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Bangladesh
Climate Change and Sustainable Development

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South Asia Region

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CURRENCY AND EQUIVALENT UNITS
(March 2001)

Bangladeshi Taka 1	=	US$0.0183993
US$1	=	Tk. 53.85

WEIGHTS AND MEASURES

1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.61 mile (mi)
1 hectare (ha)	=	2.47 acres (ac)

UNITS

cr	crore (10 million)
ha	hectare
km	kilometers
kg	kilogram
lakh	100,000
mt	metric ton
qtl	quintal (100 kg)
Tk	Taka

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Abbreviations

ADAB	Association of Development Agencies in Bangladesh
ADB	Asian Development Bank
ALGAS	Asia Least-cost Greenhouse Gas Abatement Strategy
ARMP	Agricultural Research Management Project
BARC	Bangladesh Agriculture Research Council
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Centre for Advanced Studies
BEMP	Bangladesh Environment Management Program
BIDS	Bangladesh Institute of Development Studies
BIWTA	Bangladesh Inland Water Transport Authority
BUET	Bangladesh University of Engineering and Technology
BUP	Bangladesh Unnayan Parishad
BWDB	Bangladesh Water Development Board
CBO	Community Based Organization
CCC	Climate Change Committee
CCIA	Climate Change Impact Assessment
CEARS	Centre for Environmental and Resource Studies
CEN	Coalition of Environmental NGOs
DAE	Department for Agriculture Extension
DMB	Disaster Management Bureau
DF	Department of Forest
DOF	Department of Fisheries
EGIS	Environment and Geographical Information Systems
EIA	Environmental Impact Assessment
ENSO	El Nifio Southern Oscillation
FAP	Flood Action Plan
FCDI	Flood Control Drainage and Irrigation
FEJB	Forum of Environmental Journalists of Bangladesh
GBM	Ganges-Brahmaputra-Meghna
GCM	General Circulation Model
GDA	Ganges Development Area
GDP	Gross Domestic Product
GEF	Global Environment Facility
GNP	Gross National Product
GOB	Government of Bangladesh
HTW	Hand Tubewell
HYV	High-yield Variety
ICDDRB	International Centre for Diarrhoeal Disease Research
ICZM	Integrated Coastal Zone Management
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
IWRM	Integrated Water Resources Management
LGED	Local Government Engineering Department
Mha	Million Hectares
Mmt	Million Metric Tons
MoEF	Ministry of Environment and Forests
MOI	Ministry of Information

MPO	Master Plan Organization
NARS	National Agricultural Research System
NEC	National Environment Council
NEMAP	National Environmental Management Plan
NGO	Non Government Organizations
NWMP	National Water Management Plan
NWRC	National Water Resources Council
O&M	Operation and Management
PC	Planning Commission
PET	Potential Evapo-Transpiration
PWD	Public Works Department
RA	Resource Analysis
REB	Rural Electrification Board
SBCP	Sundarbans Biodiversity Conservation Project
SEMP	Sustainable Environmental Management Programme
SIA	Social Impact Assessment
SPARRSO	Space Research and Remote Sensing Organization
STW	Shallow Tubewell
SWMC	Surface Water Modeling Centre
TCF	Trillion Cubic Feet
TGTDL	Titas Gas Transmission and Distribution Co. Ltd.
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WARPO	Water Resources Planning Organization
WRI	World Resources Institute

GLOSSARY

Aman Rice crop harvested in November-December (see B. Aman and T. Aman).

Aus Summer rice planted in March-April and harvested in July-August.

Boro Rice crop planted in December-February, and harvested in April-June; mostly HYV with higher yield potential than the local varieties.

B. Aman Broadcast aman; a rice crop usually planted in March/ April under dry land conditions, but in areas liable to deep flooding. Also known as deepwater rice. Harvested October to December. All varieties are highly sensitive to day length.

Beel Small area of standing water round the year.

Char Land formed by river activity due to sedimentation and silt accretion

Haor Extensive low lying area subject to seasonal flooding

HYV High yielding variety; introduced varieties developed though formal breeding programs. HYV's have a higher yield potential than local varieties but require correspondingly high inputs of fertilizer and soil moisture to reach full yield potential.

Kharif Cropping season comprising an early part (pre-monsoon and early monsoon), and a later part (second half of monsoon and early post-monsoon).

Kharif 1 The first part of the kharif season (April to June). Rainfall is variable and temperatures are high. The main crops are aus, summer vegetables and pulses. Broadcast aman and jute are planted.

Kharif 2	The second part of the kharif season (June to October), characterized by heavy rains and floods. T. aman is the major crop grown during this season. Harvesting of jute takes place. Fruits and summer vegetables may be grown on high land.
Khas	Government owned land
Rabi	Dry cropping season including the cool winter months, and the hot pre-monsoon months (November to March).
Sal Forest	Forest area mostly covered by *Shorea robusta,* a tropical moist deciduous species.
Shutkee	Dried fish
T. ***Aman***	Transplanted aman; a rice crop planted usually in July/August, during the monsoon in areas liable to maximum flood depth of about 0.5 m. Harvested in November/ December. Local varieties are highly sensitive to day length whereas modern varieties are insensitive or slightly sensitive.

Acknowledgement

The final report was prepared by the South Asia Rural Development (SASRD) Unit of the World Bank. The work was carried out by Sarwat Chowdhury under the general direction of Rashid Faruqee. They also prepared the executive summary of this report.

The study preparation went through several phases. In the first phase, a contract was given to Stratus Consulting Inc. (specifically Joel Smith), and the Bangladesh Centre for Advanced Studies (BCAS). Important contribution was received from the International Global Change Institute of the University of Waikato, New Zealand (including analysis of changes in flood risks in Bangladesh). This phase focused on summarizing available knowledge with respect to the potential impacts of climate change in Bangladesh, and identified vulnerable sectors. The draft aimed at building awareness, and laid the ground work for the identification of pragmatic measures to reduce Bangladesh' vulnerability to possible climate change. In 1999, Resource Analysis group was contracted to revise the report. The revision included latest developments in the relevant sectors. This phase of course incorporated specific implications of the identified impacts for development policies and programs, and practical recommendations for actions to be taken in Bangladesh. Resource Analysis group (consisting of Rob Koudstaal, Saskia Werners and Bushra Nishat) collaborated with Bangladesh Unnayan Parishad (specifically Ahsan Uddin Ahmed), and BCAS (specifically Saleemul Huq and Atiq Rahman) for completing the work. An in-country working group discussions was held on June 28, 1999, followed by submission of a second draft report by November 2,1999.

The latest draft was then substantially revised and restructured at the SASRD. This revised version was discussed at a review workshop on December 30, 1999 in Dhaka. Two additional review workshops were held in 2000 with two different group of stakeholders: one on May 8, and the other on May 25. At the suggestion of GOB Secretary, Ministry of Environment and Forests, a green cover version of the report was reviewed at a meeting at MOEF on October 19, 2000. The final report reflects the comments received from these consultative meetings. Other staff members of the SASRD team particularly S.A.M. Rafiquzzaman, Imtiazuddin Ahmad and Tajul Islam provided useful suggestions. Robert T. Watson and Walter Garvey were peer reviewers of the final draft. Mieko Nishimizu is the Vice President of South Asia Region. Frederick T. Temple is the Country Director, Ridwan Ali is the Sector Director for SASRD.

Bangladesh
POVERTY and SOCIAL INDICATORS

1999	Bangladesh	South Asia	Low-income
Population, mid-year *(millions*	127.6	1,329	2,417
GNP per capita *(Atlas method, US$)*	370	440	410
GNP *(Atlas method, US$ billions)*	47.0	581	988
Average annual growth, 1993-99			
Population *(%)*	1.6	1.9	1.9
Labor force *(%)*	2.1	2.3	2.3
Most recent estimate (latest year available, 1993-99)			
Poverty *(% of population below national poverty line)*	36	..	..
Urban population *(% of total population)*	21	28	31
Life expectancy at birth *(years)*	61	62	60
Infant mortality *(per 1,000 live births)*	57	75	77
Child malnutrition *(% of children under 5)*	68	51	43
Access to improved water source *(% of population)*	84	77	64
Illiteracy *(% of population age 15+)*	47	46	39
Gross primary enrollment *(% of school-age population)*	96	100	96
Male	93	110	102
Female	100	90	86

KEY ECONOMIC RATIOS and LONG-TERM TRENDS

	1979	1989	1998	1999
GDP *(US$ billions)*	15.6	27.0	44.1	45.7
Gross domestic investment/GDP	14.9	17.2	21.6	22.2
Exports of goods and services/GDP	4.5	5.7	13.3	13.2
Gross domestic savings/GDP	5.9	9.6	16.7	16.7
Gross national savings/GDP	10.5	13.1	20.9	20.9
Current account balance/GDP	-1.8	-5.1	-1.2	-1.9
Interest payments/GDP	0.3	0.5	0.4	0.4
Total debt/GDP	21.1	41.1	37.1	37.2
Total debt service/exports	26.6	21.3	10.2	10.4
Present value of debt/GDP	..	..	22.9	..
Present value of debt/exports	..	..	150.7	..

	1979-89	1989-99	1998	1999	1999-03
(average annual growth)					
GDP	4.4	4.8	5.2	4.8	5.1
GNP per capita	2.0	3.2	3.6	3.4	3.5
Exports of goods and services	6.1	14.2	12.4	6.0	4.9

STRUCTURE of the ECONOMY

	1979	1989	1998	1999
(% of GDP)				
Agriculture	36.7	26.0	19.1	19.6
Industry	20.7	20.4	24.8	24.3
Manufacturing	14.5	13.1	15.6	14.9
Services	42.6	53.6	56.1	56.2
Private consumption	92.2	86.2	78.6	78.7
General government consumption	1.9	4.1	4.7	4.6
Imports of goods and services	13.5	13.3	18.3	18.7

	1979-89	1989-99	1998	1999
(average annual growth)				
Agriculture	2.7	1.6	1.6	3.3
Industry	4.1	7.3	8.3	4.9
Manufacturing	2.8	7.2	8.5	3.2
Services	5.4	5.0	5.2	5.3
Private consumption	4.6	3.0	1.3	2.2
General government consumption	4.9	5.6	13.2	-0.2
Gross domestic investment	2.2	8.4	12.1	9.8
Imports of goods and services	4.6	10	- 0.3	5.0
Gross national product	4.6	4.9	5.2	5.0

Note: 1999 data are preliminary estimates.

PRICES and GOVERNMENT FINANCE

	1979	1989	1998	1999
Domestic prices				
(% change)				
Consumer prices	..	8.4	7.0	7.2
Implicit GDP deflator	10.9	7.7	5.3	4.7
Government finance				
(% of GDP, includes current grants)				
Current revenue	..	9.5	9.3	9.7
Current budget balance	..	..	2.1	1.1
Overall surplus/deficit	..	-5.3	-4.1	-4.8

TRADE

	1979	1989	1998	1999
(US$ millions)				
Total exports (fob)	..	1,286	5,172	5,523
Jute goods	..	97	108	72
Leather and leather products	..	137	190	275
Manufactures	..	871	4,531	3,515
Total imports (cif)	..	3,390	7,525	8,381
Food	..	555	373	915
Fuel and energy	..	285	506	515
Capital goods	..	1,070	1,342	1,295

	1979	1989	1998	1999
Export price index *(1995=100)*	..	62	109	107
Import price index *(1995=100)*	..	93	101	99
Terms of trade *(1995=100)*	..	67	108	108

BALANCE of PAYMENTS

	1979	1989	1998	1999
(US$ millions)				
Exports of goods and services	724	1,603	5,879	6,251
Imports of goods and services	1,675	3,716	8,049	8,824
Resource balance	-951	-2,113	-2,170	-2,573
Net income	-22	-108	-100	-109
Net current transfers	696	835	1,750	1,806
Current account balance	-278	-1,386	-520	-875
Financing items (net)	425	1,452	651	994
Changes in net reserves	-147	-66	-131	-118
Memo:				
Reserves including gold (US$ millions)	..	..	1,739	1,772
Conversion rate (DEC, local/US$)	15.2	33.2	45.4	48.1

EXTERNAL DEBT and RESOURCE FLOWS

	1979	1989	1998	1999
(US$ millions)				
Total debt outstanding and disbursed	3,282	11,118	16,376	16,994
IBRD	55	62	36	33
IDA	770	3,441	6,163	6,428
Total debt service	237	522	683	728
IBRD	5	6	6	7
IDA	6	35	105	119
Composition of net resource flows				
Official grants	495	772	657	810
Official creditors	533	975	359	248
Private creditors	9	-25	-23	-10
Foreign direct investment	0	0	308	279
Portfolio equity	0	0	3	10
World Bank program				
Commitments	202	417	646	595
Disbursements	163	299	347	441
Principal repayments	0	13	66	78
Net flows	163	286	281	363
Interest payments	10	28	45	49
Net transfers	152	258	236	314

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Executive Summary

♦ *I. Introduction*

Since record-keeping began in 1866, the 1990s have proven to be the warmest decade in human history. [1] The sea level along the Bangladesh coast is rising at about 3 millimeters a year, and the sea surface temperature is showing a rising trend.[2] Climate change due to global warming is a reality for this country, as it is for the planet itself.

