are:

i) Very low tariffs, and the political cost of increasing them;
ii) Physical and operational inadequacies of the created facilities;
iii) Charging for water on an area basis instead of volumetric basis, leading to wastage and lack of incentives to farmers to save water;

iv) Large working expenses on administration;

v) Lack of transparent information on water charges;

vi) The size of existing subsidies and environmental costs; and

vii) Inefficiency in revenue collection.

In the case of ground water, the inadequacies of water pricing are:

- Indirect pricing through diesel power costs (price of fuel) and electricity charges is unsatisfactory;
- lack of disincentives for water waste and excessive extraction of ground water due to low rural power charges, or in some cases no charge at all due to political considerations;
- Charging at a flat rate (irrespective of the amount of water pumped) for electric pump sets;
- Lack of transparent information on the actual costs of providing electricity, the size of existing subsidies, environmental costs.

Agricultural pricing and policies too have a bearing on indiscriminate water use --- the subsidies on agricultural inputs such as fertilizer, herbicides are causative factors. Distortions in cropping patterns and consequent inefficient water use due to commodity pricing and marketing systems are affecting different crops and regions differently.

In the case of rural drinking water supply the limitations are the following:

- The systems are basically managed by governments;
- There are large subsidies on supply;
- The cost recovery is deficient and the service is inadequate.

In the case of urban water supply, the lacunae in water pricing are;

- Low water charges and sporadic rate adjustments;
- Insufficiency of metering and volumetric water charging, particularly for domestic consumers.

The use rates of water for industries are not linked to pollution control. The existing financial incentives, regulations and enforcement for pollution control, water re-use, and water conservation have resulted in poor industrial compliance.

The factors identified above for India are generally true of Bangladesh, Nepal, and Pakistan as well. Thus the following suggestions to increase revenue are applicable to all the countries of the region:

a) Increasing the benefited area by water conservation;
b) Reducing working expenses by modernizing the system;
c) Better water management;
d) Organizational reforms and improved infrastructure;
e) Reducing O&M costs by providing communication facilities; and
f) Participatory management and curtailing overstaffing by redeployment.

6.7.1 Irrigation water pricing

The following measures are recommended for the revision of tariff structure in surface water irrigation, including agriculture pricing and marketing:

- The water tariff should have two components – an O&M component and a partial value linked component; the former component is to be used for O&M of the respective portion of the systems, and the latter used for modernizing the canal system;
- The production benefits per unit of water are to be optimized by linking both season and crop factors; water intensive crops should be charged higher rates compared to crops with low water intensity;
- The percentage reliability of water availability is to be charged differently; a full rate for 75% reliable supply, and two thirds of the full rate for lesser reliability of supply;

- User groups and WUOs are to be encouraged to adopt the system of volumetric measurement and distribution. WUOs could be given preferential rates over other farmers if they accept volumetric bulk supplies from the Irrigation Department;
- Water charges collected for any project should be totally allocated to the same project for its O&M;
- The water rates should be automatically revised every five years on the principle of recovering O&M costs and 20% special repair costs. It may be necessary to establish an analytical and decision making mechanism for this purpose. A water pricing authority may be setup in each state by statute, analogous to the energy pricing authorities, whose suggestions on pricing structure should be binding on all concerned;
- Public awareness should be created through a process of consensus building with the political establishment and civil society. This should be followed by a major outreach program to farmers to make them more aware of the benefits of a more productive irrigated agriculture.

O&M charges

Operation and maintenance charges as mentioned above should be met out of the water rates charged for irrigation and other uses in the four countries studied in the WASSA project.

In India, the Finance Commission of the Government of India decides the funds to be allocated to this activity under non-plan expenditure by the states, but the Government of India does not have direct control over the allocation and earmarking of such funds. The Tenth Finance Commission (GOI, NCIWRDP, 1999) had computed the admissible expenditure for O&M adopting a norm of Rs. 300/ha for utilized irrigation potential and Rs. 100/ha for the unutilized part with an additional allowance of 30% for hill areas and also an increase in the norms to take care of inflation. The Eleventh Finance Commission has revised the rates to Rs. 450/ha for utilized potential, and Rs. 150/ha for unutilized potential, with an additional allowance for hill areas of 30%. An increment of 5% per annum has been provided to take care of inflation. As the water rates are revised, the O&M

costs would also need to be enhanced so that inadequacy of funds does not hinder the O&M activity.

6.7.2 Ground water pricing

The present groundwater pricing structure does not provide for efficient and sustainable ground water resource use. The ground water pricing is indirect through diesel fuel or electricity prices. This has resulted in ground water depletion becoming a major issue; large landholders are using this resource indiscriminately for agriculture.

In Gujarat (India), the expected normal demand curve has an inverse relationship between consumption of ground water and pricing. Irrigators are sensitive to the price of water and the ground water markets are more organized and competitive. The hourly water prices are several times higher than the price charged in states like Andhra Pradesh, Tamil Nadu and Uttar Pradesh (World Bank, 1998). Hence, the options for improving ground water pricing are:

- Charges based on the electricity consumed. The Government of India has issued an ordinance that the power tariff should reflect the full cost of supply, plus a 3% return on assets;
- The electricity tariff for ground water extraction should promote ground water utilization on a sustainable basis, and the charges should be based on electricity consumption
- Electricity to panchayats (local councils) in bulk amounts, with the panchayats arranging and charging distribution according to the usage by its members;
- Public awareness about overdrawing of ground water and environmental effects should be increased.

6.7.3 Domestic water pricing

The water supply and sanitation sectors have to be made more viable and sustainable in the long run by adopting a commercial approach. The present very low and fixed charges for electricity used for agricultural pump sets and the low and fixed charges also in surface irrigation have substantially influenced rural water supply pricing. This distortion needs to be rectified to ensure across the board efficiency in water use for all sectors.

In urban water supplies, very few agencies are structured as independent commercial entities. The government absorbs losses and there is little incentive to be efficient. The tariff for domestic consumers based on water metering should be such as to encourage the customer to conserve water.

6.7.4 Industrial water pricing

Industries are charged higher rates for water, in order to subsidize domestic consumers. However, even the price they pay is very low, and does not reflect the scarcity value of water. There is thus little incentive for the industries to use water optimally.

In India, only in critically water scarce areas like Madras or Ahmedabad have the industrial units initiated measures to conserve and recycle water as much as possible, even though the return on this investment is low (World Bank, 1998). There is, therefore, an urgent need to rationalize the pricing of water for industrial use. There is also the need to limit the quantity of fresh water supply and its price to industries, linking this to the amount of effluent generated and treated by the industry.

A task force of the Ministry of Environment & Forests of the Government of India, which evaluated market based instruments for industrial pollution abatement, has recommended (GOI, NCIWRDP, 1999) the following measures, which are also relevant to the region as a whole:

- Greater reliance should be placed on economic penalties than in the past in the short and medium term;
- The current pollution control laws should be amended or new laws enacted to allow explicit incorporation of market-based instruments;
- Some provisions in the environmental laws should be replaced by market based instruments;

- The monitoring mechanism of the state Pollution Control Boards should be strengthened.
- The monitoring of discharges by firms should be done regularly;
- The public should have access to information on discharges by polluters, and on the ambient air and water quality.

6.8 Storage Reservoirs & Irrigation projects

Storage reservoirs on rivers, through dams small and large, have an important place in bridging the gap while the measures described earlier help narrow the gap between demand and supply. So much has been written in favor and against dams that it would not be useful to deal with the subject here. However, it needs to be stated that storage reservoirs have a definite place in bridging the “gap”. If there have been “bad” reservoirs in the past, there is no reason to do away with “good” reservoirs in the future.

Storage reservoirs are a conventional means of supply-side augmentation. In a recent study (IWMI, 2000), the International Water Management Institute has carried out a useful comparison of three storage strategies--groundwater, small surface and large dams, which is valuable in the South Asia context. An abstract of this study shown in **Table 50** indicates the following inferences, which are useful in evolving suitable approaches in each of the four countries of the region**.**

Table 50:

Comparison of storage alternatives

	Groundwater storage	**Small surface water reservoirs**	**Large dam reservoirs**

Advantages	Little evaporation loss; Ubiquitous distribution; Operational efficiency; Available on demand; Water quality.	Ease of operation; Responsive to rainfall; Multiple use; Groundwater recharge.	Large, reliable yield; Carryover capacity; Low cost per m^3 stored Multipurpose: Flood control and hydropower; Groundwater recharge.
Limitations	Slow recharge rate; Groundwater contamination; Cost of extraction; Recoverable fraction.	High evaporation loss; Relatively high unit cost; Absence of long-term storage.	Complexity of operations; Siting; High initial investment cost; Time needed to plan and construct.
Key issues	Declining water levels; Rising water levels; Management of access and use; Groundwater salinization; Groundwater pollution.	Sedimentation; Adequacy of design; Dam safety; Environmental impacts.	Social impacts; Environmental impacts; Sedimentation; Dam safety.

Source: *Water scarcity and the role of storage in development.* IWMI Research Report 39, as reported in *IWMI Research Update*, Nov. 2000, p. 6.

Groundwater recharge. Like surface impoundment, effective groundwater recharge would provide a means of evening out the seasonal peaks in natural water availability. It would also allow levels of withdrawal that currently create overdrafts, and maintain the control of much irrigation by wells, which tend to use water more efficiently than surface supplies. With the current technology, groundwater recharge capability appears to be limited, except in areas such as leakage from canals where there is pressure to *reduce* the current levels of groundwater recharge through lining. It should also be noted that wells are more efficient on an individual, wellhead basis. In many cases, a rebound effect has been noted, where more efficient use of water on existing land results in an over -expansion of irrigation into new lands rather than to more productive uses. This problem can confront any water saving effort that focuses solely on the micro level.

Small dams. In addition to the factors mentioned in Table 50, small dams have the advantage that they can be built and operated at a local level. With less complicated delivery networks, their water storage and release is easier for users to monitor – but, being small, they can be highly vulnerable to variations in inflow. Often, rehabilitation of traditional village-level reservoirs such as the tanks of South India is considered as a low-cost, high-return way to improve water supply at a local level. Excessive romanticizing of reviving traditional local management systems may lead to overrating their capacity, especially under the stresses and possibilities of modern life, such as off-farm income alternatives for young workers.

Large dams. Large dams are seen as a possible major element in addressing the water supply – demand gap in India, Pakistan and Nepal. With the strong seasonality of precipitation, capture of large amounts of water in the monsoon period would appear to be necessary when water demands exceed base flow in the dry season. In India and Pakistan, the reaching or exceeding of safe yield limits on groundwater abstraction, a primary form of water resource development in recent years that allows a high level of local control and low coordination costs, have made a return to surface water exploitation more attractive. In Pakistan, the total groundwater abstraction of 57 BCM (48 MAF) already exceeds the estimated ground water resources estimated at 54 BCM (45 MAF) that are usable, with less than 3,000 ppm dissolved salts (Mohtadullah, 1992). In addition, many existing dams and reservoirs are showing signs of age, with the three existing large surface dams expected to lose nearly a third of their storage capacity due to siltation by the year 2020 (from initial aggregate capacities of 19.3 BCM to 13.2 BCM).

At the same time, it is recognized that dam construction may be impeded by the possibility of significant environmental impacts, or by effective opposition resting on environmental or population displacement grounds. Other common obstacles are the generation of considerable amounts of financial support for large projects, and suspicions regarding economic viability, especially given the history of inadequate performance in many projects. Dams take a long time to build, and as the large dams in Pakistan demonstrate, they do not always last for a long time. Also, for irrigation, dams necessitate large surface delivery systems that have often proven difficult to manage or maintain.

Keeping the above aspects in view, the country - wise approaches for storage reservoirs are elaborated below:

Indian context

A storage reservoir helps to utilize more than its actual storage capacity because of the regulation of inflows and outflows. The additional amount of water stored is a matter of conjecture, and could vary between 30-50%. Taking an average figure of 40%, what would be the storage requirement in order to utilize 690 BCM? We can expect 17 M.ha. of irrigation from minor surface water projects accounting for over 100 BCM, leaving a balance of about 590 BCM for other uses. This calls for a storage capacity of about 400 BCM. Of these, 174 BCM had been created by 1995, with an additional 76 BCM under construction and 132 BCM identified. The water demand for 2025 is projected to be 1060 BCM, out of which surface water sources have to contribute 690 BCM to bridge the gap. To bridge the gap, the entire 690 BCM has to be utilized. Storages are necessary to maintain even the minimum flows in the rivers for ecological purposes.

The assurance provided by large storage dams for irrigation, municipal and industrial requirements in a country where the short monsoon climate dominates the flow in the rivers cannot be discounted totally for replacement by other modes. In the dams under planning, it would be a right step if the carryover storage requirement were provided so that shortfall in the following year due to erratic rainfall could be met. (The Narmada Tribunal examined such a provision and a carry over storage has been made in the Sardar Sarovar dam now under construction).

It should also be recognized that large irrigation systems developed under large dams are more amenable to better water management policies, enhancing irrigation efficiency. Some dams have to be built to bridge the "gap" in basins where water scarcity and water stress has been established (Cauvery, Pennar, Sabarmati, East flowing rivers of Kutch and

Saurashtra). Krishna and Mahi will also become water scarce basins by 2025 (IWRS, 1999). Storages planned in the Brahmaputra & Barak basins amount to about 63 BCM, but most of the projects are still in various stages of planning and investigation. These are unlikely to provide any benefits before 2025, except for hydropower development of some of them, as run of the river schemes in the first stage. The schemes planned are mostly hydropower and flood control specific, rather than for irrigation. Thus their contribution to food security is not substantial. In the Ganga basin the storages planned amount to about 30 BCM (IWRS, 1999), which are crucial from the irrigation and domestic water supply perspectives. The peninsular rivers of Godavari, Krishna, Mahanadi, Baitarani, and Brahmini have potential for creation of storages to the extent of 50 BCM.

The major projects under implementation or planning, which could provide irrigation benefits and also greatly help the drinking water & industrial water needs by 2025, are given in Box 2.

The important question is "Of the dams under planning, how many will be constructed in the next 25 years, considering the prevailing strong environmental opposition”?

Box 2: Major Reservoirs under implementation or Planning

Ganga Basin - Tehri dam in Uttaranchal state - Hydropower and Water supply.

Yamuna - Kishau, Renuka and Lakhwar Vyasi dams –Hydropower.

Sub -basin Irrigation and Water supply in Uttaranchal.

Godavari - Inchampalli (storage; 4.3 BCM) in Andhra Pradesh - irrigation, water supply and interbasin to supply to Krishna and Pennar basins, which are water stress basins (Figure 15 depicts this transfer).

- Polavaram - Irrigation and water supply.

Mahanadi - Manibhadra (storage: 2.43 BCM) -Irrigation and water supply;

- Ib (Storage : 1.32 BCM) -Irrigation, water supply;

- Praire (-- BCM) - Irrigation and water supply;

Brahmini & - Bhimkund (storage -2.43 BCM) - Irrigation and water supply

Baitarani - Balijhori (storage 2.22 BCM) -Irrigation and water supply

Narmada - Sardar Sarovar - terminal dam on the Narmada river in Gujarat 5.8 BCM live valley dams - storage for irrigation, water supply and hydropower - total utilization -11.685 BCM in Gujarat and Rajasthan covering the water stressed basins of Sabarmati, Mahi, East flowing river basins of Kutch and Saurashtra. (see **Figure 13**)

Narmada Sagar in Madhya Pradesh -first in the cascade of four major dams on the Narmada river in Madhya Pradesh - (storage 9.74 BCM) -Irrigation, water supply and hydropower; the Omkareshwar dam (0.8 BCM) for irrigation, Maheswar dam for hydropower. The major and medium reservoirs to be built in Madhya Pradesh in Stage I (six dams) have a live storage of 15.75 BCM.

Krishna

Basin - Narayanpur and Alamatti Dams in Karnataka (2.282 BCM) - Irrigation, water supply (municipal and thermal station)

Indus - Thien Dam (2.3 BCM) -Irrigation, power and drinking water

Bangladesh Context

The total irrigable land in Bangladesh is 7.6 million hectares, of which only 4 million hectares was being irrigated in 1996-97 (Ahmad et al., 2001). About 70% of the irrigation water requirements in 1996-97 were met by ground water sources. In a normal year of agricultural production, there is a shortfall of food grain production of 1.5 to 2 million tonnes (Ahmad, 2000). Increasing food grain production needs to be accorded the highest priority, if the growing population of Bangladesh is to be adequately fed. The increase in irrigation intensity could play an important role in raising agricultural production.

An additional area of 3.6 million ha can be brought under irrigation. There is ample surface water available for meeting the irrigation requirements. The surface canal water at present accounts for only 5% of the total area under irrigation. Bangladesh thus needs to develop water resource projects with irrigation components. This would require massive investments, and the international development agencies will have to play a very important role in the development of the irrigation sector. In this regard, a number of development options have been examined and are discussed below.

a) Ganges River

Bangladesh is planning a diversion of the Ganges waters into the southwest area (**Figure 14**), which will go a long way towards increasing the agricultural productivity of the area. This area has a deficit in food grain production. Increased saline intrusion and reduction in the flow of the Ganges threaten water supply to the domestic and industrial sectors. With the signing of the treaty for the sharing of Ganges waters in 1996, Bangladesh plans to utilize its share by constructing a Ganges Barrage Multi-purpose project.

The project site is envisaged at Pangsha, about 60 km downstream of the Hardinge Bridge on the Ganges River (BWDP, 1984). The Pangsha project is expected to bring widespread benefits to all sectors of the economy. The major objectives of the project include:

- Restoring the basic resources of the region, and safeguarding them from further degradation;
- Increasing agricultural production;
- Providing the required flows through the Gorai in the dry season to check salinity intrusion;
- Providing an impetus to overall development by improving livestock and fisheries resources, encouraging industrialization, and creating employment opportunities.

(b) Brahmaputra River

A barrage on the Brahmaputra at Bahadurabad could serve parts of the NW and most of the NE region. However, these areas are rich in groundwater, and generally free of arsenic contamination. Thus the benefits would be few, and the costs high. The maintenance of navigation routes within these regions is more cost effective if achieved by dredging than by augmenting flows.

(c) Meghna Barrage

A barrage on the Meghna at Bhairab Bridge would bring navigation benefits in the NE, conserve surface water, and reduce irrigation pumping costs. However, preliminary analysis indicates that it is unlikely to be economic. Here as elsewhere, there are obvious advantages in combining barrages with bridges wherever possible.

(d) Pumped Extraction at Chandpur

An enlarged pump station at Chandpur could supply water-short areas of the SE, and may be economical, as salinity there prevents the use of groundwater, and social benefits would be high. The river/khal system can be used to distribute water so that land acquisition costs would be low. Past experience has been that the cost recovery of such projects is low.

(e) Other Diversions

Dredging and training works to divert water into the Gorai, Dhaleswari and Old Brahmaputra are all possible, but diverted flows are likely to be small, operational costs high, and downstream dredging costs increased (WARPO, 2000). Spoil disposal will present a problem after a few years, if not from the start.

(f) *Augmentation of Main Rivers through Regional Cooperation*

With the Ganges Water Treaty in place, Bangladesh has sufficient dry season water resources in the major rivers, and there appears to be no need to augment dry season flows on these. Regional cooperation could, however, significantly reduce the costs of river development, if structures can be designed to maximize the use of available flows. Inflows on all transboundary rivers need to be secured by treaties similar to the GWT, with emphasis in the East, which is largely dependent on surface water.

Nepal context

An assessment of the water availability and demand in the various basins has shown (WRSF Consortium, 2000) that following interventions by way of implementation of flow regulating storage type projects for hydropower generation, irrigation, flood control, low flow augmentation have to be made in order to meet the future demand of water for various purposes. The terrain of the northern and middle belts of Nepal offers excellent sites for storage reservoirs. Of the 28 potential reservoir sites identified, nine are classified as large with an aggregate capacity of 110 BCM, with each site having a gross storage capacity of over 5 BCM (IIDS, 1996). Some potential projects in different basins are discussed below.

Kankai Basin: Kankai Multipupose Project, Mai Loop 2 Project;
Koshi Basin: Sun Koshi High Dams, Koshi High Dams, Dudh Koshi Project;
Bagmati Basin: Bagmati Multipurpose Project;
Gandak Basin: Kali Gandaki 2, Burhi Gandaki, Andhi Khola;
West Rapti: Naumure Project;
Babai Basin: Sharada Babai Storage Project;
Karnali Basin: West Seti, Karnali (Chisapani);
Mahakali Basin: Pancheswor Multipupose Project.

These projects will not only generate power and provide irrigation facilities to major land areas in Nepal but will also provide major downstream benefits to India in terms of low flow augmentation, irrigation water, and flood control benefits. The number of projects that can be implemented by 2025 will depend on several factors at the national level, and the availability of international financial assistance.

Pakistan context

At present, irrigation accounts for about 97% of the total water requirements. The competitive demand for water from different sectors has not yet emerged as a key issue in Pakistan, but it may become a major issue in the future. There is only limited potential for increasing water supply in Pakistan from surface or ground water sources. Some experts believe that out of 43-49 BCM/year flowing to the sea, a total of about 31-37 BCM/year can be used for future development through construction of multi-purpose storage projects (Gill, 2000).

The hydro-geological and topographic conditions of the country favor construction of new reservoirs on the river Indus. The post-Tarbela discharge data record shows an unused flow of 18.7 BCM downstream at Panjnad. Projects to utilize this flow need to be developed. Even after the development of additional water resource facilities, there will be a shortfall of at least 105-110 BCM/year of water. Pakistan not only has limitations of availability of land, but also on the availability of water, since the Indus Water Treaty allocated to Pakistan only the waters of the western rivers.

According to the last engineering estimate before it was shelved, the multi-purpose Kalabagh Dam was designed to store 7.38 BCM (6 MAF) of water at a cost of Rs. 180 billion (Kalabagh Consultants, 1987, WSIP, 1990 adjusted for current prices using Table 8.16, Economic Survey). Of this, 54 billion rupees were attributed to its irrigation component.

Furthermore, according to the proponents of this approach, all the remaining 24.6 to 36.9 BCM that flow into the Arabian Sea during the monsoon season should be harnessed for agriculture during the low season. This would entail the construction of a series of reservoirs on the main rivers and in parallel depressions. These reservoirs would also regulate the flow in the rivers during floods.

The reduced flow of the Indus into the sea has reduced the annual quantity of silt delivered into the delta. If the government of Pakistan implements further development proposals, and reduces the Indus' outflow to 12 BCM/year, or even zero, as quoted in the report, the annual quantity of silt delivered could become dangerously low and affect the long-term sustainability of the Indus Delta. Reduced freshwater flows in the Indus will increase the salinity of the tidal creeks in the delta system, and could stunt mangrove growth.

A single species of mangrove dominates the Indus Delta (over 95% of the trees). Increasing salinity levels in some regions of the mangrove forests have already created observable declines in the growth of new trees. The loss of silt is even more dangerous given the sea-level rise of 1.1 mm/year known to occur near Karachi. Mangroves can survive sea-level increases as high as 2.5 mm/year if there is a sufficient discharge of sediment-bearing waters into the mangrove forests. Without any delivery of silt, mangroves cannot sustain themselves for rates of sea-level rise of 1.2 mm/year. With increases in sea-level rise expected as a result of global warming, the mangroves of the Indus Delta could suffer a severe long-term threat.

Apart from its sediment load, the Indus River affects the delta region through its influx of freshwater and the concomitant impact on salinity levels. If the salinity levels increase sufficiently within the inter-tidal creeks that make up the trans-border areas and there is a significant impact on mangroves, coastal erosion could increase rapidly. The loss of mangroves would also cause cyclones to reach much further inland, as well as resulting in the loss of important aquatic species.

6.9 River diversion schemes

While storage dams are major projects, the river diversion schemes are just run of the river schemes, which are termed minor irrigation schemes or hydroelectric projects. These schemes play an important role in irrigation and hydroelectric power generation. Such projects have the following advantages:

- Limited investments are required;
- The time and cost over – runs are small;
- There is no time lag in the utilization of potential created, as development of irrigation systems could be completed simultaneously with the diversion structure;
- Water is used more efficiently;
- There is greater control over implementation and subsequent O&M;
- Conflict between upstream and downstream farmers is minimized;
- Problems of water-logging and salinity are rare.

In view of the above, greater emphasis is being placed on diversion schemes in minor irrigation and also in run of the river hydroelectric projects (25% of the installed capacity of hydro power is from run of the river schemes in India, Nepal's present power and irrigation schemes are mostly river diversion schemes). But this type of diversion can provide limited irrigation or hydropower, since the diversion of water is dictated by the minimum flow in the river with 75% probability for irrigation, 90% probability for hydroelectric projects, and 100% probability for water supply schemes. Hence such schemes can only be supplementary to major projects.

When diversion schemes are taken in tandem with major storage projects in the same river on the upstream, the benefits from the same diversion schemes get doubled or quadrupled. It is for this reason that most of the diversion schemes for irrigation are planned for implementation in stages, to cater for upstream cascade development of storage projects on the main stem or on the tributaries of the river.

6.10 Rain-fed or dry land agriculture

India's plans

The irrigation water requirements have been estimated based on the fact that irrigation intensity is likely to increase from the present level of 40% to 67% by the year 2025 (NCIWRDP, 1999). At present, the area under dry land agriculture is quite low. An area of 70% of the total arable land (140 M.ha) produces only 40% of the food grains, while the 30% irrigated area produces 60% of the total food grains in the country. With greater emphasis being given to such agriculture, it is expected that there will be a significant increase in the area under dry land agriculture, leading to a reduction in the total irrigation water requirements in the coming years.

It is expected that there will be significant increases in yields from dry land agriculture in the near future as a result of improvement in techniques. This is also expected to reduce the overall requirement of increase in irrigation intensity. At present half of this rain-fed area is paddy area, where there is excess water badly in need of proper management, while the remaining half is entirely dependent on the rains and only appropriate rainwater conservation measures can provide water for drinking and irrigation purposes. In this context, the Government of India has adopted the Watershed Development Approach, which propagates Water Conservation/Harvesting Technology in rain-fed areas. This program allows a degree of flexibility in choice of technology, decentralization of procedures, provision for sustainability and active participation of watershed community in the planning and execution of their watershed development projects. Similarly, programs sponsored by the central government, such as soil conservation in the catchments of river valley projects, Integrated Watershed Management in the catchments of flood prone rivers, Watershed Development in Shifting (Jhum) Cultivation Areas, reclamation of Alkali soils, Drought Prone Areas program, Desert Development Program, and Integrated Waste Land Development Project, are all unique initiatives that have been sustained for over 40 years with large investments. Over 27.5 M.ha out of a problem area of 107 M.ha had been treated up to the end of the Ninth Plan in March 2002. A Perspective Plan for the reclamation and development of an area of 88.5 M.ha with active participation and sharing of investment by the beneficiaries is proposed for implementation during the next four Five Year Plans (up to 2022).