The study under discussion focuses on Bangladesh since it is universally acknowledged to be extremely vulnerable to climate change. The low-lying topography, funnel shaped coast exposing the land to cyclones and tidal surges, seasonal flooding, widespread poverty, large population base, poor institutional development etc. have particularly made Bangladesh vulnerable to climate variability (Table 1). These vulnerability factors are described in table 1 below. The population of Bangladesh which is likely to be affected by climate change could be between 20 and 30 million.

Table 1[3]
Factors Increasing Bangladesh's Vulnerability to Climate Change

Geography Bangladesh is a broad deltaic plain with most elevations less than 10 meters above sea level.
Climate Subject to severe natural disasters: riverine & coastal floods, tropical cyclones, storm surges, tornadoes, and droughts. Most rainfall is confined to the monsoon season, causing major floods. The winters are dry.
Population 1998 population 126 million; average annual growth rate 1.6% (1992-98); population density is very high at 850 person/sq km. WRI (1998) projects population to be 190 million in 2020, and 218 million in 2050.
Economy Bangladesh is one of the world's poorest and least developed nations. GNP/capita in 1999: $370, whereas GNP/cap in South Asia $581. Agriculture, which is 25.3% of GDP[4], is particularly vulnerable to climate change.
Education Bangladesh has a literacy rate of 53%[5]. Compared to developed countries, this low rate of literacy limits the country's ability to adapt to climate change
Human Health Life expectancy at birth: 58 years; infant mortality rate: 75 deaths/1,000 live births (1992-98); 56% under five are malnourished; 84% have access to safe water. Communicable diseases caused by poor nutrition and sanitation include cholera, dysentery, diarrhea, measles, and tetanus. Parasitic diseases include malaria, dengue, filariasis, and helminthiasis. Malaria reemerged in the late 1980s.

The study identifies various climactic factors (temperature, precipitation, evaporation etc), provides possible climate change scenarios, and discusses adaptation possibilities. Details of the scenarios are provided in chapter two of this report, and chapter three elaborates on adaptation issues and strategies.

♦ *II. Likely Scenarios*

This summary of the potential effects of climate change on Bangladesh is confined up to the year 2050. Most development projects/activities have a planning horizon of 30 years or less, while a few

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1 *Vital Signs*, World Watch, 1998
2 Latest research conducted by the SAARC Meteorological Research Centre (SMRC)
Most of the data derived from the World Bank, *Bangladesh at a Glance*, September 1999
4 Latest figures from Bangladesh Bureau of Statistics, Oct 2000
5 Statistics derived from the World Bank, *Bangladesh at a Glance*, August 2000

have a planning horizon of 50 years or more. Table 2 provides below likely climate change scenarios in Bangladesh.

Looking into the changes in ***temperature***, the latest climate change projections for further increases in globally averaged surface temperatures are closer to 1-5°C by 2100 as compared with the year 1990. This is based on the latest IPCC (Inter-governmental Panel on Climate Change) Special report on Emissions Scenarios, which projects lower emissions of sulfur dioxide over the next 100 years than the previous IS 92 emissions scenarios.[6] or Bangladesh, the projections of this study are: by 2030, a 0.7°C temperature rise in monsoon, and a 1.3°C rise in winter. The impact of temperature increase on this poverty ridden country could be quite substantial. With a 4°C temperature rise (which may happen by the end of the century) and a 60 percent moisture stress added to other effects could result into an overall 32 percent decline in Boro rice production, and a 31 percent decline in wheat production.[7]

Table 2
Climate Change Scenarios

Year	**Sea Level Rise[a] (cm)**	**Temperature Increase (°C)**	**Precipitation Fluctuation Compared to 1990 (%)[b]**
2030	30	+0.7 in monsoon; +1.3 in winter	-3 in winter; +11 in monsoon
2050	50	+1.1 in monsoon; +1.8 in winter	-37 in winter; +28 in monsoon

Notes:

a. Based on Ahmed and Alam, 1998 (estimated values obtained by correlating model output data with observed data). On base year (1990): average winter temp: 19.9 °C & avg. monsoon temp: 28.7 °C
b. Estimated based on model output data regarding rate of temperature change. On base year (1990) average winter precipitation : 12 mm/mo; average monsoon precipitation: 418 mm/mo. From table 1, pg 23 (Huq, S. et al. 1998).

In terms of ***precipitation***, most models show increased annual precipitation for Bangladesh. Some models also show the possibility of increasing monsoon precipitation (May to September), and decreasing dry season precipitation (December to February). Although the magnitude of the changes in climate may appear to be very small, if added to existing climatic events (such as floods, droughts, and cyclones), these could substantially increase the magnitude of these events and decrease their return period. For example, a 10 percent increase in precipitation may increase runoff depth by one-fifth, and the probability of an extremely wet year by 700 percent.

For ***sea level rise***, following IPCC estimates, rise in sea level would be in the range of 15 cm to 95 cm by 2100. Taking the upper end, the rise would be about 30 cm by 2030 (see table 2). Even a very cautious projection of 10 cm sea level rise, which would most likely happen well before 2030, would inundate 2500 sq. km, about 2% of the total land area. Patuakhali, Khulna and Barisal regions are most at risk from sea level rise. On average, the sea would move in about 10 km, but in the Khulna region, the sea will likely move in further. With the high end estimates, sea level rise in Bangladesh would inundate 18% of the country by 2100. These interpolations are approximations.[8].

6 Comments from Robert T. Watson, WB, September 27, 2000

7 These statistics do account for C02 fertilization effect on food grain production, methodology of the projection is described in Huq et al. 1999.

8 these interpolations do not consider contour of land currently within 1 m of sea level, changes in sedimentation, and existing/future embankments etc. consultations on the draft of the study suggest that steps could include modeling taking polders, infrastructures such as embankments, sluices etc into account for a more precise projection.

Climate change will also effect ***cross-boundary river flows***. It is expected that climate change induced alterations in temperature would affect the timing and rate of snow melt in the upper Himalayan reaches. As a result, the hydrological aspects of the eastern Himalayan rivers and the Ganges-Brahmaputra-Meghna (GBM) river basins could alter significantly. During the winter period, however, the flows in the GBM rivers might decrease because of lower rainfall and higher surface evaporation.[9]

Some studies have reported that the ***El Niño Southern Oscillation (ENSO)*** events have practically influenced the record-breaking floods of 1987, 1988 and 1998.[10] It was found that the rapid transformation of La Niña from El Niño phase in early monsoon in 1998 influenced high rates of precipitation over the entire GBM catchment. As a result, after a prolonged dry season, the wettest monsoon came along with extremely high levels of precipitation eventually resulting in 1998 in the worst flood of the century. Long-term climate change might also change the magnitude and frequency of the El Niño phenomena.

Burdened by social and economic problems such as high unemployment, poor health delivery systems, low per capita income, and comparatively low levels of literacy, Bangladesh faces many difficulties in achieving sustainable development. Possibilities of climate induced changes would bring the country into an even more difficult position. Most vulnerable impact categories for climate change include: *coastal resources; water resources; agriculture; human health; and ecosystems / biodiversity.* Critical impacts, which are cross-sectoral in nature, are discussed next.

♦ *III. Critical Impacts*

The study identifies several specific problems that development policy makers will have to consider in a warmer Bangladesh.

▲ ***Drainage congestion problem*** will be a major impact of climate change. The combined effect of higher sea water levels, subsidence, siltation of estuary branches, higher river bed levels and reduced sedimentation in flood protected areas will gradually increase water logging problems, and impede drainage. This effect will be particularly strong in the coastal zone, but will also be felt in riverine flood plains further upstream. The problem will be aggravated by the continuous development of infrastructure (e.g. roads) reducing further the limited natural drainage capacity. One of the key effects of drainage congestion is that it will increase the period of inundation, and will expand wetland areas.[11]

▲ ***Reduced fresh water availability*** will become a serious problem in the dry season due to low river flows and increased evapo-transpiration in the dry period. In the coastal zone, the additional effect of saline water intrusion in the estuaries and into the groundwater stimulated by low river flow and sea level rise will be significant.[12] Pressure of the growing population and economic development could further reduce fresh water availability.

▲ ***Disturbance of morphological processes*** will also become a significant problem under climate change. Bangladesh' riverine and coastal morphological processes are extremely dynamic,

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9 According to Walter Garvey, WB, the major effect on dry season Ganges flow will be from increased water use due to the higher E-T, and reduced snow/glacier melt caused by a significant retreat of these features

10 Chowdhury, A.M. 1998. "Flood '98: Oceanic Perspectives." Paper presented to the National Seminar on Flood '98 and Management of Floods in Future, December 8, 1998

11 There may be some benefits for fisheries, for *Boro* production etc. However, the benefits will not perhaps outweigh the dis-benefits (crop loss, health affects).

12 Groundwater recharge and surface storage could improve increasing availability in some areas particularly in the late monsoon and early rabi seasons. However, higher E-T will increase water use, which calls for increased water use efficiency.

partly because of the tidal and seasonal variations in river flows and run-off. Climate change is expected to increase these variations, with two main (related) processes involved:

(i) *Increased bank erosion and bed level changes of rivers and estuaries.*

(ii) *Disturbance of the balance between river sediment transport and deposition in rivers, flood plains and coastal areas.*

▲ ***Increased intensity of disasters (extreme events)*** including cyclones/storm surges, floods and droughts will become evident with climate change.[13] The study shows that Bangladesh is particularly vulnerable to climate change in its coastal zone, covering about 30 percent of the country. Private sector investment in this area is likely to be affected by the risks of cyclones and increased flooding.

♦ *IV. Approaches & Challenges in Adapting to Climate Change*

There are strong reasons to adopt an *anticipatory long term* strategy rather than a *reactive* (as seen in our present strategy in disaster management) approach in meeting the impacts of climate change in Bangladesh. A small change in peak discharge, for example, may result in about 20 percent increase in area flooded. Climate change is human-induced, the effects are long-term, extremely slow to reverse (or irreversible especially in the case of the Sundarbans), and is global in scope with very complicated (and sometimes unknown) regional implications. While Bangladesh has considerable experience in responding to disasters, and is in a continuous process to improve on its capacity to mitigate the impacts of cyclones, floods etc., the reality of climate change forces us to reorient our perspective towards long-term preparedness.

Challenges in Adapting to Climate Change

The focus for the introduction of anticipatory measures would first be on national planning organizations. However, anticipatory adaptation faces special institutional and technical challenges. For example:

♦ *Proper attention to long-term issues requires well-defined planning structures and procedures.*

♦ *Information about climate change related issues is scattered and sometimes difficult to access.* The required political focus to establish a knowledge base for climate change, an important requirement for strategic planning and coordination is still missing.

♦ *Management of resources requires integration.*

♦ *Integrated environmental management* is a difficult issue in many countries, and it can not be expected that Bangladesh will have an effective environmental management structure in the near future.

♦ *With respect to land use planning, physical planning capacity* in Bangladesh is weak.

♦ *Adaptation needs coordination between central and local levels of management* whereas Bangladesh' system of planning and management is strongly centralized.

♦ *Traditional planning techniques are inadequate* especially since planning which would account for adaptation to climate change, faces at least two methodological problems. First, impacts may not occur in the near future (i.e. within the next decade). Second, uncertainties about changes in the regional climate and the corresponding impacts are still significant.

♦ *V. Broad Sectoral Adaptations*

This study identifies *strategic* adaptations that should be considered by policy makers and planners to strengthen the capacity of Bangladesh to address the reality of climate change. While strategic

[13] Scientists from SPARSSO support this prediction

adaptations to climate change concern all sectors of the economy, five areas (*coastal resources, fresh water resources, agriculture, ecosystems & biodiversity,* and *human health*) require most urgent attention in Bangladesh.

A general framework for a comparative tentative assessment of various adaptations[14] is proposed in this study. The framework assesses which adaptation measures are likely to be most relevant to reduce the country's vulnerability, taking into account the efforts needed for implementation. Three main criteria for assessment was used:

1. *Effectiveness* (of the measure for the reduction of key risks), and
2. *Feasibility* (considers technical aspects as well as costs, social acceptance and manageability).
3. *Current state of implementation & requirements for improvement* (refers to how they are being practiced in the country with or without consideration of climate change).

The above criteria then lead to a tentative assessment of prioritizing future action programs which are indicated by HIGH, MEDIUM, or LOW priority[15]. To emphasize, an adaptation measure if it has not been tried before could be identified as high priority as long as it is effective, technically feasible, socially acceptable, and can be implemented under the **existing or an improved** institutional and legal framework in Bangladesh. Such a program would **not** be high priority **only if** one is convinced that in the Bangladesh context, it is not possible at least in the next fifty years.

The five selected sectors[16] are obviously inter-related, and adaptation in one sector will have value for other sectors as well. While the suggested adaptations may seem to be justified independent of long-term climate change, the priority of some of the adaptations can be seen from the tables in the following pages. It should be noted that the proposed framework only provides a general guideline of "tentative assessment of climate change adaptation" in order to provoke the thinking process of policy makers. The framework is based on the best judgment of the authors and those consulted[17] for this study, and does not claim to be a prescribed policy framework for Bangladesh. However, for every sector, *guidelines to incorporate climate change in long term planning* should be considered as an essential institutional adaptation.[18]

Coastal Resources

The coastal resources will be affected by all the key risks. These include: **drainage congestion** due to higher water & river bed levels, **salinization** of land and water resources (including the Sundarbans) due to lower river flows, and higher relative sea levels aggravated by subsidence; **increased morphological dynamics** with erosion of rivers and coasts not compensated by accretion of land of equal quality; **more intense disasters** including cyclones and storm surges with higher risks because of higher water, and lower land levels in protected areas.

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14 Adaptation measures can be of various types:

- *Adaptations of climactic factors* such as negotiating water sharing arrangements and participating in international deliberations on the mitigation of greenhouse gas emissions, which is discussed in section V.
- *Physical adaptations* (protection and enhancement) in the human made or natural systems, such as: planting of mangroves, raising of dikes, construction of tidal basins.
- *Institutional adaptations* would facilitate the various types of adaptation. These may also include socio-economic measures such as changing the use of resources through non-structural measures, such as, crop diversification and sustainable shrimp cultivation, changing planning procedures and increasing awareness level etc.

15 A proposed adaptation measure may be deemed high priority even if it scores are medium on average (if it has not been tried properly or extensively in the country)

16 Discussions on human health and ecosystems/biodiversity sectors could be made more comprehensive and further research in these areas could be useful.

17 Appendix F of the main report provides a complete list of those consulted in the review workshops.

18 Consensus from reviewers -- after the issue was raised by Atiq Rahman, BCAS at the May 25, 2000 consultation workshop

♦ Specific recommendations for adaptation to **drainage congestion** include *physical interventions* and *institutional measures*. Physical adaptation includes increasing drainage capacity of infrastructure, new regulators, tidal basins, and pumped drainage; whereas institutional adaptations include guidelines to incorporate climate change, proper O & M arrangements including establishment, and support of local water management, and design criteria for drainage capacity of infrastructure.

Physical adaptation requires mainly two steps: (i) bringing water from the land into the main drainage system; and (ii) draining water to the sea. Step (i) presently is done under gravity, mostly through regulators which open during low tides. When higher water levels impede this process, pumping remains the main option. Step (ii) requires a well maintained drainage network, and dredging. Increasing the *drainage capacity of existing infrastructure* such as roads seems a feasible and effective way to reduce drainage congestion where drainage is hampered by culverts, bridges, regulators etc. *New regulators* and *tidal basins*[19] are alternative physical interventions to solve the drainage problem. Tidal basins stand out as a preferred option from an environmental and maintenance perspective (since tidal basins would substantially reduce the maintenance dredging and bring sediments to the beel areas). The *tidal basin* experience in Khulna-Jessore Drainage Rehabilitation Project proves that this is a feasible approach in south-west Bangladesh. *Pumped drainage* seems a last and expensive resort especially when the outside water levels become too high for drainage under gravity.

Institutional measures include guidelines to incorporate climate change in long term planning. Establishing *proper O&M arrangements* for the maintenance of drainage channels and infrastructure could be an effective approach, but has medium feasibility. Effectiveness of water management associations is limited because of the fact that drainage congestion is caused by factors outside their control. Developing *design criteria for drainage capacity* (both for infrastructure and embankments) is feasible but not very effective in the coastal zone.

♦ Specific *physical adaptations* for the **salinity** problem should focus on increasing surface water flows from upstream, resuscitation of river networks, increasing local storage capacity of fresh surface or groundwater, and desalinization plants and equipment. The Gorai River Restoration Project is an example of *diversion project* for diverting water from the Ganges river[20] towards the southwest. Effectiveness of such measures can be high, but feasibility is low because of high cost. Proper implementation of impact assessments are also required to assess potential environmental and social consequences. *Resuscitation of river networks*, in spite of the physical constraints, could be meaningful in the short-term especially in the south-west (e.g. Satkhira). Possibilities for *increased local storage* of surface and groundwater in the area itself are low as well. *Desalinization plants and equipments* are too expensive as possible adaptation measures.

Institutional adaptations for salinity include maintenance and operation of sluices and other regulators, groundwater management, land use practice, extension services, and water saving techniques etc. The first two are management options. Improving *maintenance and operation of sluices* and other *regulators* to hold water in areas that are under increased stress from salinization score low on feasibility, but high as priority for incremental action since they need to be implemented. Establishing effective *groundwater management* may be effective but scores low on feasibility. *Land use practice* can be influenced by incentives to change agricultural practices so that agricultural demand for fresh water goes down.

19 In the tidal basin approach, the dynamics of the tidal system is maintained, fixed major structures such as regulators are avoided as much as possible, and applied only on a local scale.

20 Of course, the flow in GRRP depends on the Ganges flow.

♦ For the impact of **increased morphological dynamics,** several methods can be adopted. *Physical adaptations* to the threat of increased **erosion** would include mangrove greenbelts, cross dams and/or river training works. *Mangrove greenbelts* in the foreshore areas and along the coastal embankments, and *cross dams* at the same time enhance accretion. *River training works,* e.g., through bank protection or strong holds are confined to the estuarine river branches. All these measures are effective. The main challenges for cross dams and river training works are in feasibility. While costs of cross dams and river training works are progressive; the latter requires long term maintenance, making it basically unsustainable. The high effectiveness and feasibility of *mangrove greenbelts* are well acknowledged.

Institutional adaptations would aim at protecting mangroves & wetlands, and land use arrangements (including land tenure laws) & policies. Although loss of land, and the creation of new land are common phenomena in Bangladesh, there does not appear to be a functional legal and administrative system for addressing these issues. The mangrove belts could be managed in a much more flexible way than the present practice. Changing *land tenure laws and policies,* though potentially effective, will meet serious institutional limitations. A sustainable adaptation to climate change will require reforms in these policies.

♦ In terms of more intense **natural disasters,** *physical adaptations* include construction of new infrastructure such as cyclone shelters[21] and / or coastal embankments and landfills[22], modification of existing infrastructure combined with improved warning systems, and mangrove greenbelts. New and existing *mangrove belts* (as mentioned earlier) appear to be effective in protecting against coastal storms, and in facilitating sedimentation. For example, mangroves can be an effective barrier against winds and storm surges (Haider, 1992). Such activities in Bangladesh needs to be streamlined by ensuring peoples' participation in maintaining and benefit sharing.

Institutional adaptations in this respect include improving forecasting, warning and evacuation procedures, adapting land use & development policy, and maintenance of existing and future coastal embankments. Improvement of the *forecasting system* seems highly promising, though implementation could be deterred by institutional and communication problems. *Dissemination system*[23] could also be improved. Adopting *land-use development policy* seems an effective tool. Required institutional arrangements, however, seem almost unattainable, and therefore this adaptation scores low on feasibility, and scores medium as priority for incremental action. *Maintenance of embankments* are effective, though they do not score high on feasibility because of costs and organization needed to maintain them. For its role in saving lives and property, this is considered a high priority future incremental action.

In terms of overall coastal resources: physical interventions such as building coastal defenses can be expensive. Huq *et al.* (1995) estimated that the cost of defending against a 1 m sea level rise would be US$1 billion. Hard coastal defenses such as sea walls can have negative effects on beaches and on biodiversity.

Table 3 summarizes a tentative assessment based on the discussion above.

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21 Past experience have shown that the holding capacity of existent shelters is barely adequate for people, and there is often no room for them to bring in livestock, and other assets, which are vital to the livelihood of the poor.

22 Landfills here refer to land elevated to keep up with the flood levels, that can be used on a multi-purpose basis, e.g. community usage in the form of a village market place.

23 In terms of alerting coastal residents about the seriousness of storms, for example, making sure they do not confuse the danger signals applicable for "inland river ports" with the signal for "maritime ports" (as experience shows the result of such a mistake could be literally deadly).

Table 3: Tentative Assessment of Adaptation Measures[24] for Coastal Resources

Key impacts and adaptation measures	Effectiveness /Feasibility	Current state of implementation and/or requirements for improvement/	Priority for incremental future action
[illegible] drainage congestion			
Physical adaptations[25]			
Increasing drainage capacity of infrastructure	Medium/ High	Some bridge & culverts are poorly designed, water & road infrastructure lack maintenance & proper operation	HIGH [26](needs better implementation)
New Regulators	High /Medium	To be designed	MEDIUM
Tidal basins	High/ High	New concept (some trade off with salinity), overall early results are promising, should be pursued especially in south-western Bangladesh	HIGH (in SouthWest Bangladesh
Pumped drainage	Medium/ Low	Applied in selected places	LOW
Institutional adaptations[27]			
Proper O&M arrangements including establishment and support of local water management	High/ Medium	Very poor, often non-existing, institutional framework a major problem, local govt. institutions to be involved	MEDIUM (needs implementation) WSIP can possibly play an important role
Design criteria for drainage capacity infrastructure	Low/ Medium	Poorly designed & implemented, may not be effective in the coastal zone	LOW (however, HIGH priority for new regulators)
To mitigate salinization			
Physical adaptations			
Surface water flow from upstream, e.g. by diversion or withdrawal from major rivers	Medium/ Low	Highly capital intensive, however by building cross-dams (barrier across tidal flow), can prevent saline water intrusion[28] . This process should include EIA to assess potential env/social consequences[29]	MEDIUM/ HIGH[30]
Resuscitation of river networks	Medium/High	Despite physical constraints, could be meaningful in the short-term exp. in the	HIGH

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24 Guidelines to incorporate climate change in long term planning is an essential institutional adaptation for the various impacts in the coastal zone

25 Physical adaptations must be linked with institutional adaptations

26 During one of the consultations, Ainun Nishat of IUCN suggested that the priority should be MEDIUM since this can be a slow process in the coastal areas, however others felt it was a HIGH priority for coastal areas also

27 Institutional adaptations must also be linked with physical adaptations

28 Comment from Jalaluddin M. Hye, Head, Coastal Hydraulics, SWMC

29 Comment from Robert T. Watson, World Bank

30 This may be a judgement call, during a consultation T. A. Khan, D.G. WARPO suggested that considering the critical problem of salinity in south western Bangladesh, this should be of HIGH priority over there. Some others differed. GOB places HIGH priority on this.