Pakistan's plans

The rainfed area, called *Barani* Area, for agriculture in Pakistan is diverse, integrated, and sustainable as it incorporates many elements into the system. Although *barani* agriculture yields lower levels of productivity, its balance between on-farm and off-farm opportunities, its integration of livestock, forestry, and crops and its use of inputs represent a more sustainable system of production. The soils in the *Barani* areas are generally fertile as there is no major problem of salinity and water-logging. The climate is favorable for agriculture and there exists un-harnessed potential for further development. A major constraint for sustainable agriculture is the absence of assured irrigation supplies. There are certain pockets in the *Barani* areas that have considerable amounts of ground water, which can be exploited for irrigation purposes, while other *Barani* areas are suffering from over-exploitation and depletion. Several approaches to improve the water availability situation in these areas, and thus to enhance crop yields, have been undertaken in recent years. These are discussed below.

Water storage tanks: The water sources (perennial streams and tube-wells) in mountainous areas and plateaus often have small discharges. A direct application of these low flows results in high conveyance losses. Water storage tanks can improve the efficiency of water use by increasing the volumetric flow through intermittent and timely releases. Water from the storage tanks can be conveyed to the point of use either through lined watercourses or through small diameter pipes. Storage tanks can help improve the productivity of cultivated land. Barren lands can also be brought under cultivation owing to the increased effective availability of water.

Water Lifting Devices: The locally developed low cost technology of hydra-ram pumps does not require an external energy source. It can be introduced in the hilly and sub-mountainous rain-fed areas of the country. These devices can be installed on natural springs and perennial and non-perennial streams to lift water to irrigate upland crop. The pump runs with the kinetic energy of flowing water and does not require any engine or motor for its operation. This technology can be employed even on the streams having small discharges and can run day and night for years. A drip irrigation system can also be linked to a hydra-ram device to enhance the efficient use of scarce water.

Water turbine pumps can be installed on natural streams and springs to lift water for irrigating upland crops. The water turbine pump technology has proved successful in China and Thailand, where more than 30,000 pumps are in operation. The pumps can also be used to generate electricity. Such dual-purpose pumps can contribute to agriculture development in Pakistan's *Barani* areas.

Advanced Irrigation Technologies: In the *Barani* areas, water must be used judiciously, since it is a scarce resource. Furthermore, in most *Barani* areas, the terrain is undulating and gravity irrigation from tube-wells or other sources is not practical. In other tracts, such as Thal, where the soil is sandy, gravity irrigation results in significant seepage. On fertile soils in such zones, an efficient irrigation system has the potential of raising crop production two to three fold. At such locations, advanced technologies, such as drip or trickle irrigation, portable single-gun units, or multi-sprinkler hand moved systems could be used for raising high value crops.

Hand dug wells and 'Peter' Pumps: Apart from stream flows, small pockets of fresh ground water are also available at certain locations in the rain-fed areas. Dug wells can be constructed to skim the small pockets of ground water. A feasibility study (Gill, 2000) conducted for the Pothowar Integrated Agricultural Development Project found it easy to construct dug-wells using locally available materials. Small motors can be added to pump water from the shallow depths. This technology can contribute to *Barani* development at a small scale.

6.11 Watershed Management, Catchment Area Treatment and Soil Conservation

The countries of the region have adopted sound watershed management as a good and long-term strategy to combat the threat of floods and preserve the ecosystem. Watershed development has an important place in WRD but cannot be a substitute for the major, medium and minor irrigation schemes. The advantages and limitations of such programs are given below.

Advantages

- The basic concept is to maximize retention of precipitation where it occurs and minimize run-off from the watershed. It is a rainwater harvesting mechanism, partly above the ground (storage) and partly underground (recharge);
- It has considerable potential in certain situations of low rainfall (greater than 700-750 mm), erodable slopes, non-availability of good storage sites, mostly in arid and semi-arid areas of the country. It facilitates utilization of rainwater before it reaches large rivers for micro irrigation;
- The physical and hydrologic characteristics of the area influence the success of the program.

In India, the potential which watershed development holds for micro-irrigation may be of the order of 3-4 million ha.

Limitations

- It is not applicable universally;
- In areas with less than 700 mm rainfall it would not give the desired results, as it would not be possible to grow even one crop;

- There are serious planning and design problems, since designing such structures for large storms and for reasonable levels of sedimentation may not be feasible;
- Shallow storage depths also increase evaporation losses;
- It is not cost effective;
- It has a short life and there are maintenance difficulties.

Considering both the advantages and the limitations referred to above, this type of development can at best be complementary to other water resource programs.

With the philosophy of integrated river basin development getting greater emphasis, the concept of watershed management has gained a significant role. It has also been recognized that bed cultivation practices such as jhooming (shifting cultivation practices in the hills of N.E. India), burning and cutting of forests, overgrazing, and forest fires have contributed to catchment degradation resulting in increased runoff, more soil erosion and excessive sediment transport. If a watershed is treated and managed scientifically, it will retain more rainfall on the land, improve the recharge of groundwater, and reduce silt load.

A special program for watershed management of reservoir projects has been in operation in India for many years, with the objective of reducing the silt load into reservoirs to enhance their utilizable storage capacity and provide a longer life span. The storage saved is as precious as storage created, and the program of watershed management thus needs to be continued. Incidentally, it is also accepted that this program can reduce soil erosion substantially and moderate smaller and medium floods.

Bangladesh is concerned about the increased amount of sediment in the GBM river system because of the indications of constituent material getting coarser, with a higher percentage of sand and lesser content of organic matter. The probable causes are attributed to environmental damage in the upper reaches of the catchments in China, Nepal and India. A regional approach is therefore suggested - under an appropriate institutional structure - for integrated catchment planning and management.

Within Bangladesh, the reforestation of denuded areas to obtain tree cover in at least 20% of the area is proposed (Ahmad, 2000). Catchment management, especially on steep slopes for soil conservation, is also envisaged. Other measures under consideration are: an implementable forestry master plan, full enforcement of regulations against illegal logging, and large scale tree planting schemes through social forestry programs.

In Nepal, the Department of Soil Conservation and Watershed Management, established in 1974, started a number of soil conservation and watershed management works with its own resources (GoB, 1995). A number of bilateral and multilateral donor agencies have also supported this activity. The program is now addressed through integrated development schemes, with the active participation of beneficiaries. However, the assessment of such projects from the perspective of contributing to ecological security has not yet taken place.

6.12 Interbasin Diversion

This is a geographical option for transferring water, increasingly under consideration across basins because of marked differences in water surpluses and gaps between nearby river basins. Even though such transfers are attractive options in principle, they run into many of the same problems as large dams, and are unlikely to be significant in the period up to 2025 considered in the WASSA project. Interbasin transfers have been examined very intensely in India and to a limited extent in Nepal (WRSF Consortium, 2000 and WECS, 2002). Bangladesh has also examined in the past such an option for transfer of the Brahmaputra water into the Ganges within its territory, but has not pursued it in recent years. The Indian and Nepal perspectives in this respect are discussed below.

6.12.1 The Indian Perspective

The water scarcity and water stress situation in the country has been discussed in the earlier sections of this report. There are imbalances in water availability in the basins of Cauvery, Sabarmati, Pennar, the east flowing rivers between Pennar and Kanyakumari, the west flowing rivers of Saurashtra and Kutch, and the entire region of Rajasthan. It has been argued that the in-basin supplementation or augmentation from surface and ground water is limited (IWRS, 1996). The solution advocated is to create storage potential in the water surplus basins and carry out interbasin transfers. The National Water Policy (MOWR, GOI, 1997) has stressed this need stating that "Water should be made available to water short areas by transfer from one river basin to another, based on national perspective, after taking into account the requirements of the areas/basins".

There are also views that question the need for an interbasin transfer in the immediate future. NCIWRDP (1999) does not appear to think that such transfers are necessary, at least for the next 25 years. Notwithstanding some existing examples in the country, new transfers may be non - starters in the immediate future. It may not be altogether advisable to depend on interbasin transfers to bridge the water supply – demand gap up to 2025, but may be feasible in the longer term. Since the option has to be examined, we elaborate on the issue here.

The Brahmaputra-Ganga-Barak river system accounts for 40% of the surface water resources of India, while Rajasthan State has only 1% of the surface water resources of the country. The imbalance has to be bridged to attain inter-regional equity with respect to the socio-economic well being of the people of the country. A viable approach to doing so is to plan for and ultimately implement interbasin diversions. In the early 1970s, Dr K.L.Rao (IWRS, 1996) proposed the famous "Ganga-Cauvery link", while Captain Dastur suggested his plan of the "Garland Canal". However, the Ministry of Water Resources embarked on an elaborate exercise in 1982, through the specifically established National Water Development Agency, to plan all possible interbasin diversions in the river basins of the country (NWDA, 2000 & 2001). It is not a new approach, but a continuation of similar plans implemented or under construction for many years prior to and after the independence of the country. The important interbasin diversions implemented, under implementation, and planned are listed below.

6.12.1.1 Existing Trans basin diversions

a) For multi purpose uses:

i) The Periyar Vaigai project, completed in 1896, is an interbasin diversion from the Periyar dam built across the Mulla Periyar River, a west flowing river in Kerala. It provides irrigation to an area of about 76,893 ha in the Madurai district of Tamil Nadu.

ii) The Permabikuliyar - Aliyar Project integrates the waters of seven rivers viz., the five west flowing rivers Nirar, Sholayar, Parambikulam, Tunakadavu, & Peruvaripallam, and the two east flowing rivers Aliyar and Palar. Dams have been built across all these rivers, and inter - linked through tunnels diverting the west flowing river waters into the east flowing rivers. They provide irrigation to 97,130 ha in Tamil Nadu and 10,000 ha in Kerala, and also generate 185 MW of hydropower.

iii) Krishna waters (East flowing), to the extent of 3.5 BCM, have been diverted, taking advantage of the deep escarpment into the Western Ghats, to generate hydropower at the Koyna Hydroelectric Project and the Tata hydroelectric stations.

iv) Rajasthan Canal Project (Indira Gandhi Nahar) is the largest trans -basin diversion built so far in the country, whose Stage I and Stage II have been substantially completed, providing irrigation to an area of 540,000 ha in Stage I and 964,000 ha under Stage II. The waters of the Indus rivers (Indian part) allocated for diversion to Rajasthan is 11.9 BCM (9.71 MAF). Of this water allocation, 11.5% is committed to providing municipal and industrial water.

b) For water supplies to urban and rural conglomerates

v) The city of Mumbai (Bombay), the largest urban conglomerate in India, is receiving most of its supplies of water through an interbasin diversion from the Vitarana and Ulhas river basins. The present water supply is 1.06 BCM, which is expected to increase to 1.97 BCM by 2021 (NWDA, 2001). Plans for trans basin diversions from other basins have been examined as discussed later;

vi) The inter basin diversion of Bhavani River waters to Coimbatore and Tiruppur cities in Tamil Nadu;

vii) Chennai city is provided with Krishna river waters (425 MCM or 15 TMC including transmission losses) through the interbasin Telugu-Ganga canal from the Srisailam reservoir on the Krishna, over a distance of more than 400 km. The demand is much larger than this, and a new proposal is under consideration, as discussed later.

viii) The city of Hyderabad lies in the Krishna basin. It gets the bulk of its water supply from the Manjira river (a tributary of the Godavari river) by pumping water (150 MCM) from the Manjira reservoir over a distance of 82 km with a head of 40 m. Further supplementation is being planned through more inter - basin diversions.

ix) Visakapatnam, the highly industrialized port city on the East Coast, is supplied with water from the reservoirs built on the small east flowing rivers of Gosthani, Sarada, Tandava and Yeleru. Future water demands can be met only by an interbasin diversion from the Godavari, which is being planned.

x) Indore city, though located in the Chambal sub-basin of the Ganga basin, gets its water supply (55 MCM) from the Narmada river through a interbasin pumping over 550 m head in five stages. The future projection of 200 MCM can also be met only from the Narmada River.

xi) Delhi, the capital city of India, gets water from the Bhakra reservoir on the Sutlej of the Indus basin (0.28 BCM) through inter-basin transfer over a distance of 300 km. It also gets supplies from the Ramganga river, a tributary of the Ganga, through an interbasin diversion over a distance of 200 km apart from the in-basin supplies from the Yamuna river from the Western Yamuna Canal. The future requirements are very large and can be met from new reservoirs to be built on the Yamuna (Renuka and Kishau dams) and also from the Tehri dam under construction on the Ganga.

xii) Calcutta City (Kolkatta) meets its water needs from the Ganga River water diversion at Farakka on the Ganga in West Bengal (Figure 14). This diversion also helps navigation along the Baghirathi and further on along the Ganga upstream of Farakka upto Allahabad, and caters to industrial water needs and super thermal station. The international aspects of this diversion have been discussed in a separate volume of the WASSA reports.

6.12.1.2 Interbasin diversions under construction

1. The Sutlej-Yamuna link canal, a interbasin diversion scheme to utilize 7.06 BCM (5.74 MAF) of Indus waters in Punjab, Haryana and Rajasthan, is under implementation.
2. The largest interbasin transfer in the world will be the Narmada Canal, taking off from the Sardar Sarovar Dam in Gujarat which is under construction. It envisages the utilization of 11.7 BCM (9.5 MAF) of water for irrigation and water supply, enriching several water - short basins en-route its 458 km long travel in Gujarat and 74 km in Rajasthan (Figure 13). It will irrigate 1.8 M.ha in Gujarat and 75,000 ha in Rajasthan. The allocation of water supply is 1.06 BCM (0.86 MAF) (for which use?) and 0.25 BCM (0.2 MAF) for industrial use. This is achievable before 2025.
3. The Tista - Mahananda link is the first interbasin endeavor to divert Brahmaputra basin waters into the Ganga basin. The diversion from the Tista barrage near Gajaldoba, after the river emerges from the hills in West Bengal, envisages irrigation of 0.925 million ha (right bank canal 710,000 ha and left bank canal 215,000 ha) to be developed in stages as upstream storages are built.

6.12.1.3 Trans Basin Diversions under Planning

The National Water Development Agency (NWDA) was set up in 1982. The mandate is to give shape to the National Perspective Plan evolved in 1980 by the Ministry of Water Resources for water development, keeping existing uses undisturbed and awards in view, and providing for the reasonable needs of the basin states for the foreseeable future (NWDA, 2000 & 2001). The National Perspective enunciated two components viz., the Himalayan Rivers Development and the Peninsular Development. Inter-alia, the scheme envisages the creation of irrigation potential for about 35 M.ha. (25 M.ha. from surface irrigation and 10 M.ha. from increased use of ground water) and hydropower generation of about 30,000 MW, a part of which would be in Nepal and Bhutan.

The Himalayan component envisages construction of storage dams on the main Ganga and the Brahmaputra and their principal tributaries along with inter - linking canals to transfer surplus flows from the Eastern tributaries of the Ganga to the west. The envisaged benefits of this plan include provision of irrigation to 22 M.ha. in the Ganga -Brahmaputra basin in Haryana, Rajasthan, Punjab and Gujarat, besides providing 1120 cumecs (cubic meters per second) to Calcutta port and hydropower generation of 13,000 MW in Nepal and India. The peninsular component proposes four different parts viz., i) Inter - linking of Mahanadi -Godavari-Krishna-Cauvery rivers, ii) Inter -linking of west flowing rivers north of Bombay and South of Tapi, iii) Inter - linking of Ken-Chambal and, iv) diversion of other west flowing rivers. This development is expected to provide additional irrigation benefits to over 13 M.ha.

The National Water Development Agency (NWDA) has done a fair degree of pre-feasibility study on both the above components of the perspective plan. However, the peninsular component's pre-feasibility has been established first in greater detail.

The basic approaches adopted by NWDA (2000 & 2001) in its studies are:

- Water balance study of the basins and sub basins by analyzing the rainfall, stream flow, existing water utilization and other relevant data;
- 75 % dependability for the ultimate scenario;
- Population of the country likely to stabilize by 2050 and hence projections are made for that time frame;
- Ultimate water requirement for irrigation assessed based on all existing on going and proposed or identified irrigation projects in the basins, including imports and exports, if any, into or out of the basin;
- Requirement for domestic water supply, hydropower, and industries, based on reasonable assumptions;

- Preliminary water balance studies carried out to assess the quantum of water that could be transferred from surplus basins to deficit basins;
- Alternative alignments identified for various links for such transfers with due consideration of existing or already proposed reservoirs and diversion structures with the concept of substitution and exchange (water from one river delivered at the lower reaches of the second river and drawn from the second river basin at appropriate higher locations);
- Gravity flows to the maximum extent with limited pumping.

A) Peninsular inter - basin links

Based on the broad principles mentioned above, the NWDA has evolved 16 possible interbasin link canals in peninsular India. The Mahanadi and Godavari rivers are the surplus basins on the east identified for meeting water deficit in the Krishna, Pennar, Cauvery, and Vaigai/Gundar river basins of the east. This involves 9 links, collectively known as the "Southern Water Grid". The other 7 inter basin links relate to: I) Five surplus river basins between Par and Tapi feeding the deficit basins of North Gujarat through the Narmada river, 2) Surplus in the Damanganga to Pinjal to meet the city water needs of Mumbai, 3) Pamba and Achankoil surplus to meet the deficit in the Vaipar basin, 4) Netravati surplus to meet deficit in the Hemavati basin, 5) Bedti surplus to meet the deficit in the Varda basin, 6) Surplus of Ken basin to feed deficit areas in Betwa basin, and 7) Surplus of Kalisindh basin to meet the deficit in Chambal basin.

The nine links of the "Southern Water Grid" (A key plan showing the links is depicted in **Figure 15**) are explained below.

i) Mahanadi to Godavari link - The diversion is envisaged from the proposed Manibhadra reservoir in Orissa into the existing Dowleswaram barrage on the Godavari in Andhra Pradesh. The surplus proposed for diversion is 11.176 BCM out of which accounting for enroute utilization of 3.954 BCM and evaporation loss of 822 MCM, release into the Prakasam barrage would be 6.5 BCM.

ii) Godavari to Krishna link - The surplus delivered at Dowleswaram on the Krisnna is proposed to be diverted in the upstream through three links. The first link is from the proposed Inchampalli reservoir to the existing Nagarjunasagar reservoir. The surplus proposed for diversion is 16.426 BCM, enroute utilization is 1.85 BCM for irrigation, utilization under Nagarjuna sagar is 4.41BCM, release into Krishna for further diversion is 9.79 BCM, and transmission loss is 0.375 BCM.

iii) From the proposed Polavaram reservoir below Inchampalli reservoir on the Godavari into the existing Prakasam barrage on the Krishna river link - Diversion is 5.33 BCM (includes 2.27 BCM as originally planned under Godavari Water Disputes Tribunal Award), enroute utilization is 1.40 BCM, 162 MCM is for domestic and industrial use, transmission loss is 822 MCM and utilization in the Krishna is 3.50 BCM

iv) From the proposed Inchampalli reservoir on the Godavari into the proposed Pulichintala reservoir on the Krishna link - Diversion is 4.37 BCM out of which enroute utlization is 2.60 BCM (including 470 MCM as originally planned under Inchmpalli project), transmission loss is 150 MCM and use under Pulichintala right bank canal is 1.623 BCM.

v) Krishna to Pennar Link - Three links are proposed in this diversion. The first link is from existing Nagarjunsagar reservoir to existing Somasila Reservoir on the Pennar river. Diversion from Nagarjunasagar is 9.79 BCM with enroute utilization of 810 MCM. After accounting for transmission loss of 332 MCM, the release to Pennar is 8.55 BCM

vi) Srisailam reservoir on the Krishna to Pennar river link - Diversion of 2.30 BCM. After accounting for transmission loss of 215 MCM, the release into Pennar is 2.10 BCM.

vii) Alamatti reservoir on the Krishna to Pennar link - Proposed diversion is 1.98 BCM, en route utilization is 1.78 BCM, and transmission loss is 202 MCM. There is no release into Pennar.

viii) Somasila reservoir on the Pennar to Grand Anicut on the Cauvery link - Utilization in the delta of Pennar river basin is 1.30 BCM, diversion for Telugu Ganga Canal for Chennai water supply and enroute irrigation is 890 MCM, domestic and industrial water use is 1.16 BCM. Accounting for transmission loss of 385 mCM the release to Cauvery is 3.86 BCM.

ix) Existing Kattalai regulator on the Cauvery to Gundar River crossing Vaigai River downstream of Madurai - Diversion proposed from Cauvery is 2.25 BCM. Irrigation utilization enroute is 2.01 BCM, domestic and industry use is 109 MCM, and transmission loss is 136 MCM

In the entire scheme of above interbasin links (shown schematically in **Figure 16**), there are eight (8) reservoirs - four are existing and four more (4) are planned by the states - two barrages, one diversion (anicut) and one regulator which are all existing. The grid has outstanding potential for realization, if not fully, at least partially before 2025, provided the Manibhadra reservoir in Orissa and Inchampalli reservoir in Andhra Pradesh (both under the list of planned reservoirs mentioned in para 5.7 above), which hold the key to the entire grid network, are finalized soon. There are, however, many stumbling blocks. The states of Orissa and Andhra Pradesh have to agree that there are surpluses to share with other states of Tamil Nadu and Karnataka, particularly when they are claiming that all the flows could be utilized within their own state. The Inchampalli high dam as proposed now has submergence problems. Optimization studies seem to indicate an alternative of a low dam with minimum environmental and ecological impact instead of the high dam proposed by the Andhra Pradesh State (even development in stages could be conceived). The concerned states have to act expeditiously to discuss the issues and come to a settlement soon. The central government could take a lead in the matter of resolution of disputes through negotiations.

From the other seven (7) links of the peninsular development mentioned above, the links that have the best prospect of realization before 2025 are:

a) the Damanganga -Pinjal link is almost entirely within the State of Maharashtra, and it would be essential to build it to meet the domestic and industrial water demand of Mumbai. It envisages three reservoirs (Bhugad, Kargill and Pinjal) with tunnels connecting the reservoirs. The possible diversion at 95% availability is estimated to be 1.49 BCM (NWDA, 2001). NWDA is firming up the feasibility of this proposal. The interstate problem is minimal as only a small part of the Damanganga catchment lies in Gujarat.

b) the Netravati -Hemavati link in the Cauvery basin lies entirely within Karnataka State. The cost is high, but can be justified by the development of high value agriculture, horticulture and floriculture. If it is to augment water supply to Bangalore City, the link envisages transfer of 188 MCM of water at 75% dependability or 146 MCM at 100 % dependability, which is the norm for domestic water supply. But this falls short of the projected requirement for the city. An alternative proposal is now under consideration.

c) The Bedti -Varda link project in the Tungabhadra basin lies entirely in Karnataka State, and has a good likelihood of being built.

II) Himalayan component

Some of the augmentation proposals linking Brahmaputra and Ganga have been discussed under bilateral water issues in another volume of this study, in the limited context of augmenting the Ganga flow at Farakka. From India's national perspective, the studies have not reached a stage where one could categorically say that large scale transfers from the north bank tributaries of the Ganga (Kosi, Gandak and Ghaghra) to the west, and the Ganga-Brahmaputra link extending into Mahanadi river and further into the south of India, are feasible for implementation before 2025. Hence those links are not discussed in this report.

6.12.2. The Bangladesh Perspective

Under a 'package proposal' for a permanent division of cross-border rivers between Bangladesh and India mooted in the late 1980's, a new technical proposal put forth was centered around the long term development of barrages within Bangladesh, across both the

Ganges and Brahmaputra, with an interbasin link canal connecting the two rivers to allow for transfer of water from the Brahmaputra to the Ganges (Figure 14). Crow (1995), citing this proposal, has observed:
"Because of the political sensitivity of this scheme (in Bangladesh), these projects were seldom referred to in the public accounts or in the joint official reports or in discussions between India and Bangladesh."

This was apart from the alternative of interbasin diversion of Brahmaputra waters from the Jogigopa barrage in India, passing through India and Bangladesh and India, and emptying into the Ganga above the Farakka barrage. These two proposals are shown in Figure 15. The details of bilateral discussions between the two countries are discussed in Volume 3, dealing with water conflicts between countries.

6.12.3. The Nepal Perspective

Ground water utilization projections show that about 53,000 ha and 293,000 ha of land in the mountains and hills, respectively, will be covered by irrigation by 2016/17, which will exhaust almost all available land that is suitable for agriculture. By that time, all potential groundwater projects would also have been developed. In the remaining irrigable areas, where groundwater resources are not good, three interbasin major irrigation projects to transfer water from "surplus basins" to "dry basins" have been proposed. These are:

- Bheri-Babai Interbasin Transfer Project covering Bardia District (59,416 ha);
- West Rapti Multipurpose Project covering Banke, Kapilvastu and Deukhuri Valley; and
- Sun-Koshi Kamal Interbasin Transfer Project covering Mahottari, Dhanusa, Siraha and Saptari Districts (138,000 ha).

6.13 Water Rights

The United Nations guidelines (United Nations, 1991) state: "Any water law to be drafted or amended, should be based on a number of principles, which are in particular relevant to areas deficient in water resources, but also applicable, with certain modifications, to other uses." It further defines that "Adequate powers must be vested in the authorities to control the utilization of all water resources in the country or in specific areas to prevent their depletion or pollution, and to enable their development and exploitation for the benefit of the area as a whole."

With the above broad guidelines, let us look at the water rights prevailing in the countries of the region with respect of surface water and ground water uses, and consider any changes that may need to be introduced.

6.13.1 India

Surface water

The Government of India Acts on water, and the State Government Acts on Irrigation and Drainage, have made it abundantly clear that surface water is public property, whether it is natural flow in a river, or stored behind a dam or a natural lake. It is also well known that the government controls the use of such water and allocates it to users. Under the present water allocation policy, at the state level (since water is a 'state' subject), water allocation is supposed to be assured, depending on availability, during every season in every year. However, the established rights protecting such allocations under the Irrigation Acts of the states (a colonial legacy from the British who ruled India for 200 years) state that “Whereas throughout the territories to which this Act extends, the provincial government is entitled to use and control for public purposes the water of all rivers and streams flowing in natural channels, and of all lakes and other natural collections of still water; and whereas it is expedient to amend the law relating to irrigation, navigation and drainage in the said territories." These have probably served the purpose for government controlled irrigation development.

The current laws lack specificity with respect to user - type rights in natural surface waters. This has resulted in legal battles by riparians who have the means to approach the courts for legal redress. Are there enough international parallels that can guide the framing of rules to establish new water rights systems? In the United States, the common law with respect to riparians has been dispensed with in the eastern states. As mentioned in the World Bank India Sectoral Review (World Bank, 1998), "It has been done away with altogether as recently as 1995 by Jamaica and in 1989 by the Australian State of Victoria, which has vested in the state a superior "right to the use, flow and control" of all waters in that state for the common good". However, in India, with water already scarce in six river basins and likely to become scarcer in more basins by 2025, it may be essential to implement water rights in selected basins initially where water trading is evident.

Ground water

The current situation is that legal and absolute rights rest with the owners of the overlying land. In the Land Acquisition Act of 1894, in Part I under "Definitions", “(a) the expression ‘Land’ includes benefits to arise out of land, and things attached to the earth or permanently fastened to anything attached to the earth”. Mr. C. Singh, of the Indian Law Institute has commented on the legal and absolute rights of ground water as under:

“Ground Water is considered an easement connected to land under tenure laws and the dominant heritage principle implicit in the Transfer Property Act IV of 1882 and the Land Acquisition Act of 1894. Under the law of riparianism applicable in India, ownership of ground water accrues to the owner of the land above and its use and disposition are governed by the tenancy Laws. By virtue of these laws, groundwater is “attached like chattel” to land property and cannot be transferred separately from the land to which it is attached”.