Key impacts and adaptation measures	Effectiveness /Feasibility	Current state of implementation and or requirements for improvement	Priority for incremental future action
		south-western block especially Satkhira	
Storage of water in the area itself	Low/Low	Not yet implemented	LOW
Desalinization plants and equipment	Low/ Medium	Not yet planned	LOW
Institutional adaptations			
Operation of sluices and regulators	Medium/ Low	Existing management very poor, often non-existent	HIGH (needs implementation)
Groundwater management	Medium/ Low	Not yet evaluated (technical aspects) for example, to prevent salinity intrusion, need to preserve a prism of surface water	LOW
Land use planning	Medium/ Low	Management aspect needs to be worked out. For example, for shrimp cultivation, salinity is not a problem, but for agriculture: soil salinity can become a problem	MEDIUM
Extension services	High/ Medium	Need to be improved especially since coastal areas have lower agricultural growth & need special module for	HIGH
Water saving techniques (with consideration of long term climate changes)	High/ Medium	Not applied at their maximum capacity, may pose socio-economic problems to the farmers	HIGH
To improve morphological dynamics			
Physical adaptations			
Mangroves greenbelts	High/ High	Started, needs -evaluation, should continue	HIGH
Cross dams	Medium/ Low	Needs-assessment is necessary for new dams, adverse affect elsewhere, could be expensive as well	LOW[31], can be applied for land accretion purposes
River training and bank protections	Medium/ Low	Poorly done, would be high cost since exposed to the sea	LOW (in the coastal areas)
Institutional adaptations			
Protection of mangroves and coastal wetlands	High/ High	Evaluation of activities needed especially in terms of maximizing social benefits	HIGH
Land tenure laws	Medium/ Low	Evaluation needed	HIGH
Land-use policy	Medium/ Low	Evaluation needed	HIGH
Adaptation to disasters			
Physical adaptations			
Cyclone shelters for people, livestock, food, and assets	High/ High	Already proven, high social acceptability	HIGH

31 Some of those consulted suggested that this could be high priority from water policy, and embankments can prevent storm surges.

Key impacts and adaptation measures	Effectiveness /Feasibility	Current state of implementation and/or requirements for improvement/	Priority for incremental future action
Embankments and landfills	High/ Medium	Poorly done, effective up to a certain limit	MEDIUM
Mangrove greenbelts	High/ High	Started, needs evaluation	HIGH
Modification of infrastructure (including elevation of embankments etc)	Medium/ Low	Needs design modification	LOW (raising height of embankment is a slow affair, & the physical aspects are low in planning phase)
Institutional adaptations			
Forecasting and dissemination	High/ Medium	Flood and cyclone forecasting could be made location specific	HIGH
Land-use development policy	High/ Medium	Evaluation needed	MEDIUM
Involvement of volunteers, CBOs in pre- & post disaster work	High/ High	Should continue	HIGH
Modification of infrastructure	High/ High	Institutional aspects need further work (at planning phase, roads & embankment approach is high priority)	HIGH
Maintenance coastal embankments	High/ Medium	Poorly done, local EMG (embankment maintenance groups) could be made more effective. Contingency planning & preparedness could be developed for example in Coastal Zone Development Program.	HIGH

Fresh Water Resources

The suggested adaptation for fresh water resources examines areas of **reduced fresh water availability, drainage congestion, increased morphological dynamics,** and **increased flooding.**

- Possibilities for *physical adaptations* to **reduced fresh water availability** refer to increasing surface water availability through *additional inflows from upstream, increasing drainage capacity of infrastructure,* and *increase of storage of water* in the area itself. Increasing drainage capacity of infrastructure scores high as a priority for incremental future action. Increase of inflow, e.g., by diversion of rivers is in itself effective but seems not so feasible because of the conflicts with upstream users even within the country. One way of storage would be through rain water harvesting, excavation of ponds etc which could be a promising alternative.

Institutional adaptations include reducing water demand, and participatory management of infrastructure. For example: groundwater extraction, which is basically uncontrolled, could be better regulated and monitored; or farmers could be trained to increase water use efficiency through farm practices. Again, market concepts could be introduced (by having consumers pay for water use, or allowing trading of water rights) which may help ensure that water goes to the most efficient applications. Another important and promising institutional mechanism to increase the flexibility to adapt to climate changes are proper *participatory arrangements for operation and maintenance of water resources infrastructure.*

♦ *Physical adaptations to* **drainage congestion** include restoration of channels, flushing capacity enhancement, drainage capacity infrastructure in roads, controlled sedimentation and land fills, and pumped drainage. *Institutional* adaptation includes *improved design criteria* for openings in drainage blocking structures, such as culverts and bridges in roads and *community involvement in the operation and maintenance of the water resources infrastructures.* Both are considered to have medium to low effectiveness and feasibility, however score high as a priority for incremental future action.

♦ *Physical adaptations* to **increased morphological dynamics (erosion & accretion)** can include river training and bank protection, and dredging of navigation channels which suffer from increased sedimentation. *River training* and *bank protection* have long been practiced in Bangladesh, in particular on a local scale. More recently efforts are being taken on a national level to harness the main rivers (e.g., the Right Bank Protection of the river Jamuna). On the *dredging of navigation channels*, the study on the morphological dynamics of the Jamuna River (EGIS, 1997), showed a continuous increase in river width, which is partly compensated by a decrease in river depth. Dredging activities could be intensified, but they have low feasibility, and medium priority.

Institutional adaptations (which includes improved monitoring and forecast of changes, relocation of victims of erosion, and navigation management and information), at present face limitations in implementation. *Monitoring* and *forecasting morphological changes* become more and more important to prepare for anticipatory measures to protect the increasingly important infrastructure (such as the Jamuna bridge). Knowledge and experience to analyze the morphological behavior of the rivers in Bangladesh is growing though still inadequate for proper management. Other institutional arrangements include programs to *relocate the victims of erosion.* An institutional and *regulatory framework* is necessary to relocate the victims in government owned *Khas* lands, which may be supplemented by NGO-driven micro-credit programs to facilitate income generation activities in those areas. This highly effective and sustainable mechanism may, however, have a low feasibility. Navigation would greatly benefit from proper and real time *information about the navigability* of rivers during the dry season and demarcation of navigation channels. This is again effective and sustainable but has low feasibility. Overall priority for this measure is high.

♦ *Physical adaptations* to **increased flooding** include full flood protection embankments, controlled flooding, elevated land as flood refuge, and flood refuge areas. *Full flood protection embankments* are widely practiced in Bangladesh in areas where full flood control is economically needed and justified. Although effective, their feasibility is medium because of the O&M requirements. *Controlled flooding* in combination with compartmentalization has been practiced under the FAP project (FAP20), and deserves more attention. In terms of feasibility, controlled flooding scores low. *Landfills (elevated land)* and *flood refuge areas* focus directly on the affected people and assets rather than on limiting or managing the excess floodwater. In response to the need for increased dredging operations in Bangladesh, introduction of larger scale landfill or flood shelter operations could be considered. Most of the pucca schools and the elevated roadsides are considered now as flood refuge areas. These measures are quite effective, and feasible.

Institutionally, improved flood warning and forecasting, limit on developments in high-risk areas, and evacuation of vulnerable people and valuables are some possible adaptation measures. *Flood warning* should not only predict water levels in rivers, but should also give an estimate of depth and duration of floods, which is much more useful to farmers. *Improved forecasts* need to be combined with proper dissemination mechanisms and techniques. Improved damage assessment techniques would then support efficient and effective relief measures. *Involving local community in maintaining flood protection embankments* should be a priority both as physical and institutional adaptation.

Table 4 summarizes a tentative assessment based on the above discussion.

Table 4: Tentative Assessment of Adaptation Measures[32] for Fresh Water Resources

Key risks and adaptation measures	Effectiveness/ Feasibility	Current state of implementation and /or requirements for improvement	Priority for incremental future action
To mitigate reduced fresh water availability			
Physical adaptations			
Increasing drainage capacity of infrastructure.	Medium/ High	Some bridge & culverts are poorly designed, water & road infrastructure lack maintenance & proper operation. [33]	HIGH
Enhanced surface water flow from upstream	Medium/ Low	Not very feasible within the country.	LOW. However, on a basin wide approach, it would be HIGH priority, though politically difficult
Storage in area itself	Low/ Low	Not evaluated in terms of recharging groundwater aquifers or special operation of regulators, but can be attempted through simple methods such as rain water harvesting, excavation of ponds etc	HIGH for fresh water resources
Institutional adaptations			
Guidelines to incorporate CC in long term planning	High/ Med	Not existing	HIGH
Reduction of water demand	High/ Medium	Need more coherent policies for monitoring groundwater extraction, pricing groundwater, promoting water use efficiency etc	HIGH
Participatory management of infrastructure (including water resources infrastructure)	High/ Medium	Needs appropriate policy guidelines & implementation	HIGH
Adaptation to drainage congestion			
Physical adaptations			
Channel restoration	High/ Low	Poor maintenance, for large rivers considered not feasible; for medium & minor channels, may be feasible	MEDIUM
Flushing capacity enhancement	Medium/ Low	Limited attempts made	LOW
Sufficient drainage capacity infrastructures in roads	High/ Low	Poorly designed/ lacks maintenance. Construction of any drainage infrastructure should pay special attention to the requirements of drainage capacity.	HIGH
Controlled sedimentation and land-fills	High/ Medium	New concepts, needs more understanding	MEDIUM
Pumped drainage	High/ Low	To be considered for major cities only, generally not a high priority	LOW
Institutional adaptations			
Guidelines to incorporate CC in long term planning	High/ Med.	Not existing	HIGH
Improved drainage criteria infrastructure	Medium/ Med.	Not tried yet	HIGH (needs implementation)
Participatory management of water resources infrastructure	Medium/ Low	Needs adequate policy reforms	HIGH (needs improvement)

32 Guidelines to incorporate climate change in long term planning is an essential institutional adaptation for the various impacts on fresh water resources

33 During consultation, reviewers suggested that infrastructure construction should take hydrology into account

Key risks and adaptation measures	Effectiveness/ Feasibility	Current state of implementation and /or requirements for improvement	Priority for incremental future action
Adaptation to increased morphological dynamics			
Physical adaptations			
River training and bank protection	Medium/ Med.	Poorly done, capital cost very high; however river bank protection is a high priority for GOB	LOW[34] (can be used selectively for protecting high value assets)
Dredging of navigation channels	Medium/ Low	Limited coverage	MEDIUM
Institutional adaptations			
Guidelines to incorporate CC in long term planning	High/ Med.	Not existing	HIGH
Improved monitoring and forecast of changes	High/ Medium	Needs capacity enhancement	HIGH
Relocation of victims of erosion	Medium/ Low	Social aspects affect economy of the country in the long run, needs proper relocation policies	MEDIUM
Navigation management and information	Medium/ Low	Poorly managed	HIGH
Adaptation to increased flooding			
Physical adaptations			
Flood protection (including flash floods) embankments	High/ Medium	Local community should be made responsible for maintenance; should be area specific, flood proofing could be improved	MEDIUM
Controlled flooding	Medium/ Low	Practiced under the FAP project	MEDIUM
Elevated land as flood refuge or flood shelters	High/ High	Practiced throughout the country	HIGH
Flood refuge areas e.g. Dhaka city itself	High/ High	Needs evaluation	HIGH
Institutional adaptations			
Improved flood warning and forecasting	Medium/ High	Already proved to be effective, more cooperation needed, and needs to be location specific	HIGH
Limit developments in high-risk areas	Medium/ Low	Flood zoning (based on avg water level, not extreme water levels) exists, but not applied	LOW
Involvement of local community in maintaining flood protection structures	High/ Medium	Should continue	MEDIUM
Evacuation of vulnerable people and valuables	High/ Low	Very limited capacity exists, per person cost may be very high in less dense areas. For the poorest, for whom evacuation means losing lives' savings—it's a difficult choice	HIGH (as saving human lives is the main objective)

Agriculture

Critical impacts of climate change will adversely affect agriculture, and proposed adaptations in this sector distinguishes between socio-economic and institutional adaptation measures.