From the above explanation it is established that the owner of the land has full control over the ground water resources available under his property, and this is a major factor which has contributed to the over - extraction of the resource. Further, the lack of any kind of regulation has compounded the problem. The Ministry of Water Resources, Government of India, realizing the gravity of the problem in many states of the country like Andhra Pradesh, Gujarat, Haryana Punjab and Tamil Nadu, has drafted a Model Ground Water Bill. This bill suggests strict licensing in areas of ground water overdraft, on new ground water pumps, both private and public, to enforce the law more rigorously, and to impose penalties for violation.

Suggestions for Legal water rights

Considering the above existing situation of rights in respect of surface and ground water, the following approach is suggested for appropriate action so that the surface and ground water demands projected for 2025 are utilized in the best interest of the country.

a) Surface water rights

Individual usufructuary (Usufruct is the right of enjoying a thing, the property of which is vested in another -say forest or river - and to draw from the same all the profit, utility and advantage which it may produce, provided it be without altering the substance of the thing) rights are recognized only in the case of natural streams but such rights can be established only by taking legal recourse. Indian courts have accepted that an individual abutting upon a stream can use water if it is done without disturbing a similar benefit to other riparian. The adverse consequences of such a state of uncertainty are the reluctance of the private sector to invest in water projects, constraints in allocation and reallocation of water resources across sectors, and consequent imbalances in water development.

A possible legal question would be the change of water allocations to various uses from those originally granted or in current use. Even the government's sovereign rights considered as absolute rights have been challenged in the courts and upheld. These are issues that need to be addressed and better clarified, since water scarcity and water stress situations in river basins have already occurred and will increase during the next 25 years. The options available to the government to address this situation within the existing riparian rights of individuals are discussed below.

- Existing water rights, if not beneficially utilized, should be withdrawn. The legal right should be limited to allocated quantities to be determined from time to time by the authorities. Conditions should be prescribed specifying quantity and rate of withdrawal, duration of the right, purpose of water use, manner of use, point of abstraction and point of return of excess flows. Legally conferred rights (temporary or permanent) should be transferable to resolve legal ownership rights.
- The right of water consumers should not be linked to a specific source or to a definite category of water. This is to ensure that users, on the strength of specific rights to a definite source, do not hold up development work.
- Water authorities should streamline procedures for accurate registration of water rights of claimants under existing laws, with due regard to existing customs and past use.

- The beneficiary's land holdings and identified water uses for the same, provided water is used in an efficient manner, should become the legal rights with due provision for adjustment to changing demands.
- In water short and water scarce river basins, administered licensing procedures should be immediately introduced, to be extended to other basins gradually, for withdrawal or use of water, whether from sources already exploited or with respect to the new water.
- Licenses should be issued to local authorities regulating the consumption of water for all uses such as agriculture, industry, or domestic use.
- The penal code should be enforced for unauthorized use of water.
- Legal procedures may be introduced for establishing principles for assessing compensation to a consumer disconnected from a source of supply, or for other damages resulting from implementation of water development scheme, including the settlement of any dispute arising therefrom.
- Water courts and joint committees may be considered to settle water disputes between individuals or between an individual and the authorities.
- Enact laws to encourage free trade of water and create water markets.

B) Ground water rights

The model ground water (GOI, NCIWRDP, 1999) bill now under consideration for implementation provides the state governments with stand-by authority to institute a permit system for ground water extraction and use on a selective basis limited to the aquifers. The legislation offers flexibility to direct effort and resources where the need is the greatest. Legislation on these lines has been enacted in the states of Maharashtra, Gujarat, Karnataka, and the Union Territory of Pondicherry. The World Bank (1998) has also suggested a second option of replacing the absolute ownership of ground water with a statutory system of permits for ground water prospecting, extraction and use. This option may be considered if the first option now under the legislative process encounters impediments in implementation.

Some of the salient provisions in the Ground Water Bill deal with:

- Monitoring and evaluation of ground water resources;
- Infrastructure of ground water development, including license for drilling and sinking of tube wells, and installation of wells and tube wells in poor ground water areas;
- Ground water environmental protection, with special measures for public drinking water sources;
- Ground water management for social progress, conjunctive use, conservation and augmentation;
- Artificial recharge in water scarcity areas and subsurface ground water drainage;
- Development, establishment, and upgrading of information systems, research and development, and education and training;
- Ground water regulation and control in critical areas, notification for regulation and control, prohibition on drilling and sinking of wells and tube wells, registration of existing users in notified areas, granting of permits and their cancellation;
- Offences and penalties; and
- Optional mechanisms and power to make rules.

Other rights suggested earlier for surface water could also selectively be made applicable to ground water use rights.

It is desirable that an Act with the provisions mentioned above be introduced expeditiously, so that the central government and the states could define procedures and organizations which would be required to implement the legislation.

6.13.2 Bangladesh

The ownership of water in Bangladesh vests in the state; the individual has only water-use rights, which are not well defined. There is considerable interdependence of decisions about water usage across space and time; and at the sectoral level, there are also many competing and conflicting uses of water.

A comprehensive scheme should be developed to regulate the use of water through prioritizing sectoral allocation, regulating and monitoring the installation and application of water abstraction structures, and ensuring the minimum requirement for stream channel maintenance. Existing laws and regulations relating to water rights, user responsibilities, water licensing, and administrative aspects are not adequately enforced. The principal inadequacy is the lack of a a comprehensive legal framework relating to water and drainage rights and the facilities for the upholding of those rights.

The gaps in laws have to be filled up through enacting new laws and updating or expanding existing laws as necessary. At the some time, a pragmatic enforcement mechanism must be evolved. Bangladesh should formulate detailed water allocation objectives in economic, social, and environmental terms that may be readily understood by the people, and can be implemented through public and private action.

6.14 Private Sector Participation

The policy in each of the four countries of the region is to attract private investments in water resources now through appropriate reforms, where feasible. Avenues considered are a) encouraging the role of the market and b) exploring possibilities for partnership with the private sector through mechanisms such as Build-Own-Operate (BOO) or Build-Own-Operate-Transfer (BOOT). This calls for a solid legal framework and clear enunciation of the roles of government and the private sector. The efforts made in this regard in the countries of the region are discussed below.

India

The financial resource allocation to the water sector, as a percentage of total allocation for development plans in the country, has been gradually declining over the years. This is due to financial constraints, and it is expected that the liberalization of the economy would result in greater private sector participation in the water sector. In a nation used to free water for irrigation, free water for the rural sector, and indifference to environment water quality, what has been the response of the private sector to invest in irrigation, major multipurpose projects, rural water supply, and pollution abatement? It has been lukewarm, and rightly so, since an adequate return on investments does not appear likely. An expert committee appointed by the Ministry of Water Resources to elicit views from private sector has recommended (MOWR, 1995) the following:

- The investigations and techno-economic clearances should be carried out by the government organizations and agencies. The state governments should take the implementation decision, with private sector participation;
- A leasing period of 25-30 years is considered adequate, after which the project should be transferred to the concerned state government departments;
- Funding of projects could be through the promoters' equity in full or partly by the state and the financial institutions.
- Incentives such as tax holidays, floating tax free bonds, loans at concessionary rates, moratoria on payments, facilities for the development of tourism,

aquaculture, limited use of reservoir water for horticulture, right of water sports, navigation in reservoir areas, and lands for commercial use in embankments, should be provided;

- Private sector participation in drinking and industrial water supply projects should be encouraged;
- The private sector could be involved in O&M in all sectors, including irrigation, by splitting the system into manageable units.

Private sector participation in hydropower sector is already taking place, since the incentives are well defined, but this is not the case in the irrigation sector.

The GWP (GWP, 2000) considers the private sector as an agent of change, proving an engine for action to achieve the water security targets. Increased private sector investments are considered essential for reaching water security targets and attaining the Water Vision. GWP has also observed that opening water service delivery to private groups brings additional financing and shifts parts of the risk. It also brings competition and stronger regulation, which compels the public sector to improve. The private sector, operating in a sound legal and regulatory framework, has been the engine of growth in the developed world and in newly industrialized countries. A similar push is needed for irrigated agriculture in India.

Nepal

A significant strategy relates to the adoption of norms that are commensurate with the free market economy. A notable element in the new approach to development (WECS, 2002), having direct relevance to the water resources sector, is the creation of an environment that facilitates and encourages private sector participation in the development of water resources projects, and in this context the following policy initiatives are significant:

- ❖ Formulation of hydropower development policy;
- ❖ Formulation of water resources acts and regulations;
- ❖ Electricity acts and regulations;

- Institutional restructuring in the water resources sector.

With the above policy initiatives, investments in the hydropower sector through joint ventures and foreign direct investment has gained momentum.

Pakistan

The interests of the private sector in Pakistan are manifold, as it has a strong hold on supplies of all agricultural inputs including seed, fertilizer, and pesticides. This vested interest would like to ensure a more efficient production function and in this effort would like to see that good quality water is available. It would also like to institute a mechanism where adequate arrangements are made for water use and the disposal of effluents in a cost - effective manner. The private sector would like to have better representation in policy formulation and its implementation.

6.15 Water Markets and Public Utilities

The socio-economic conditions in the four countries of this region have a great bearing on the issue of water markets, which have been extolled by the World Bank (1998) as a means to promote improvements in water use efficiency. At present such markets exist only to a limited extent in some parts of the region, and their advocacy for wide application has already invited the ire of the non-governmental organizations. What has been termed success in countries like Chile, western USA, and Australia, has very limited application at this stage to the countries in South Asia. The situation as it exists in the countries of the region, and the pitfalls or otherwise of its adoption as an approach to be introduced before 2025, are discussed below.

India

Water trading in India is still in an experimental mode in some parts of the country, mainly in the ground water sector, in states where the water stress situation is intensely felt, such as Tamil Nadu, Gujarat and Rajasthan. Legislation, Institutions and regulatory framework are at present not even remotely favorable to pursuing this agenda. The National Water

Policy of 2002 (MOWR, 2002), recently approved by the National Water Resources Council, only makes a reference to private sector participation, and not specifically to water markets, as it states " Private sector participation should be encouraged in the various aspects of planning, development and management of the water resources projects for diverse uses, wherever feasible. Private sector participation may help in introducing innovative ideas, generating financial resources and introducing corporate management in improving service efficiency and accountability to users. Depending upon the specific situations, various combinations of private sector participation, in building, owning, operating, leasing and transferring of water resources facilities, may be considered."

The Prime Minister of India, while announcing the new NWP, stated (Times of India, April 2002) that “The community is the rightful custodian of water, and exclusive control by the government machinery would not help the cause of the community management of water resources." The World Bank, in its sectoral review of Water Resources Management in India, has also observed (World Bank, 1998) that "Introducing more formal markets in India would first require careful reflection, review of experience in other countries, and appropriate adaptation to Indian realities, including features to enable workability in the Indian context."

Bangladesh

Defining and enforcing water-use rights is a prerequisite for the private sector water market to develop. In principle, water markets should result in an economic allocation of the available water. However, a market-based allocation system would depend on the existence of an efficient water distribution system, an efficient information system that disseminates information on supply and demand conditions, and an appropriate regulatory framework. These prerequisites are not in yet in existence in Bangladesh. In spite of this, a fairly well developed water market system is in operation in the tube well irrigation sector, which is the largest water user in the country. An informal water market also operates among the urban poor who do not have access to piped water and buy water from private suppliers. The government can facilitate, by putting in place necessary prerequisites, such water markets to flourish based on the dynamics of supply and demand as well as the principles of equity, fair play, and the user's ability to pay.

Pakistan

The Government of Pakistan and the provinces treat irrigation water as a public good, whereas according to the World Bank, it is a private tradable good, for which markets can operate. At present, they operate informally, but the lack of well-defined individual property rights and the illegality of sales of surface water severely constrain informal irrigation water markets.

The World Bank's choice is clear World Bank, 1994). Pakistan "should seek to commercialize any service or product which is not a public good. Irrigation is not a public good and so should be commercialized. In this way, market incentives can promote improvements in efficiency. Within the Indus Basin Irrigation System (IBIS), a series of autonomous public utilities, independent of the regular civil service, are an absolute must. Complete privatization is preferable in the long run, as it removes any doubts about independence and commercialism, and clearly resolves property rights issues.

"Public utilities would be created at the canal command level. This size is large enough to capture any scale economies of administration, yet small enough to provide much needed responsiveness to users. This would allow a reasonably broad base for comparative assessment of managerial efficiency. The public utilities would be responsible for delivering provincially allocated canal waters to users in the command and for collecting charges" (World Bank, 1994).

Small farmers are afraid of any form of metering and volumetric pricing. Given their illiteracy and bad experience of electricity metering by WAPDA, this is not surprising. There is also strong opposition to these ideas from the large farmer lobby.

6.16 Investments

Investments are required to improve the efficiency and productivity of irrigation services, ensure the spread of drinking water supplies and sanitation facilities, protect surface waters through the treatment of municipal and industrial effluents to water courses or aquifers, and protect the environment and the basic water resource through the clean up of contaminated waters. Globally, the investment cots to achieve water security have been estimated at $56 billion per year (GWP, 2000). The World Bank has estimated this figure at $ 60-80 billion.

The investments required in the water sector, with respect to current levels of spending, are a major challenge, considering the low level of public sector resource commitment to the water sector in the past. The irrigation sector may require only a marginal increase in investment, while in the domestic water supply investments would need a five-fold increase in order to meet future demands. This has lead to a general feeling that private sector involvement should be encouraged in the water resources sector. GWP analysis of sources of funds for investment in water security in developing countries to achieve the Vision 2025 shows that in-country government and public sector funding would decrease from the present level of 64% to 28 %. The private sector has to record an increase from the present 19% to 39%, international private sector investment should increase from present 5% to 27%, and bilateral and multilateral donor funds would decrease from the present 12% to 7%.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

Fresh water is renewable, but is limited in quantity. Legitimate requirements are increasing, making water a scarce resource in South Asia. The reasons for the supply – demand gap in the region are:

- Irrigated agriculture continues to be the dominant user of water, though demand for the other sectors is increasing;
- Food security is required to meet growing population needs;
- There is over - irrigation in some areas and under - irrigation in other areas in India and Pakistan.
- Presently the use of ground water and surface water is disjointed. These two resources are a unitary reserve and need to be managed accordingly;
- There is a gap in terms of quality as well as quantity, particularly for drinking water and sanitation;
- Even with enough water in the Ganges and Brahmaputra, its non-availability during the lean season is evident in India, Nepal and Bangladesh;
- The development of hydropower in Nepal, which holds the key to overall security, is still very low;
- The human element is a principal factor in the inefficiency in all sectors of water use, although it is hard to quantify;
- Property and use rights are often unclear, which may place obstacles in the way of water user organizations and the financial self-sufficiency of water distributors. Related gaps are in “governance” and institutional reform, including greater participation of the public;
- The delay in the settlement of interstate and inter-provincial disputes on water sharing is also a cause for gaps, as in India and Pakistan.

The approaches discussed and recommended below, on country – specific basis, are expected to bridge the "gap" over the next 25 years, even in those basins which are not so well endowed with water resources.

7.1 India

Demand - Resource Gap

Considering the country as a whole, the total precipitation, the surface flows and dynamic groundwater, India is endowed with enough water to provide for a comfortable balance between “resource” and “requirement” up to the year 2025.

The demand projections always tend to be high. This is a natural reflecting of a “no regrets” syndrome typical of most projections. However, some river basins are clearly headed towards a gap between “demand” and “resource” in the next two decades. This is directly attributable to the large spatial variation in rainfall across the country. The temporal variation further exacerbates the gap in some of these basins. However, the situation is manageable up to 2025.

What is really critical in the next 25 years is the gap between demand and supply at the consumer level. This gap has more to do with administering water than with its availability as a natural resource. The specific approaches towards reduction of this gap are summarized below.

Governance

There is an urgent need for a paradigm shift in political thinking, and most importantly an attitudinal change in administering water. Water must move out of the political agenda and should not be used as a ball game to score points in electoral politics.

Integrated Water Resource Management (IWRM)

IWRM is focused on eliminating inter-sectoral abnormalities in sectoral allocations and use of water and to bridge the intra-sectoral gaps. Only IWRM can ensure optimal use and maximization of benefits and environmentally sustainable development.

Integrated River Basin Planning and Management (IRBPM)

For IWRM to be successful, IRBPM is an essential prerequisite. Given the Indian context of basins being divided by political boundaries, IRBPM may not be currently viable, at least until political maturity transcends short - term concerns about electoral gains. Notwithstanding this man - made hurdle, there is absolutely no reason why each state cannot put into practice IRBPM and IWRM within its own political boundaries of a basin. State levels RBO’s can be easily established even now.

Groundwater

Ground and surface water need to be integrated across their various uses to realize the full benefits of IWRM. Their conjunctive use will be a major step in bridging the Gap between demand and supply. Establishing more precisely the utilizable groundwater potential at the sub basin, or even smaller area levels, will have to be the foundation for such integration.

Remodeling and Modernization (R&M) of Irrigation Systems

India is in a major bind with respect to long - established irrigation systems, which have not been properly maintained due to the paucity of funds. Physical deterioration, together with the lack of scientific operational mechanisms, has led to wastage of water, inefficiency in carriage and application and inequitable distribution. Remodeling and modernization will increase the efficiency in irrigation systems, and would go a long way in bridging the gap. R&M is equally essential in water supply projects to save water.

Mechanized Irrigation

Sprinkler and drip systems are technological innovations that help not only to save water, but also to increase productivity. The constraint of high investment cost can be easily overcome, if water is appropriately priced. The economic savings derived from the water saved and high productivity will more than offset the initial capital investment.

Effluent Treatment

The pollution of watercourses and underground aquifers has reached alarming proportions. Though non-point pollution from agriculture cannot be discounted, the most visible pollution is from domestic and industrial effluents. Their treatment is a priority issue.

Storage

Storages have come to be identified with dams. So much has been written in favor of and against dams that it is not useful to deal the subject further here. However, it needs to be stated that storage reservoirs have a definite place in bridging the gap. If there have been “bad” reservoirs in the past, there is no reason to do away with “good” reservoirs in the future. In the monsoon climate of India, with large spatial and temporal variations in rainfall, storage reservoirs are imperative to bridge the gap.

Interbasin Transfers

Thirty years after “Ganga-Cauvery” made headlines, and sixteen years after the government set up the National Water Development Agency to carry out studies, the subject still remains a study and may remain so for many more years - if not generations!

Is there a need for an Interbasin transfer in the immediate future? The National Commission (NCIWRDP) did not appear to think so, at least for the next 25 years. Notwithstanding some existing examples in the country, new transfer projects seemed unlikely. It was not considered advisable to depend on Interbasin transfers to bridge the gap up to 2025 and that they may be possible thereafter. But the Government of India has acted now on popular demand from politicians and as directed by the Parliament has set up a high level "Task Force" to pursue this option.

Investment

This is the *most* vital issue in all efforts to bridge the gap. The criticality derives from the simple fact that the government does not have the monetary capability. Bridging the gap through budgetary provisions alone is impractical. Alternatives have to be found, and found quickly.

Participatory Irrigation Management (PIM)

It would be desirable to turn over irrigation management to the farmers. Operation and Maintenance (O&M) should be made the responsibility of the Water Users Associations (WUA), sometimes referred to as the Water Users' Organizations, or WUO.

Private Sector Participation (PSP)

PSP is still not considered practical in the irrigation sector in India. However, all drinking water schemes, new and old, should be turned over to the private sector.

Pricing

The addition of value makes water a commercial good. Thus pricing should reflect the cost of services rendered. Both PIM and PSP require the pricing of water. Pricing is necessary not only to be able to fund new development works, and O&M of old works, but also to save water. Pricing invariably results in increased efficiency, which is necessary to bridge the gap.

The above does not mean that the government withdraws from the water sector. Major portion of the seed investment still has to come from the government. PIM, PSP, and Pricing will bring down the investment burden on the Government to more sustainable proportions.

7.2 Bangladesh

Stream flows are only a part of the surface water availability, and a complete picture, incorporating surface inflows, rainfall, evapo-transpiration, percolation to underground aquifers, and diversion for irrigation and other consumptive uses, can only be obtained through hydrologic simulation in a dynamic water balance model.

Surface water is an important strategic resource for Bangladesh in the dry season. Under the directions of the National Water Policy, however, much more attention is now being given to in-stream demands and the environmental benefits that will come from healthy river systems.

The Ganges flows secured under the 1996 Treaty with India are critical to the sustenance of the Southwest Region. They also indicate that there is little overall margin in total water balance if all foreseeable eventualities are factored in.

A key feature of the NWMP should be the improvement of long-range water resource and agricultural demand assessment, coupled with preparation of a strategy for maintaining water balances beyond the plan period, and beyond the 2026 end-date for the Ganges Water Treaty. At the same time, treaties securing Bangladesh's share of the flows of the other 53 trans-boundary rivers should ideally be brought into place. Though many of these contribute only a small proportion of the overall balance, locally they are important.

There are a number of constraints that affect either the accessibility of groundwater, or the quantity, which can be stored at reasonable depth, or the amount of recharge during the flood season. Research is continuing into the impacts that irrigation with arsenic-contaminated water might have on food safety. No firm conclusion can be drawn as yet. The implications, if it is shown to be unsafe, will depend on whether the health hazards are applicable to some or all crops, and whether treatment is a viable option. However, if there were a need to ban irrigation from groundwater in these areas, the impacts would be moderated by the fact that most shallow tube well irrigation is not in areas of high arsenic contamination.

In general, water shortages do not occur during the monsoon season from May to November. But the main issue for the monsoon, however, is the excess of water. Annual inundation has both negative and positive impacts. The positive impacts of floods are increases in soil fertility, the enhancement of capture fisheries and navigation, increased groundwater recharge, and the flushing of pollutants. The negative impacts include damage and loss to property, infrastructure and crops, and frequent loss of life.

The consumptive demands represents 44% of the total water demand, and in-stream demands the remaining 56%. Agricultural demands, the focus of previous studies, amount to only 32 per cent of total demand. At present, only about half the area is irrigated, but as much of the remaining agricultural land is classified as unsuitable for irrigation, existing demands are already 85-90% of the future potential.

The dry season scarcity of water resulted in the government's medium - term strategy to increase food production through irrigation. In recent years, remarkable growth in irrigation has been achieved through deregulation and privatization of groundwater use. This has led to a situation where the country’s dry season irrigation is heavily dependent on groundwater. It is now widely accepted that future irrigation based mainly on groundwater would not be sustainable, as the amount of groundwater recharged each year is finite, and there is the dangerous phenomenon of arsenic contamination of groundwater.

The government has recognized that over-dependence on groundwater is not wise, and the NWPo accordingly envisions improving efficiency of resource utilization through conjunctive use of all forms of surface and groundwater for irrigation and urban water supply. Increased emphasis is being given now to harness and develop the nation’s surface water resources, so that in the long run a balance can be struck between the use of surface and groundwater.

Use of Groundwater

Where groundwater is usable, the sustainable yield is adequate in most places to permit full irrigation of all lands, but in many areas levels will fall below the reach of suction mode pumps. By accelerating rural electrification, and promoting a change to force mode pumping through the adoption of small electric submersible pumps, groundwater-based irrigation and domestic water supplies can be protected from the effects of seasonal shortage and drought. In some areas, where boulders make hand drilling of wells difficult, the government can subsidize the drilling of tube wells for farmer groups to equip and manage.

Expansion of Surface Water

Water short areas are the High Barind in the NW Region, western parts of the SW Region, southern parts of the SE Region, and the coastal plains of the EH Region. Diversion in the first three areas is possible from the major rivers --- Ganges, Brahmaputra and Meghna. Large scale irrigation of the EH would require the construction of multi-purpose storage dams, which would displace upwards of 30,000 people in the Chittagong Hill Tracts, and is thus unlikely to be socially or environmentally acceptable.

Regional cooperation could, however, significantly reduce the costs of river development if structures can be designed to maximize use of available flows. Inflows on all trans-boundary rivers need to be secured by treaties similar to the GWT, with emphasis in the east, which is largely dependent on surface water.

As a public and economic good, water demand management approaches of water rights and allocation, water markets, water-use efficiency, and pollution control are needed in Bangladesh for the sustainable development of this increasingly scarce resource. The National Water Policy lays special emphasis on measures to increase the efficiency of water use in irrigation. Such measures could include drainage water recycling, rotational irrigation, adoption of water-conserving crop technology, conjunctive use of surface and ground water, and better management of canals to reduce wastage. For household use, the practice of the simple, but productive, means of rainwater harvesting may be encouraged as an indigenous conservation measure.

7.3 Nepal

Basic water supply and sanitation has so far covered about two-thirds of the population, but the coverage of the remaining one third, before 2025, is the first priority. A substantial part of the irrigable area is yet to be irrigated, especially with year round irrigation facilities. Approaches to cover all the irrigable areas with year - round irrigation are yet to be addressed. More then 80% of the population still does not have access to electricity, and hence hydropower development, which is considered the mainstay for future all round economic prosperity of Nepal, would be the bulwark of planned development activity in the time frame of 2025.

Water quality and the pollution of watercourses are also matters of serious concern, especially in urban areas. Water related natural disasters, including floods and landslides, and food scarcity due to dry spells without rain are now common occurrences in certain areas of the country, and need urgent remedial steps. The temporal and spatial variations of water availability and demand need to be addressed, with viable interventions, to meet the gap between supply and demand.

There are various options or approaches that could be taken to meet the gaps between the supply and demand of water. These approaches may be categorized into two types, one at the basin level where multipurpose, inter-sectoral and regional water allocation is carried out, and the other at the sectoral level where the sector - specific demand is met. The multipurpose water use and allocation and the sectoral approach should be carried out on a hierarchical basis. The basin level planning should be first carried out, and the sectoral approach undertaken to plan and manage the demand at the level of the lower hierarchy. Continuation of only the sectoral approach without considering the other sectoral uses and demands cannot be the optimal approach. The National Water Resources Strategy recently approved by His Majesty's Government of Nepal has thus recognized and advocated the need of a "holistic, systematic approach, honoring, respecting and adhering to the principles of integrated water resources management”. River basins are therefore treated as fundamental planning units in water resources planning and management for rational decision-making.

7.4 Pakistan

The people of Pakistan will have to realize that water is a renewable resource up to the limits of availability, but is quite an inelastic resource beyond that limit. Given that Pakistan is reaching the internationally accepted water scarcity index, while still an agrarian economy, the uses (consumption) of water will have to adjust to changes in the composition of the economy. More water will be needed in the industrial and municipal sectors, and can only come from the agriculture sector.

Water is consumed in irrigated agriculture. There is much scope for water use efficiency and productivity in agriculture, as measured by crop yields per unit water applied. The various possible technical innovations for the efficient use of water display a wide range of unit investment costs. There is a need to go for the more cost-effective solutions, but they have social organization implications. It is recommended that Pakistan invest in social organization and in creating markets for water. In addition, Pakistan should think strategically about desirable cropping patterns and bio-saline agriculture.