Physical adaptations for agriculture will focus on improved irrigation efficiency, crop diversification, and conjunctive use of surface and groundwater for irrigation. Present day irrigation practices are rather water intensive. Although the technical and financial feasibility of improved irrigation efficiency is promising, it might require adequate training and extension (institutional support).

34 Some of those consulted, suggested that this should be a HIGH priority based on a systems approach (supporting on GOB prioritization), others differed

Economic *pricing of water* is already in practice in the private irrigation schemes in Bangladesh, and this could be introduced in public irrigation schemes.

Crop diversification with an emphasis on more drought resistant crops in drought sensitive areas should help to reduce vulnerability to climate change. For example, wheat requires significantly less irrigation water compared to Boro paddy.

Adaptation may also be possible by *promoting conjunctive use of both surface and ground water.*

Institutional adaptations include training programs and dissemination, research and development of new crops, change in practices, expanding access to credit etc. *Development of varieties* that are less climate change sensitive including drought-tolerant crops, faster growing or stronger & less inundation sensitive varieties, with adequate research, can be highly effective and feasible. *Training and extension* is necessary, and scores high as an adaptation measure. Specific to drought impacts, more *efficient water* use can be stimulated further. A promising approach could be found through community-based adaptations rather than regulation, i.e. the community deciding on how to share a limited common resource. *Expanded access to credit* requires institutional support, and is a high priority.

Overall, since agriculture is expected to remain a key sector of the rural economy, Bangladesh is very sensitive to climate change impacts on the agricultural sector. These risks are particularly pronounced in the coastal zone where agricultural activities will likely be in conflict with industrial development. The study highlights the need for further research on the adaptation of agriculture sector under climate change scenarios. More training programs and dissemination are also promising as adaptation measures.

The table 5 summarizes the above discussion.

Table 5: Tentative Assessment of Adaptation Measures[35] in Agriculture

Adaptation measures	Effectiveness / Feasibility	Current state of implementation and /or requirements for improvement	Priority for future incremental action
Physical adaptations			
Improved irrigation efficiency	Medium/ Med	Poor, needs institutional support	HIGH
Crop diversification	Medium/ Med	Some efforts have been made with limited success	HIGH
Conjunctive use of surface & groundwater for irrigation	High/ Med	Optimization of surface & ground water use needed	MEDIUM
Institutional adaptations			
Guidelines to incorporate CC in long term planning	High/ Med	Not existing	HIGH
Training programs and dissemination	High/ High	Poor dissemination, activities need to be enhanced	HIGH
Research and development of new (salinity & drought resistant) crops	High/ High	Research needs to be enhanced	HIGH
Change practices	Medium/ Low	Needs social persuasion & advocacy	MEDIUM
Expanded access to credit	Medium/ Low	Institutional support is vital, should be pursued	HIGH

[35] Guidelines to incorporate climate change in long term planning is an essential institutional adaptation for the various impacts in the agriculture sector

Human Health[36]

The threat to human health in developing countries is one of the salient risks of climate change.
Drainage congestion and standing water will increase the potential for outbreaks of cholera and other waterborne and diarrheal diseases, such as malaria, dengue and dysentery. Possible adaptations can be two types: physical, and institutional.

Possible *physical adaptations* will include water treatment facilities, improved sanitation, access to improved health care system etc.

In terms of *institutional adaptation,* improved *surveillance and monitoring* of conditions that can act as a catalyst to the outbreak of diseases should be undertaken. Such programs should be coordinated with the media to ensure early warnings and enhanced social response. *Improved public education especially in reproductive health system* is another important adaptation measure.
Rational incorporation of *technological/engineering control* for example, biological pest management systems could be attempted. However, consideration must be given to potential negative environmental consequences of the use of technological adaptation methods. Feasibility of such adaptations is tentative and questionable.

Table 6 summarizes a tentative assessment of adaptation measures in human health.

Table 6: Tentative Assessment of Adaptation Measures[37] in Human Health

Adaptation measures	Effectiveness/ Feasibility	Current state of implementation and /or requirements for improvement	Priority for future incremental action
Physical adaptations			
Water treatment facilities	High/ Low	Very low coverage, poor service quality, should be expanded	HIGH
Improved sanitation	High/ High	Coverage increasing	HIGH
Access to improved health care system	High/ High	Coverage increasing, quality needs to be increased	HIGH
Institutional adaptations			
Surveillance and monitoring of conditions favorable for outbreak of diseases	High/ Medium	Not so satisfactory, needs enhanced activities-- should be coordinated with media to issue early warnings and enhanced social response	HIGH
Improve public education especially in reproductive health system	High/ High	Coverage increasing, quality needs to be increased	HIGH
Technological/engineering controls for pests	Medium/ Low	Needs rational use	LOW

Ecosystem and Biodiversity

Ecosystems and biodiversity may be at greatest risk of all possible impacts of climate change. While adaptation to reduce vulnerability of the other sectors can be addressed as part of existing programs, the management of ecosystems in Bangladesh exists only as a concept, and the institutions that are involved lack the needed capacity.

The proposed adaptation measures to protect the threatened ecosystems/ biodiversity from impacts of climate change include general activities to protect ecosystems as a whole, as well as activities to save

[37] Guidelines to incorporate climate change in long term planning is an essential institutional adaptation in the human health sector

threatened species. These are: introduction of integrated ecosystem planning and management, management of mangrove ecosystems in the Sundarbans, management of protected areas and 14 ecologically critical areas, reduction of habitat fragmentation and promotion of establishment of migration corridors & buffer zones, coastal greenbelts, and various studies on risks from climate change to endemic species and ecosystems.
Introduction of integrated ecosystem planning and management would reduce institutional fragmentation and focus on protecting a variety of species & natural systems together with their users. The proposed coastal zone development program could be a useful vehicle for this.

Protection of the Sundarbans; through linking in climate change considerations in ongoing activities is a must. *Agroforestry* expansion is also of high importance. *Reduction of habitat fragmentation and development of migration corridors and buffer zones* scores low in the context of Bangladesh. Adaptation to *conserve the 14 ecologically critical areas* of the country is absolutely necessary. *Introduction of "alien" species/genetically modified organisms* as practiced in the country is highly questionable, and only mentioned here to highlight the need for more research prior their introduction.

Table 7: Tentative Assessment of Adaptation Measures[38] to Protect Ecosystems & Biodiversity

Adaptation measures	Effectiveness/ Feasibility	Current state of implementation and/or requirements for improvement	Priority for future incremental action
Integrated ecosystem planning and management	High/ Medium	Not practiced yet, the proposed Coastal Zone Development Program could be a vehicle for this	HIGH
Management of mangrove ecosystems in the Sundarbans	High/ Low	Proposed Ganges barrage would be high cost Need to look for appropriate option	HIGH
Management of protected areas and 14 ecologically critical areas	High/ Medium	Improved understanding is needed	HIGH
Reduction of habitat fragmentation and promotion of establishment of migration corridors and buffer zones	Low/ Low	Trans-boundary cooperation needed	LOW
Coastal greenbelt	High/ High	Recently started, results are promising	HIGH
Introduction of "alien" species/ genetically modified organisms	Low/low	More research needed	LOW
Agro-forestry development	High/High	Ongoing programs such as FRMP/Coastal Greenbelt need further expansion/improvement	HIGH
Studies on, e.g., risks to endemic species and ecosystems	Medium/ Medium	Improved understanding is required e.g. biodiversity action plan to be prepared & implemented	MEDIUM

♦ *VI. Strategic Cross-cutting Adaptations*

The study recommends that Bangladesh's overall adaptation to climate change should produce a coordinated response with specific cross-cutting adaptations that affect a number of sectors at a time. This response can be at three different levels: a)*coordinated institutional response*, b)*research needs, management and dissemination*, and c)*international positioning and representation.*

A. Coordinated Institutional Response to Climate Change in Bangladesh

There are several options for a coordinated institutional response to climate change within the GOB, including: i) the *National Councils on Water Resources and Environment (NWRC and NEC)*, ii) the

[38] Guidelines to incorporate climate change in long term planning is an essential institutional adaptation for the various impacts in the ecosystems & biodiversity sector

inter-ministerial *Climate Change Committee (CCC)* (since 1992, this has been responsible for coordinating climate change activities in Bangladesh), iii) a *multi-ministerial task force* at a suitably high level with representation from all relevant ministries, agencies and the non-government sectors, iv) a *technical secretariat* with a permanent staff dedicated to coordinating climate change adaptation activities (the secretariat could be located at the government, or at a Community Based Organization or Non-governmental Organization).

The coordinated institutional response should be based on integrated planning with community participation on different levels and effective strengthening of local management organizations. The following specific actions are recommended: 1) support and continue to improve structures and procedures for Integrated Water Resources Planning, and 2) strengthen Integrated Coastal Zone Management (ICZM) plan through the proposed Coastal Zone Development Program.

B. Research Needs, Management and Dissemination

A national research agenda is recommended to include at least the following issues: i) *Estimates of regional climate change effects.* ii) *Weather and disaster forecasting.* iii) *Research on demand oriented measures.*[39] *iv) Coordinated evaluation of projects.* v) *Taking advantage of traditional knowledge.* Over the centuries, people of Bangladesh have developed many ways to survive with climate variations. In addition to studying the existing adaptations for coping with climate related phenomena, means should be taken for enhancing the adoption of those adaptations that have the advantage of being indigenously developed (and hence are more likely to be adopted by local people than any new or foreign technologies). Documentation, dissemination and support of traditional knowledge are therefore essential. IPCC has adopted a policy of only using well-referenced documentation, and its work has faced some criticism for ignoring the massive experience that exists in the vast area of traditional knowledge. As IPCC moves gradually into the area of adaptation, these experiences will become important to document.

Development of a *modern CC knowledge base* (integrated and widely shared) to support policy and development planning is of great strategic importance to Bangladesh. Regional climate data monitoring and recording networks for Bangladesh, South Asia, and the Bay of Bengal should be maintained and enhanced. Climate change adds a long-term strategic perspective to the ongoing development of an integrated information system including GIS and Remote Sensing for the coastal zone.

An important recommendation for the short term is the *preparation of planning guidelines* for climate change issues that agree on: best possible estimates of the expected impacts, a typology of anticipatory adaptation measures, and a framework for the analysis and assessment of possible adaptations. A criterion could be developed to evaluate proposed projects with respect to the expected impacts, just as they might be evaluated with respect to social transformation or economic impacts. Development of an analytical framework for analysis of climate change impacts is within present Bangladeshi capacity. These impacts and criteria should become integrated into the frame of mind of policy makers in Bangladesh as well as in the protocols for infrastructure design.

Additionally, a national *awareness building program* should coordinate the dissemination of knowledge on the effects of climate change and adaptation. As part of these activities, guidelines on including climate change issues in planning may be formulated and shared among various ministries.