After domestic and industrial use, about 60 to 85 percent of the water is returned to the ecosystem but frequently as polluted flows. There is need for water conservation in cities outside the irrigated Indus Basin, and a need for strict water treatment after industrial and municipal uses before discharge into fresh waters and croplands.

The technical requirements for adjusting to water scarcity are known and can be assembled in defined time horizons. It will be more challenging to bring about the necessary institutional reforms that will enable these technologies to be widely adopted. The strategic institutional development approach would be based on values for conservation and sharing, and capitalizing on the knowledge of best practices.

CHAPTER 8: REGION: CONCLUSIONS AND RECOMMENDATIONS

8.0 General

In the previous chapter, conclusions and recommendations have been given for each country of the region. In this chapter, the emphasis is on conclusions and recommendations that are significant for the entire region.

8.1 Water availability (supply at source)

The water availability projections are based mostly on historical flow data and on projected utilization data. As a basic starting point for analyses, the data are indicative of water stress in the region. The present per capita availability in Pakistan is about 1600 m^3 and in some basins of India it varies from 360 m^3 and about 1000 m^3. This situation will get worse in the years ahead. In Bangladesh, and in some smaller rivers in Nepal, the water stress situation is evident in the lean flow season of March/April, even though the overall picture for these countries is one of excess average water availability. Even in India, some rivers have excess availability but its exploitation is limited due to topographic and political constraints.

One important aspect common to the entire region is that water availability (considering the consumptive use alone) in the lean flow season in most of the river systems indicates a severe water stress situation. The estimates of non-consumptive uses are vague, since scientific assessments have not been made. The situation is, however, critical with respect to the availability of water in the coastal zones (fisheries, mangroves, control of salinity intrusion, navigation, and minimum flows required for environmental and ecological sustainability of river regimes).

8.2 Water Requirements

The demand projections for various consumptive uses for the year 2025 are dictated largely by population growth and increasing use per capita.

8.3 Demand-Supply Gap

The gap represents the overall difference at the National level between total water availability at source and the need-based requirements in the year 2025. However, the gap is larger between demand and supply at the consumer end. The gap is based on total water availability within a nation’s borders, regardless of whether it can be tapped or not and provides an upper limit to supply development initiatives. Looking at the total potential at the National level, Pakistan has a deficit, and India is on the brink of one, with large areas within the country showing stress. Bangladesh has shortages both under consumptive and non-consumptive uses, in March/April, even though the overall picture is one of excess availability on an annual basis.

8.4 Approaches to Meeting the Demand-Supply Gap

The approaches are well defined but their implementation is beset with many problems -- the basic one being one of governance. There has to be a paradigm shift in political thinking and attitudinal change in administering water. Broadly, the approaches are categorized under a four level strategy envisaged to achieve sustainable development.

- Governance & Institutional reforms;
- Increasing water use efficiency of in all sectors;
- Run-off conservation;
- Conventional wisdom - Precipitation Conservation.

8.5 Governance

i) RBOs and IWRM:

There is a need for institutional reforms and restructuring to administer water, treating the river basin as a Unit, and applying the principles of Integrated Water Resources Management (IWRM). River Basin organizations (RBOs) are a prerequisite to preparing IWRM plans.

IWRM is universally accepted as a good approach to ensure the optimal use of water, maximization of benefits, and environmentally sustainable development. The Global Water Partnership (GWP) is promoting Integrated Water Resources Management (IWRM) in the region through Country Water Partnerships (CWPs) by establishing Area Water Partnerships (AWPs).

RBOs need not necessarily cover the entire basin in the case of regional and interstate rivers. Their jurisdiction can be restricted to the area in a state or province. India's Ministry of Water Resources Action Plan (MOWR, 2003) envisages each major state establishing a RBO for the basin area falling within that state. The MOWR's Action Plan (MOWR, 2003) envisages helping each major state in establishing a Basin Organization for each basin falling within the state.

GWP-South Asia has set up a South Asia Network (RBO-SASNET) with Sri Lanka's Mahaweli Authority as the nodal agency and is taking action to promote at least two RBOs in each Country. Th International Network of Basin Organizations (INBO) is also supporting this activity.

ii) Pricing

The value added by water makes it a commercial good. Thus pricing should reflect the cost of the services rendered. Pricing is necessary not only to be able to fund new development work and maintenance of existing infrastructure, but also to save water.

iii) Conjunctive use of Surface and Ground Water

A major step in bridging the Gap between demand and supply is the integration of surface and ground water across their various uses. This can be done by establishing more precisely the utilizable groundwater potential at the sub basin, or at even smaller area levels. This will be the foundation for such integration. In India, this has been done fairly extensively, and the Ministry of Water Resources has guidelines for this purpose. Bangladesh, which relies on ground water irrigation to the extent of more than 70%, has to introduce this technique in a major way. Pakistan has already acted on this policy to reduce the drainage problems in the Indus basin and needs to expand it substantially in the near future. Nepal also has adopted this technique increasingly in the terai region where both surface water and ground water potentials are high.

iv) Renovation and Modernization (R&M) of Irrigation Systems

In all the countries of the region there are projects built 25 or more years ago. These have serious problems in supplying water in designed and desired quantities, mainly because of the neglect of operation and maintenance of the systems, due to the paucity of funds. Remodeling and modernization (R&M) will increase the efficiency in irrigation systems, and would go a long way in bridging the gap. R&M is equally essential in water supply projects to save water, since distribution losses are sometimes estimated to be as high as 40%.

v) Participatory Irrigation Management

Irrigation management should be turned over to the farmers by making Operation and Maintenance (O&M) the responsibility of the Water Users Associations (WUA), sometimes referred to as the Water Users' Organizations (WUO). India and Pakistan have taken several steps to introduce this measure in a big way. Though not an unqualified success, it has to be reviewed and extended gradually to cover minor, branch, and main canals. Pakistan's experience is encouraging from the NGO point of view, as reported in earlier sections of this report, but a cautious approach was recommended by senior government officials (who attended the Conference organized by WASSA in Islamabad in February 2003) who manage these systems in Sindh and Punjab. They advocated the need for adequate safeguards, particularly fund allocations to the Associations. India's experience is no different and a measured approach is, therefore, required to avoid a sudden collapse of the whole system.

vi) Private Sector Participation (PSP):

The policy in all countries of the region is to attract private investments in water resources through appropriate reform. But PSP is still not considered practical in the irrigation sector, since the farmers of the region are used to almost free irrigation supplies. However, all drinking water schemes, new and old, should be turned over to the private sector. There are a few instances of O&M of municipal supply being contracted out. More such efforts are needed. The water markets are an untested ground, and need to be approached with caution, but cannot be discounted entirely. They are closely related to the efficacy of ground water extraction laws. Water markets operating within the framework of IWRM have a place in bridging the Gap.

vii) Water Quality and Effluent Treatment.

Surface and ground water quality has deteriorated all over the region in urban areas and watercourses. Though non-point pollution from agriculture cannot be discounted, the most visible pollution is from municipal and industrial effluents in urban areas. Their treatment is a priority issue. "Polluter pays" should be supplemented by the policy of "Polluter gets punished".

viii) Water Rights

Surface water rights rest with the State in the countries of the region, while the groundwater rights rest with owners of the land. The Individual riparian next to a river course does not enjoy any rights unless he approaches the Courts for redress, but in the case of wells on private land extraction goes unchecked and water markets flourish, resulting in indiscriminate over - extraction. Both need to be rectified with suitable legislation to ensure optimal use and to usher sustainable water markets.

8.6 Efficiency in water use

Improved water use efficiency will go a long way in bridging the gap. This is the situation across the board, in all water sectors, in all the countries of the region, particularly in irrigated agriculture and in domestic and industrial water supply. Measures to improve efficiency include: Pricing water, improved operation and maintenance (O&M), renovation and modernization of projects, the conjunctive use of surface and ground water, Participatory Irrigation Management (PIM), Private sector Participation (PSP), and Municipal and Industrial (M&I) effluent treatment. These aspects have already been discussed earlier under Governance, which is the overall theme of such actions, and is an integral part of good administration.

8.7 Run-Off Conservation

This covers a broad spectrum of activities from creating water storages, inter-basin water transfers and changed cropping pattern to technical innovations like drip and sprinkler systems. It also includes actions discussed to improve water use efficiency, which results in saving water, and is thus a conservation measure.

i) Technology innovations

Sprinkler and drip irrigation systems are known to give water use efficiencies of 94 to 97%. These systems are being used in the region but not on a significant scale. In India, the government subsidizes the cost of equipment to some extent. Still the systems are too expensive for an average farmer, and are generally confined to ground water use in horticulture and orchards. Looked at in its totality, this option is not costlier than the conservation option and increased subsidies should be considered, if necessary, to encourage this program.

ii) Cropping pattern

It is common knowledge that rice, sugarcane and banana are grown extensively in the region, even in severely water - stressed areas. This should be phased out and give way to less water - intensive crops, which will not adversely affect the local or the country's economy.

iii) Storage projects

Dams may become unavoidable if the demand - supply gap has to be bridged for food security, health security, and environmental sustainability. Since most of the precipitation occurs in the entire region as monsoon rainfall concentrated in four or five months of the year, and varies widely within the region, the net utilizable flow becomes very limited, unless conservation measures are extensively adopted to utilize the monsoon flows. All countries of the region have planned for building storages, notwithstanding growing opposition from a section of the society. India has many such under construction, and Pakistan had planned the Kalabagh dam and renovation of existing dams to increase storage to compensate for the loss due to siltation. Bangladesh needs them to be built in the upper riparian countries of India and Nepal to increase the lean season flows in the Ganges river. Nepal needs to build storage facilities to attain the full irrigation potential (mostly in the Terai region) and to exploit the hydro potential for maximization of benefits. However, dams have to be the last option but one, because of their socio-environmental effects and perceived non-sustainability. The last option is discussed below.

v) Interbasin Water Transfers

This is not really a new option. Such transfers have taken place for quite a long time. However, what is now being promoted is on a much larger scale, both in terms of quantity of water and length of transfer. In the region where drought and flood co-exist and are sometimes a simultaneous phenomenon, though in different parts of the countries, transferring flood water to the drought prone area appears to be a natural solution. The opposition to the proposal is not based on technical feasibility but on economic and environmental viability, besides the not fully answered question about the need itself.

In India, this option, though beset with interbasin water conflicts and unwillingness of states to share the excess flows in their basins to other deficit basins, has now been given top priority for action. The Government of India has recently set up a high level "Task Force on Interlinking of Rivers" with a mandate to complete the task assigned t it by 2016. Opposition to the proposal is growing.

8.8 Precipitation Conservation

The concept of conserving precipitation is gaining momentum. The idea is to catch rain where it falls. Water Shed Management (WSM), Catchment Area Treatment (CAT), Soil Conservation (SC) - they all help in reducing the run-off and in recharging the ground water aquifer in addition to promoting rain-fed agriculture.

(i) Rain-fed or dry land agriculture

There has to be a major shift in favor of rain-fed agriculture since all areas cannot be served by storage projects. A great deal of research has been done in several research stations devoted to rain-fed and dry land agriculture, which needs to be widely disseminated in the region for the benefit of all. It is expected that there will be significant increases in yields from dry land agriculture in the near future as a result of Water Shed Management (WSM), Catchment Area Treatment (CAT), and Soil Conservation (SC). This improvement should reduce the demand for water for irrigated agriculture. Their success in meeting rural drinking water requirements is also on record.

ii) Roof Top Water Harvesting

This “traditional wisdom” in India is reportedly helping to bridge the supply-demand gap.

8.9. Concluding Remarks

The anticipated demand -supply gap by 2025 can be bridged significantly by management options rather than by pursuing development options alone. Technical solutions for adjusting to water scarcity are known and can be put in place over time. It will be more challenging to bring about the necessary institutional reforms that will enable technologies to be widely adopted. The strategic institutional development approach would be based on values for conservation and sharing, and capitalizing on the knowledge of best practices.

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ANNEXES

Annex 1: Sabarmati basin: supply and demand gap

(A case study by VIKSAT)

The Sabarmati basin drains into the Arabian Sea on the West Coast. The basin area covered by the states of Rajasthan and Gujarat falls under the semi - arid region. It is characterized by a number of competing uses -rural domestic and irrigation, urban domestic and industrial. The average annual utilizable water flow is estimated to be 1.9 BCM, out of which the utilization so far is 1.8 BCM (CWC, 1989). Water resources development has thus approached the extraction limits in the basin. The per capita availability is only 360 cubic metres/year, which indicates a severe water stress. The urban and rural water supply source is highly polluted because of domestic and industrial pollutants. The storage position in the existing reservoirs in the basin in the last few years has been dismally low. As a result, the irrigation supplies had to be suspended in 6 out of 22 years since 1978, when the Dharoi project was commissioned to meet demand for domestic water needs of major cities in the basin.

The industrial development in the basin in Gujarat can be gauged from the fact that there are 103 large industries, apart from thousands of small-scale units (85% concentrated in the three districts of Ahmedabad, Mehsana and Gandhinagar) in the basin. These industries have depended heavily on the easy availability of ground water from deep aquifers underlying most of the basin. Effective mechanisms for disposal of contaminated water and industrial wastes discharged into the river, have been lacking. This has caused significant impacts on the quality of the Sabarmati river water and sometimes in the surrounding land areas; the result is the river has become a trunk sewer in the Gandhinagar -Ahmedabad section. This has created a serious problem in itself, and exacerbated water scarcity. Over - development of ground water for rural and municipal water supplies has resulted in a rapidly declining ground water table and lower yields in tube wells. The domestic water (including livestock) demand of 330 MCM in Gujarat is about 10% of the total water demand for agriculture.