[39] Such measures aim to change the behavioral pattern of individuals and economic activities and are considered important tools in natural resource management and therefore in the anticipatory adaptation for impacts of climate change. For example, experience could be built up with measures including water pricing, setting quota, licensing and trading in emission rights.

The Climate Change Committee (CCC) could play a major role in raising awareness in the ministries concerned. The Association of Development Agencies in Bangladesh (ADAB) in coordination with the Coalition for Environmental NGOs (CEN) can *disseminate information* at the grassroots level. The media can also play an important role for creating general awareness on climate change. The Federation of Environmental Journalists of Bangladesh (FEJB) and the Ministry of Information (MOI) could also have a role in raising awareness about climate change related issues with the general public.

C. International Activities

A special type of adaptation measure focuses on the causes or sources of climate change. They are not under the exclusive control of the planners and policy makers in Bangladesh, but can and should be addressed in an international level. Examples are cross-boundary river flows, and mitigation of greenhouse gas emissions.

Recommendations in this regard include *active participation in all international debates on climate change*. While the country's contribution to greenhouse gas (GHG)es emission is minimal, because of its own vulnerability, Bangladesh should become a more active participant in the international efforts (IPCC, UNFCC, COP) addressing the underlying causes of climate change, and encourage countries (both developed and developing) to agree on binding targets for greenhouse gas emission reductions (in line with the Kyoto protocol targets). A strategy is needed for participating in international negotiations with a team of negotiators, backed up by a national team of experts.
Incorporating climate change considerations in water sharing negotiations is also an important cross-cutting adaptation measure. A treaty on sharing the Ganges waters at Farakka was signed in December 1996. This treaty provides a commitment for settling water-sharing arrangements of all common river basins. It is recommended that such negotiations include contingencies for changes in runoff and demand due to climate change.

♠ *VII. Conclusion*

The study shows that Bangladesh faces very grave socio-ecological and economic risks if it fails to adapt to climate change. Many of the changes are gradual and difficult to differentiate from the high background variability in climate conditions that Bangladesh faces normally. While this is especially true in upland areas of Bangladesh, the coastal zone offers a greater potential for monitoring/detecting changes and trends, and to promote effective and timely adjustment and adaptation. This is unlikely to be possible without a sound, modern information system, improved and more cost-effective monitoring, and requisite institutional changes including more open sharing of information.

This study can be used as a discussion document to enable a broad consensus of practitioners and planners in Bangladesh on priorities for further action. After achieving such consensus, we should move to the next stage of developing more project–specific or sector-specific guidelines.

Finally, climate change threat for Bangladesh is integrally related to the country's sustainable development. The case of Bangladesh is unique in the sense that: unlike other vulnerable island countries, this country will eventually face the multidimensional manifestations of climate change (e.g. flood, cyclone, sea level rise, drainage congestion, salinity, drought etc. Rather than being mutually exclusive, adapting to climate change should be seen as a requirement for sustainable development, and mainstreamed in our developmental endeavors. Climate change is not just an "environmental" concern but really a "development" concern for Bangladesh. This means that climate change as an issue must take center stage as a major developmental problem that the country will have to face in the coming days.

Introduction

Bangladesh: A Country Striving to Achieve Sustainable Development

1.1 Introduction

1.1.1 Study Objectives and Outline

The overall aim of the report is to mainstream climate change adaptation issues in the regular development strategies and operations in Bangladesh, and serve as an example for other countries of the world. This study endeavors to provide directions on how the potential effects of climate change and adaptation options can begin to be factored into development activities affecting natural resources in Bangladesh that are sensitive to climate change. The objective thus is to identify and propose adaptation measures for development activities with the aim to reduce Bangladesh' vulnerability for impacts of possible climate change.

An important activity of the exercise has been to summarize the existing knowledge on expected impacts of potential climate change, and to develop and apply a methodological framework that allows the classification and assessment of possible adaptation measures. Selected development policies, programs and projects have been analyzed, leading to the identification of possible adaptation measures. The study addressed the following questions.

i. *What are the expected climate changes?* Through a literature search and using the most recent results of scientific research, uncertainties in these impact estimates are reduced to the level of best technical assessments. *(chapter 2)*

ii. *What are the consequences for Bangladesh?* This not only deals with the sensitivity of ecological and socio-economic systems for Climate Change (CC) induced impacts, but also deal with non-CC induced changes because of other developments, such as further reduction of low water flows due to upstream water consumption. *(chap 2)*

iii. *For what CC-induced impacts, Bangladesh is most vulnerable?* Vulnerability is related to sensitivity, and adaptability. This implies that in addition to the above, an identification is needed of adaptation measures in terms of effectiveness. The effectiveness to adapt for CC-impacts is obviously linked to their relative importance in relation to the non-CC induced changes. *(chap 3)*

iv. *How can the potential effects of climate change be factored into policy making, and what adaptation measures for Bangladesh are feasible?* The study looks at the strategic implications of climate change for policy makers and the strategic adaptations that are needed. It is not meant as a guide or manual for policy makers and project task managers in Bangladesh to incorporate in their project planning without any further work. Rather it is meant to be used as a discussion document to enable a broad consensus of practitioners and planners in Bangladesh on priorities for further action. (chap 3) This also deals with questions of implementation, and for that reason the study examines existing policies, programs and development projects on a limited scale. Tentative criteria have been established for the screening of potential adaptation measures, which consider their effectiveness in addition to their implementation feasibility (including costs). (chapter 3 and Appendix E)

1.1.2 Methodological Considerations and Main Assumptions

Vulnerability (the extent to which climate change may damage or harm a system[1]) considers *sensitivity* (the degree to which a system will respond to climate change) and *adaptability* (the degree to which adjustments are possible in practices, processes or structures). For example, highly sensitive systems[2] may be considered less vulnerable than less sensitive systems if the adaptive capacity is high.

Adaptation is defined as any adjustment of physical infrastructure, natural systems, social and economic activities or institutional arrangements, that (i) reduces the vulnerability to climate change, or (ii) enhances the opportunities these changes offer. *Adaptation* looks for a pragmatic way to reduce the society's vulnerability for possible climate changes, and their uncertain impacts. Focus will thus be on anticipatory, rather than on reactive measures. Insight on the possibilities for adaptation would greatly contribute to the awareness of how serious these changes are and which trigger the need for such anticipatory measures.

Climate changes and their consequent impacts on natural resources, human beings and human activities can be viewed as a complicated chain of causes and effects. Underlying such cause-effect relations are processes which are only partly known or understood. Their practical control in order to reduce the vulnerability to climate change -- either of the source of these changes or their impacts -- often meets insurmountable problems. The problems arise due to the uncertainties, the international character, the unequal distribution of sources and impacts, and the costs involved in the process. For practical purposes, the approach in this study considers the following differentiation.

- *Climactic factors* which cause the impacts in the natural and social and economic systems. These changes are considered to be exogenous, or beyond the direct control of policy makers and planners in Bangladesh. For this study, the following climactic factors are considered (both CC and non-CC induced): temperature, evaporation, precipitation, sea level rise, cross boundary river flows, and El Niño Southern Oscillation (ENSO) events.

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1 Definitions from IPCC (Watson *et al.*, 1996).

2 This encompasses ecological and socioeconomic systems, including hydrology and water resources management, human infrastructure and human health (Watson *et al.*, 1996)

- *Primary impacts* are first order impacts in the natural (physical) environment. These are usually relate to large-scale processes: such as: inundation of the major flood plains, low flows, salt water intrusion, flash floods, droughts, storm surges and river and coastal morphology. For Bangladesh it is important to differentiate between
  - ◊ changes in the frequency and intensity of extreme events, such as cyclones and floods; and
  - ◊ gradual changes in the conditions of the natural environment, such as increasing salt water intrusion and deteriorating drainage conditions in the coastal zone.
- *Ecosystem and socio-economic consequences* represent effects on ecosystems such as the Sundarbans, and on human beings and human activities. These consequences often are interpreted as stress, they are caused by the climactic factors either directly of indirectly through the primary impacts on the natural environment.

The above resulted in the following classification of adaptation measures which will be used in this report.

- *Adaptation of climactic factors.* As mentioned, climactic factors are beyond the direct control of Bangladeshi planners and policy makers. This does not imply that actions can not be considered. For example, adaptation of the Ganges treaty which would influence the cross-boundary river flows, or participation of Bangladesh in the global efforts to mitigate the continued emissions of greenhouse gases.
- *Physical adaptations*, that aim to change the conditions of the natural system and resource base through structural interventions. These measures are mainly oriented towards the "supply" side of problem. They aim to change the primary impacts, for example, through the planting of mangroves, raising of dikes or construction of tidal basins.
- *Institutional adaptations.* Feasibility of the above mentioned adaptations would depend on the institutional and procedural mechanisms for their implementation. This may relate to the establishment of planning procedures to properly account for impacts of climate change, for example, the introduction of Climate Change Impact Assessments (CCIA). These may also include socio-economic measures such as changing the use of resources through non-structural measures, such as, crop diversification and sustainable shrimp cultivation, increasing awareness level etc.

1.1.3 Value Added and Limitations

A number of previously published studies examined the potential impacts of climate change on Bangladesh (e.g., Qureshi and Hobbie, 1994; Huq et al., 1996; Warrick and Ahmad, 1996; Huq, Karim, Asaduzzaman and F. Mahtab eds. 1999), assuming certain changes in the climate and corresponding sea level rise. The focus of this study is on examining the needs and possibilities for addressing adaptation. The aim is to reduce Bangladesh' vulnerability to climate change and sea level rise impacts, and enhance the country's potential for sustainable development.

The study also aims to raise awareness among staff at the World Bank, other donor agencies, the GOB, and NGOs about the potential risks of climate change and how to think about adaptation. In making decisions about development or management of climate sensitive resources, planners and decision makers should be triggered to take climate changes into account. As a first step, they should identify where there could be high risks, particularly in the next few decades, and where to consider feasible, cost-effective modifications to development and management decisions that may reduce these risks of climate change.

This report is of course not a manual to provide exact remedies or formulas on how to address all risks to climate change. It does attempt to identify key issues and provides the outline of a framework for identifying potential adaptations to address these issues. The report, therefore, contributes to awareness building and enables policy makers to begin address this important, and challenging issue in their ongoing and future development activities.

In terms of limitations, the sectoral discussions of the study leaves out some climate change adaptation relevant sectors such as human settlement & land use; energy & industry/infrastructure. The five sectors selected in the study were selected based on the consultants' prioritization. A more comprehensive study of climate change adaptation in Bangladesh would include in-depth analysis of these sectors as well.

1.1.4 Structure of the Report

The report is organized as follows.

- Chapter 1 is divided into two sections. First, basic information on research team, methodology, structure and value added etc are presented. The second section, elaborates on the current situation and development trends in Bangladesh.
- Chapter 2 summarizes the risks of climate change to Bangladesh based on a review of published literature. Vulnerabilities to climate change faced by Bangladesh are summarized in matrices in section 2.7.
- Chapter 3 is divided into two sections. The first gives a brief overview of how one can think about adaptation to climate change and identifies four key risks (critical impacts) to the greater goal of sustainable development. It presents a classification of adaptation measures and develops a framework for their identification and assessment. It also describes some of the socioeconomic causes of vulnerability to climate change, such as level of development, and examines how different development paths may affect the country's ability to cope with climate change.

  The second part of this chapter addresses adaptation measures for Bangladesh for the selected key sectors and the identified key risks. It provides an indication and a preliminary assessment of the specific adaptation measures. The chapter concludes with strategic cross-cutting adaptation measures that affects a number of sectors at a time.
- Appendix A provides some basic information on climate change as well as the Bank's involvement in mitigation efforts.
- Appendix B gives a definition of vulnerability to climate change and adaptation responses.
- Appendix C gives a brief history of water development activities in Bangladesh.
- Appendix D briefly describes the United Nations Framework Convention on Climate Change and the Kyoto Protocol. It also describes the role of adaptation in these agreements.
- Appendix E examines selected development activities in some detail to assess whether they are affected by impacts of climate change or could consider climate change risks and

adaptations. Special attention is given to the water sector.