The Narmada River waters are to be diverted from the Sardar Sarovar Dam to serve 1. 8 million ha of irrigation and water supply to 8125 villages and 136 towns (SSNL, 2000). This is a gigantic interbasin diversion, which passes through the Sabarmati basin, en-route its 437 km long journey by the world's largest lined canal system (carrying capacity of 1185 Cumecs) to the Saurashtra and Kutch regions in Gujarat and Barmer and Jalore districts in Rajasthan. In the Sabarmati basin, the Narmada Canal will serve 596 villages and 25 towns in respect of water supply and also provide irrigation. The amount of water to be added to the basin is estimated to be 157 MCM, which would partially relieve the water stress in the basin. The quality of the river water, which serves municipal uses in the Ahmedabad city and other towns and villages in the state, is also to be improved.

The Vikram Sarabhai Centre for Development Interaction (VIKSAT) has carried out a study on the water scarcity problems of the basin in the Gujarat state. In this study, the Water Evaluation and Planning (WEAP) modeling system has been adopted to evaluate local water management options. The alternatives analyzed are, i) local recharge using excess runoff within the basin, ii) adoption of efficient water use practices and reduced conveyance losses, iii) conjunctive management using imported water supplies, and iv) a combination of efficient water use and local recharge activities. The studies show that:

- The gap between demand and supply can be bridged only marginally by local recharge - less than 1% by 2020 and 2050;
- Interventions of efficient water use technologies of drips, sprinklers, and efficient conveyance system in the fields, and domestic and industrial sector, could reduce the gap between supply and demand by 324 MCM and 1,005 MCM in 2020 and 2050 respectively, i.e. roughly one-third of the gap projected for 2020 and more than half for 2050; and
- The recharge of surplus monsoon flows diverted from the Sardar Sarovar reservoir (Narmada Canal) would increase by 157 BCM and 156 BCM by 2020 and 2050 respectively - a significant contribution to reducing water shortages.

The WEAP model studies indicate that the most effective avenues for addressing water scarcity options that require changes in water use are: a) the level of individual users (that is, adoption of efficient water use technologies and practices); b) the level of systems (that is, improved conveyance system); and c) the level of regions (that is, aquifers for conjunctive management).

In the final analysis, it has been inferred that a combination approach, namely, demand side management, allied with conjunctive management of locally available and imported surface and ground water supplies, holds the best prospect of addressing water scarcity problems on a sustainable basis. It has been observed that the existing organizations dealing with water need improvement by involving all the stakeholders throughout the planning, implementing and monitoring stages.

Annex 2: North China case study (for illustration of a methodology)

(By James E. Nickum)

The State Science and Technology Commission of China (SSTCC) and the East-West Center (EWC) carried out, from 1985-1987, a joint study of water management options in the growing North China Plain cities of Beijing and Tianjin. They used demand-supply gap analysis, with a short-term time horizon of the year 2000, (EWC 1988; Nickum 1994). The methodology used was a refinement and adaptation to Asian developing nation conditions of one developed for Denver in the early 1980s by Milliken and Taylor (1981). There are a number of important differences between this methodology and that adopted to date in other topics addressed in the WASSA project, so some time will be devoted here to reviewing the characteristics of these studies and the lessons they may provide for South Asia.

The main distinguishing features of these approaches are:

- The Beijing and Denver studies each covers a municipality and its potential water supply region. Gap analyses are likely to be more informative when done at a smaller (e.g., river basin, municipal) scale, especially in very large and diverse countries such as India. Average surpluses often mask serious local shortages;
- The approach projects a demand-supply gap to a certain year, identifies alternative strategies for closing the gap, and makes a comparative assessment of alternative projects and strategies.
- It is grounded in an economic rather than a hydrological view of supply and demand. Thus, for example, demand (sometimes termed “requirements” or “needs” by non-economists) is seen as sensitive to scarcity value (as expressed, for example, in price), and an effort is made to sort various kinds of supply augmentation and demand reduction by their economic returns, with due consideration to less quantifiable elements such as social, political, institutional (including stakeholder interests), and many environmental factors. The WASSA analysis has not yet taken this step, which may be critical in terms of providing information on priorities to policy makers who operate with limited resources.

Hence the operational definition of water supply is that which is deliverable, given existing and committed projects and water rights (i.e., business-as-usual, BAU) rather than total hydrological supply. In the case of Milliken and Taylor, and the EWC-SSTCC study, this was used to actually calculate a gap. In other cases (including Wolf and much of the WASSA work), this is implicit but not made explicit.

At the same time, there is recognition that, since even moderately free markets rarely operate in water, pricing is usually a policy choice, and therefore a political act. It is only one of a range of options for reducing demand. This appears to be recognized, at least implicitly, in the WASSA work. At the same time, it should be recognized that informal markets are actually quite common in South Asia, for example, in urban water supply (Zerah, 2000). The prices in these markets are an indicator of the scarcity value (opportunity cost) of clean water.

The approach allows the consideration of a wide range of options, including demand management as well as supply augmentation, "exotic" as well as conventional, in a common framework that allows explicit comparison. For example, Milliken and Taylor (1981) consider the following for Denver: Water conservation programs, pricing, improved system management, increasing surface water supply, reallocation of agricultural water, using groundwater, watershed land management, augmenting precipitation, desalinization, and reuse of wastewater. WASSA studies also touch upon a very wide range of options, including almost all of these (except rainmaking), but not always in a framework that allows direct comparison.

Uncertainty in both demand projections and supply are considered explicitly. In WASSA to date, only variation in demand estimates by different parties has been presented, not hydrological uncertainty or ranges in demand.

Alternative options are considered in order to seek least-cost means of closing the gap, where cost is broadly defined, but based in economic cost or, more narrowly, least direct cost to water supply agencies.

Matrices of alternatives are presented rating options using non-economic criteria as well as economic ones. (a) Milliken and Taylor (1981) make a detailed listing of the impact on various stakeholders ("parties at interest") of all alternatives to indicate political feasibility. They also make "typical" comparisons of pairs of alternatives, notably groundwater mining vs. desalinization and potable vs. dual reuse systems, including indirect economic effects, quality of life impacts, environmental effects, energy effects, political aspects (in general), legal uncertainties, technical uncertainties, and "miscellaneous" (in effect, other institutional problems). (b) EWC-SSTCC offer a matrix of demand-management options for Beijing that includes assessments of effectiveness, characteristics of water saved, level of cost, difficulty of implementation, and incidence of cost burden. (c) Wolf presents viability assessments using various technical, economic and political measures for both unilateral and cooperative measures for the Jordan basin entities. Because this involves regional (cross-border) options as well as national ones, it may be of the greatest direct use to the WASSA project.

Where BAU deliverable supply is used to calculate a gap, as in the Milliken and Taylor and EWC-SSTCC studies, it provides a useful first-cut heuristic for understanding the gap problem, at least in quantitative terms. For example, in cases such as Pakistan where there is a severe and pervasive decline in storage and delivery capacity and possible overdraft of groundwater, the BAU deliverable supply line may be expected to *decline*, creating a widening gap even in the unlikely case that demand does not increase! This focuses attention on the need to consider rehabilitation on equal standing with other projects and programs (as is done in the Pakistan study). The supply saved is equivalent to adding new sources. This effect would not necessarily show up where the hydrological water availability is used for supply. A graph indicating the implications for the gap of different supply assumptions is presented below.

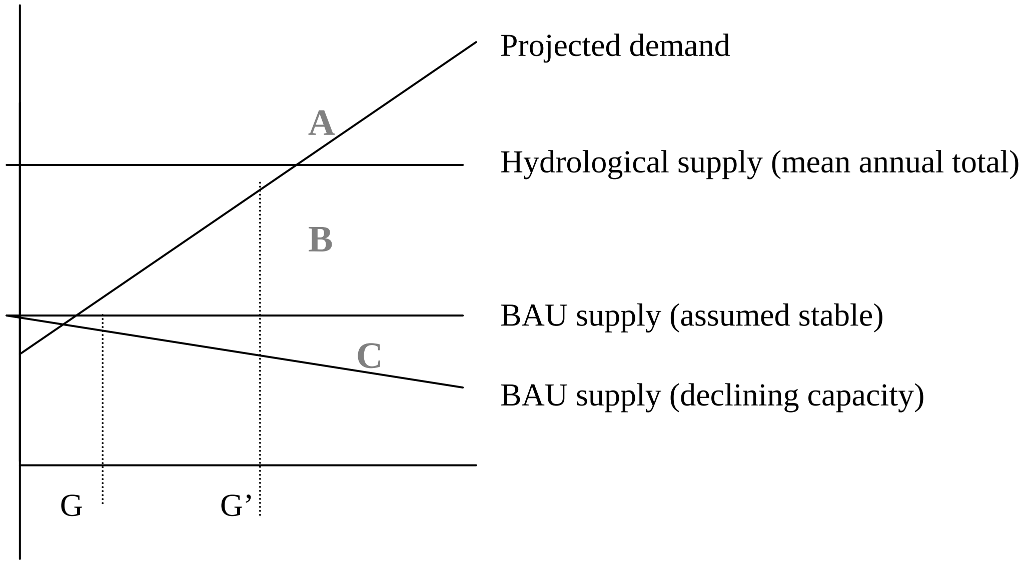

Figure : Implications of different supply assumptions on the gap.

A: Impossible or highly expensive to increase supply after G'; nearly entire focus has to be on demand management (Pakistan?)

B: Demand outgrows BAU supply at G; mix of policies probably necessary to bring up supply, bring down demand.

C: Similar to B, but special consideration should be given to rehabilitation and ensuring against future declines.

Nonetheless, while the EWC-SSTCC and Milliken-Taylor studies attempted a quantitative calculation of the BAU gap, there are a number of reasons that this is not necessary. As noted later, calculations are difficult and of necessity imprecise because of data limitations, especially but not exclusively in low-income countries. It is also hard to incorporate critical non-quantitative factors such as quality and different water uses into a simple gap analysis. Perhaps most importantly, it is not all that necessary to establish a precise estimate of a gap for a considered view of alternatives; what is necessary is that there is a mechanism to compare and rank.

Annex 3: Pakistan case study

Comparative Benefit-Cost Evaluation of Selected Options - Indus Basin Model

An Indus Basin model that forecasts *Rabi* water demand over time (1993 – 2017) against anticipated supplies has been developed by Qutub (1992). With no water development or conservation, an increasing shortfall is demonstrated that varies as a function of the rate of depletion of the Tarbela reservoir. The model then sequentially introduces a range of water conservation and development options along with their costs. These are:

- Land leveling and forming;
- Watercourse renovation;
- Lining of distributaries;
- Canal earthwork rehabilitation;
- Lining of canals passing through saline tracts;
- Watershed protection; and
- Construction of a large new storage.

The model then allows posing the question whether the first six water saving activities can compensate for the increase in water demand and decrease in dry season water availability, if they were to receive water sector funding that would otherwise go toward a large storage reservoir. The conclusions from runs of the model are as follows (in 1992 prices):

- Watercourse renovation is the most cost-effective program at a cost of Rs. 2.13 billion per MAF delivered to crop roots. As such, lining of 75,000 watercourses by 2017 is recommended. Under departmental practice, this would cost 29 billion rupees and would provide 4.15 MAF to crop roots in the terminal year. However, this will still fall short of the additional *rabi* demand of 11-13 MAF. As such, other conjunctive programs are required;

- The lining of distributaries is the next most cost-effective program, at a cost of 2.16 billion per MAF delivered to crop roots. As such, lining of 3,000 miles of distributaries is recommended at a cost of Rs. 4.8 billion by 2017. However, in the terminal year, the savings of 0.74 MAF will be marginal compared to the shortfall of 11 – 13 MAF;

- Because land leveling or forming has to be repeated every three to five years, it is not a particularly cost-effective option, at Rs. 12 billion per MAF delivered to the crop roots. Also, its share in averting the shortfall is minuscule (0.28 MAF if one million acres are leveled every five years). Progressive farmers may see it as an adjunct program for private initiative.

- Successful implementation of the on-going water conservation programs can reduce the 2013-17 projected *rabi* shortages by half at a cost of Rs. 60 - 70 billion. In absolute terms, these shortages would still be double the present levels (at 6 to 7.3 MAF);

- More aggressive implementation, accelerating land leveling and canal earthwork rehabilitation runs into physical and cost thresholds, reduces projected 2013-17 *rabi* shortages to 5 – 6.5 MAF, but at much higher costs (Rs.171 billion);

- Limiting *rabi* shortages to current levels requires – in addition to on-going programs – the lining of “saline” canals at an additional cost of Rs.30 billion ,or the construction of interceptor drains along the main canals, or demand side management, entailing research and extension of low delta crops and varieties. By itself, the lining of saline canals will deliver only an additional 1.0 MAF in rabi to the crop roots in the terminal year;

- The construction of a large storage dam (6 MAF) alone will not stop *rabi* water shortages from rising to 5 – 7 MAF, but could cost substantially more (Rs. 77 billion in 1992 prices, of which at least 23 billion should be attributed to irrigation). It is not a standalone option warranted over a 25 years timeframe.

One major limitation of the model is that it treats the Indus irrigated plains as a single entity suffering current and increasing *rabi* water shortages. It ignores the possibility of simultaneous water shortages and surpluses in certain agro-ecological zones, and their constituent fresh and saline groundwater sub-zones. This defect could be overcome by working with the much more detailed (2500 equations) Indus Basin Model (Revised) of the World Bank and WAPDA (World Bank, 1990). Awareness of a such a low-cost "win-win" solution based on water trading between agro-ecological zones does not, however, necessarily imply the foresight and political will to implement the same.