- Appendix F presents new analysis on flood potential in 2020 (as commissioned for this report)
- Appendix G contains attendance lists & programs of the i) June 28, 1999 working group discussions, ii) December 30, 1999, iii) May 8, and iv) May 25 review workshops held in Dhaka. The discussions were organized to receive input from potential users of the study, as well as experts on the subject.

1.2 Current Situation and Development Trends

1.2.1 Bangladesh, an Overview

Bangladesh is a South Asian country with an area of 147,570 sq. km. and a population of 126 million (in 1999). It is bordered on the west, north and east by India, on the southeast by Myanmar and on the south by the Bay of Bengal (see Figure 1.1). Bangladesh has a humid, warm, tropical climate which is fairly uniform throughout the country. There are three main seasons: a hot summer season with heavy rainfall from March to June, a hot and humid monsoon season with heavy rainfall from June to October, and a drier and cooler tropical winter season from November to March. Average annual temperature ranges from 19 to 29 °C. Rainfall ranges from 1,250 mm in the west to 2,500 - 5,000 mm in the north-east (annual averages). Most of the country has an elevation of less than 10 meters above sea level. With the exception of the Chittagong Hill Tracts in the southeast and the Modhupur tract in the central region, the country is located in the floodplains of three main rivers namely Ganges, Brahmaputra and Meghna.

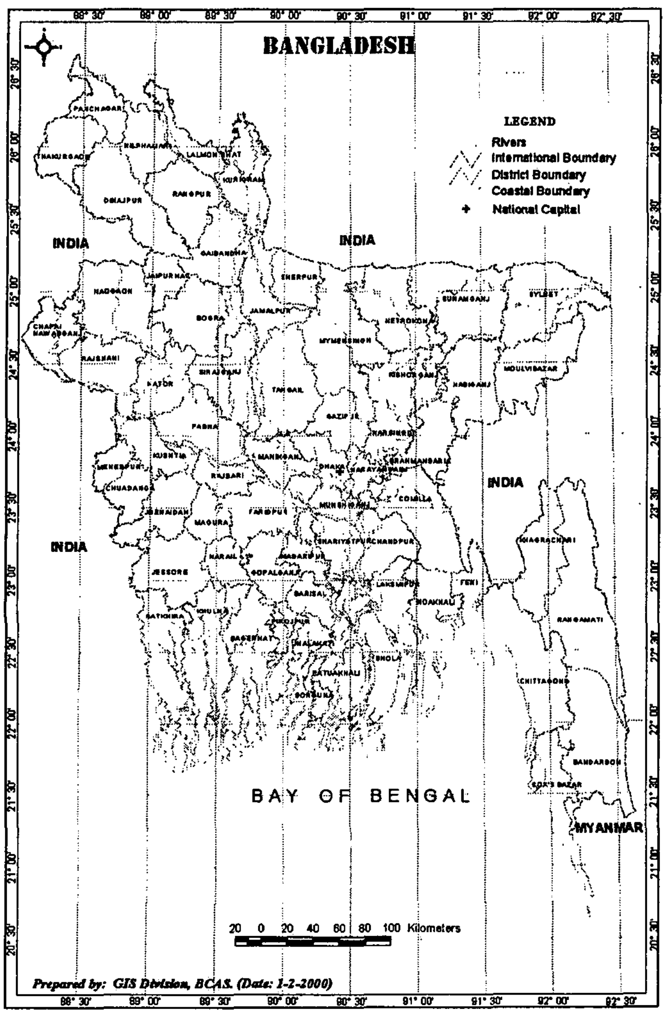
Bangladesh suffers from many climate dependent natural hazards, such as: riverine and coastal floods, riverbank erosion, tropical cyclones and droughts. The 1998 riverine flood, one of the worst this century inundated two-thirds of the country, damaged crops, physical infrastructure and assets of over US$ 2.5 billion and caused hundreds of deaths and hundreds of thousands of cases of diarrhea. A tropical cyclone in April 1991, which had winds over 225 km/h and a storm surge over 7 meters high, and resulted in about 138,000 deaths(Haider *et al.*, 1991).

Bangladesh' high population density and poverty increases the country's vulnerability to these natural hazards. The country's population density is 868 inh/km^2 (BBS, 1998). Its population is projected to grow to over 200 million by 2050, implying the density to increase to about 1,400 inh/km^2 (WB and BCAS, 1998). The average population growth rate during 1981-91 was 2.17 percent per year, which came down to 1.80 percent per year by the year 1996 (PC, 1998). High population density implies that more people live in areas vulnerable to climate change, and therefore could limit the capacity of people to move in response to climate change.

Despite sustained domestic and international efforts to improve economic and demographic prospects, Bangladesh remains one of the world's poorest and least developed nations. Annual GNP growth has averaged over 4 percent in recent years from a low base, and GNP per capita in 1999 was about US $350. The economy is largely agricultural, with cultivation of rice, the single most important activity in the economy. In 1998, agriculture comprised 22 percent of GDP and employs about two-thirds of the country's labor force. Climate variability and change could have a substantial effect on total economic output and employment.

An important recent development in Bangladesh is related to the energy sector, particularly in the coastal zone. In addition to the need for huge foreign investments for the exploration and exploitation of oil and natural gas, additional investments are required for the development of infrastructure, supporting industries, etc., so that these developments are truly beneficial to the local population. Such efforts might be seriously hampered due to the threats posed by climate change and its induced impacts.

Figure 1.1 Map of Bangladesh



1.2.2 Development Goals and Policy Thrusts

In order to steer Bangladesh on a path of self-sustaining development, the government of Bangladesh has formally set out the following goals and objectives in its current fifth year plan[3] (PC, 1998).

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[3] A selection has been made of those development objectives which were assessed to be particularly sensitive for impacts of climate change.

Alleviation of poverty through accelerated economic growth to bring about a noticeable improvement in the standard of living by raising income and meeting basic needs.

Poverty of Bangladesh is reflected in its low per capita GDP, low standards of nutrition and dominance of cereals in food intake and low levels of education. The low GDP growth rates are only marginally above the population growth rates, and are too low to improve the standard of living within a foreseeable future. The current fifth year plan therefore targets an increased economic growth at an average compound rate of 7 percent per year. Average daily per capita calorie intake hardly exceeds 2,000 kcal, compared to the desired value of 2400 kcal.

Attainment of food production beyond self-sufficiency level and higher production of diversified high-valued export foods.

Agricultural development is still closely related to economic development in Bangladesh. The main development objective is to boost agricultural productivity through increased irrigation coverage, increased cropping intensity and improved water and farm management practices. During the terminal year (2001/2002) of the current Five Year Plan, estimated food grain production (including wheat and other coarse grain) is 22.61 Mmt leaving a surplus of 0.67 Mmt, provided that the population does not exceed the estimated 132.5 million.

Development of necessary infrastructure and utilities.

Land is an extremely scarce resource in Bangladesh and infrastructure development is often delayed by lengthy and cumbersome land acquisition procedures. There is virtually no land-use plan for the rural areas of the country, which comprise about 85 percent of the total land area. Present facilities with respect to physical infrastructure, housing, water supply and sanitation are inadequate. Sustainable infrastructure growth is a necessity for meeting the needs of a growing population. For example, the expected growth in the transport sector alone is 7.7 percent. The recently constructed Bangabandhu Bridge has increased road transport substantially, especially in the northern region.

Development of industries essentially based on comparative advantage of the country with emphasis on export-led industrialization.

Bangladesh is densely populated with a narrow land and water resource base, and limited per capita availability of arable land. Accelerated growth of industry (projected to about 14 percent) is required to support the overall growth of GDP at the rate of 7 percent. The considerable human resource base potential of Bangladesh should be exploited in industrialization, with the aim of generating employment opportunities and increasing per capita productivity.

Development of services needed to promote growth, particularly in the private sector, with special attention to the generation of power, exploitation of gas, coal, and other natural resources.

Sustainable development of the oil and gas sectors is vital for further strengthening of the economy. Currently, about 90 percent of power generation is based on natural gas. Urea fertilizer requirements for agriculture is totally dependent on gas. Current gas reserve (proven) has been estimated at 22.90 TCF and new discovery in Sanghu (offshore), Shahbazpur (Bhola), and other blocks may augment the gas reserve substantially.

Achievement of a lower population growth rate coupled with provision of necessary health care and improved nutrition of mother and child, and human resources development with emphasis on compulsory primary education.

Poverty, malnutrition and low education lower the resistance of a large segment of the population to disease and their income capacity. While recent trends in improved health care and education is encouraging, access to medical and education facilities is still limited. For example, the average number of persons per physician is 4915. The projected population coverage under essential health care by the year 2002 is 70 percent. The objective of the current five year plan pertaining to education is to attain about 70 percent literacy rate by the year 2002 so that 100 percent literacy rate can be reached by the year 2007.

1.2.3 Considerations of Climate Sensitivity

The country is known for its high sensitivity to natural calamities. Burdened by social and economic problems such as low levels of literacy, poor health delivery systems, low per capita income and high unemployment, Bangladesh faces many difficulties in achieving sustainable development. Possibilities of climate induced changes, including increases in frequency, duration and intensity of extreme events such as floods, droughts and cyclones, and their expected adverse impacts on the resource base and human activities, would bring the country into an even more difficult position.

Although the extent of climate induced changes are not fully assessed, one would hope that the targeted social and economic developments will contribute to making the country less vulnerable to these impacts. Based on WRI (1998)[4] and some optimistic assumptions, the future prospects of both population and per capita income are listed in Table 1.1.

Table 1.1 Future Prospects of Population and Per Capita Income

Indicators	Present	2030	2050
Population (million)	126	190	218
Per capita income (US$)	350	600	825

However, many of the critical development components still depend to a large extent on the country's natural and human resource base, and are thus sensitive to climate induced changes. Vulnerable development components include: the need to substantially improve the health and living conditions of the country's human resource potential; importance of the agricultural production both for the country's economy and for the poverty reduction of its population; and the growing importance of the energy related developments in the coastal zone (these factors increasing Bangladesh's vulnerability are summarized is summarized in Table in the next page). *Consequently, the study selected the following impact categories: coastal resources; water resources; agriculture; human health; and ecosystems / biodiversity.* In the next chapter, these categories are discussed along with specific climate change impacts scenarios.

4 Note that population projections for Bangladesh have dropped considerably. The United Nations (1995) projected that 2020 population in the country would be 174 million to 196 million and 2050 population would be 195 million to 289 million. WRI's (1998) projection for 2020 population is below the low end of the UN's range. Birth

Table 1.2[5] **Factors Increasing Bangladesh's Vulnerability to Climate Change**
Geography Bangladesh is a broad deltaic plain with most elevations less than 10 meters above sea level.
Climate Subject to severe natural disasters: riverine & coastal floods, tropical cyclones, storm surges, tornadoes, and droughts. Most rainfall is confined to the monsoon season, causing major floods. The winters are dry.
Population •1998 population 126 million; average annual growth rate 1.6% (1992-98); latest projected growth rate 1.4% for 1997-2015; population density is very high at 850 person/sq km.•WRI (1998) projects 2020 population to be 190 million and 2050 population 218 million.
Economy Bangladesh is one of the world's poorest and least developed nations. GNP/capita in 1999: $370, whereas GNP/cap in South Asia $581, Agriculture, which is 25.3% of GDP[6], is particularly vulnerable to climate change.
Education Bangladesh has a literacy rate of 53%[7]. Compared to developed countries, low literacy limits ability to adapt to climate change.
Human Health Life expectancy at birth: 58 years; infant mortality rate: 75 deaths/1,000 live births (1992-98); 56% under 5 malnourished; 84% access to safe water. Communicable diseases caused by poor nutrition and sanitation, include cholera, dysentery, diarrhea, measles, and tetanus. Parasitic diseases include malaria, dengue, filariasis, and helminthiasis. Malaria reemerged in late 1980s. The need to substantially improve the overall health and living conditions of the country, makes it particularly vulnerable to climate change.

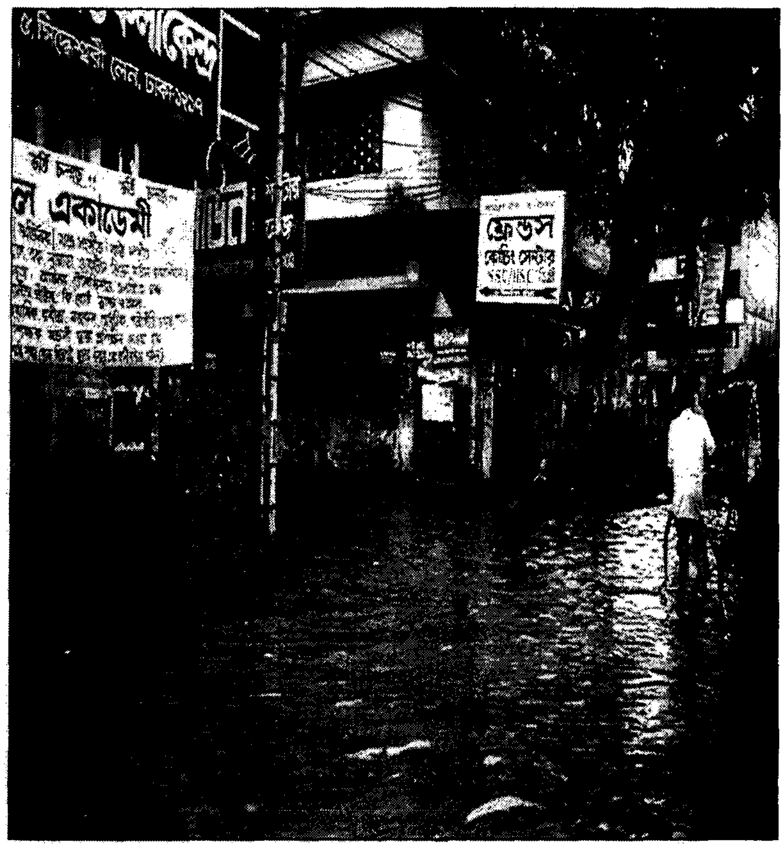
rates are dropping considerably; in the late 1970s, the birth rate was 47.2/1000, and as of the late 1990s it is 26.8/1000.

5 Source: World Bank, *Bangladesh at a Glance*, September 1999.

6 Latest figures from Bangladesh Bureau of Statistics

7 Statistics derived from the World Bank, *Bangladesh at a Glance*, August 2000

Potential Impacts of Climate Change in Bangladesh



Floods in Dhaka, the Capital of Bangladesh

The potential effects of climate change on Bangladesh is considered for the period from the present to 2050. Most development projects have a planning horizon of 30 years or less, while a few have a planning horizon of 50 years or more. Results on potential impacts by 2030 and 2050 are qualitatively summarized below. At the conclusion of the chapter, an indication is given of the development sectors that may be most sensitive to climate change.

Analysis of changes in climate is based on model outputs for creating climate change scenarios. These tools incorporate latest scientific information on the sensitivity of global climate to greenhouse gas emissions and the effects of sulfate aerosols on global and regional climate (see Houghton *et al.*, 1996, for more information).

The main sources for information on impacts of climate changes were the ADB Study (Qureshi and Hobbie, 1994), the BCAS study (BCAS/ RA/Approtech, 1994), and Warrick and Ahmad (1996). Many of the results are for a 1 m sea level rise or for climate change caused by CO_2 doubling, both of which may not happen until 2100 or beyond. Results from the U.S. Country Studies Program, e.g., Karim *et al.*, (1996), Ahmed *et al.* (1996), Asaduzzaman *et al.* (1997), and Huq *et al.* (1998), were also used where a moderate and a severe climate change scenarios were considered for the years 2030 and 2075, respectively. As part of the study, Kenny *et al.* (1998) have developed a climate change scenario for 2020 which was of use to the writers (please see annex to this chapter). Using the climate change scenarios for 2030 and 2050 described below, results were interpolated to these two time periods, assuming linear relationship between changes in temperature, precipitation, and sea level rise and the results in the literature.

Any study on climate change and their potential impacts faces limitations. This study has some limitations as well, which are important to keep in mind. First, the analysis is based on studies that did not use consistent assumptions about climate change or development in Bangladesh. This implies that *results from different studies may not be comparable.*

Second, impacts of changes in climate and sea levels should not be considered in isolation from other exogenous changes, such as: subsidence of the coastal area and developments in upstream (shared) river basins. For example, increased salt water intrusion in the coastal zone of Bangladesh will result from a combination of reduced river flows from upstream basins and sea level rise. *Effectiveness of adaptation measures should be weighed against the relative importance of these other exogenous changes.*

Third, physical and other conditions in Bangladesh fluctuate very strongly with climate variations that are observed at present. It can be difficult to separate natural variations from climate change induced impacts.

The results presented in this chapter should be interpreted as indicative of the potential climate change impacts, not as predictions or forecasts.

2.1 Climate and Other Changes by 2030 and 2050

Climate

As described earlier, two time horizons are chosen for the present study. Table 2.1 summarizes potential changes in sea level, temperature, and precipitation for Bangladesh in 2030 and 2050. The climate change scenarios for 2030 and 2050 have been constructed by using general circulation models (GCM) superimposed on long-term climatic patterns over ten locations in Bangladesh (see Ahmed and Alam, 1998).

Table 2.1: Climate Change Scenarios for Bangladesh in 2030 and 2050

Year	**Sea Level Rise[a] (cm)**	**Temperature Increase (°C)**	**Precipitation Fluctuation Compared to 1990 (%)[b]**
2030	30	+0.7 in monsoon; +1.3 in winter	-3 in winter; +11 in monsoon
2050	50	+1.1 in monsoon; +1.8 in winter	-37 in winter; +28 in monsoon

Notes:

a. Based on Ahmed and Alam, 1998 (estimated values obtained by correlating model output data with observed data). On base year (1990): average winter temp: 19.9 °C & avg. monsoon temp: 28.7 °C

b. Estimated based on model ouput data regarding rate of temperature change. On base year (1990) average winter precipitation : 12 mm/mo; average monsoon precipitation: 418 mm/mo. From table 1, pg 23 (Huq, S. et al. 1998).

Most of the general circulation models (GCM) show increased annual precipitation for Bangladesh, but a few show a decrease. Output[1] of over two dozens GCMs revealed different set of data for precipitation and temperature. Ahmed *et al.* (1996) also demonstrated that there were substantial differences in output of different GCMs, and a very few could correlate with the long-term observed climatic data. In constructing scenarios for the years 2030 and 2050, the rate of change in climatic data were superimposed on observed mean-monthly data. Based on the above information: an increase in precipitation appears to be highly probable, though not certain. However, the possibility of increasing monsoon precipitation (May to September), and decreasing dry season (December to February) precipitation indicate that the existing differences in inter-temporal distribution of precipitation would be accentuated under climate change scenarios.

Although the magnitude of these changes in climate may appear to be very small, if added to existing climatic events (such as floods, droughts, and cyclones), these could substantially increase the magnitude of these events and decrease their return period. For example, a 10 percent increase in precipitation may increase runoff depth by one-fifth and the probability of an extreme wet year by 700 percent. Thus, within the planning horizon for development activities, it is quite possible that there could be a significant increase in the intensity and frequency of extreme climate events.

Sea Level Rise and Subsidence

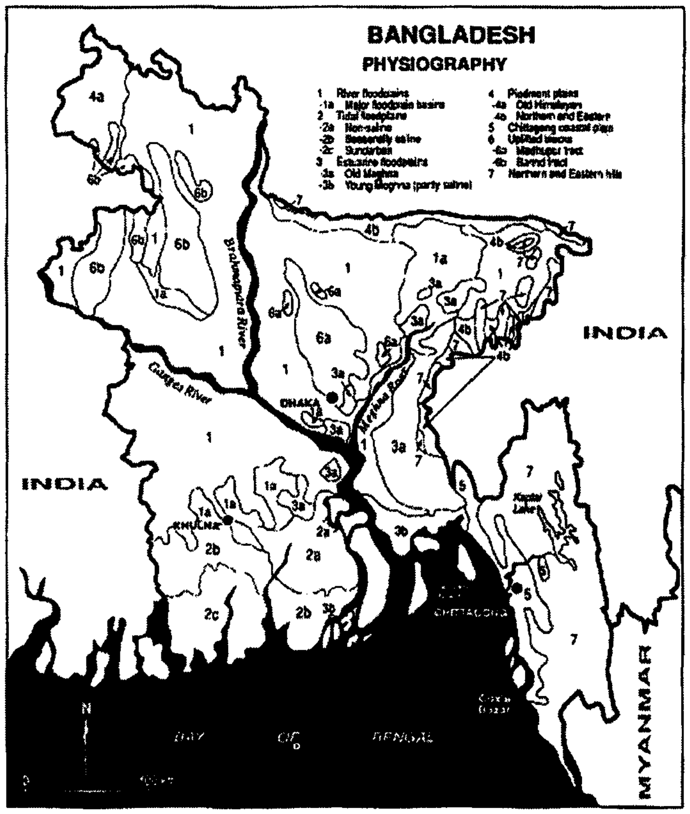
According to the IPCC (Inter-governmental Panel on Climate Change), an increase in mean global temperature would result in a possible rise in mean sea levels across the globe. Such a rise can be attributed to the expansion of the ocean's water volume when water temperatures increase and the atmospheric warming which causes melting of mountain glaciers and other cryospheric systems, resulting into an additional amount of water in the oceans.

A change in mean sea level alters the elevation of the land surface with respect to the sea. In addition to sea level rise, the land surface of the planet also undergoes changes in elevation due to sedimentation and tectonic activities (i.e., subsidence). The *relative sea level change*, should reflect a combination of all these factors.

Geologically, Bangladesh is located on an active sedimentary basin known as the Bengal Basin. The eastern Himalayan rivers (for example, the Ganges, the Brahmaputra and the Meghna) carry a large amount of sediments, part of which is deposited each year on the riverbeds and on the floodplains. The generalized physiography of Bangladesh is presented in Figure 2.1

[1] The scenario generating tools called SCENGEN (Wigley, 1998) and COSMIC (Yohe and Schlesinger, 1998; Williams *et al.*, 1998) were also used to estimate the ranges for Bangladesh. They were run with a 1°C and 4.5°C global sensitivity to CO_2 doubling, and with and without sulfate emissions (which tends to reduce the magnitude of warming and cause more precipitation).

Figure 2.1: Physiography of Bangladesh



Source: Brammer *et al.*, 1996

It is believed that a part of the sediment load is also deposited on the shallow continental shelf of the basin. In addition, the basin is undergoing subsidence, that may be attributed to the following two major factors: one is related to the isostatic adjustment of the crust (sediment load and rise of Himalayas); the other is related to de-watering and compaction of shale and mud ofProto-Bengal Fan (Alam, 1989). However, there is not enough evidence in favor of the latter factor. Tectonic subsidence usually occurs over a large extent of area, in a uniform manner and at a very slow rate. These areas are generally bound by active faults or hinge zones. Although the entire Bengal Basin is subsiding slowly, more rapid subsidence has been taking place in the Bengal Foredeep, particularly in the Sylhet Trough, Faridpur Trough and Hatiya Trough.

Existing literature provides a wide range of estimates of the rate of subsidence. It is therefore difficult to estimate the overall extent of relative sea level rise in the coast of Bangladesh. If it is assumed that the rate of subsidence in the Hatiya Trough (in the coastal areas) will be equal to the rate of sedimentation, one may infer that the rate of change of mean sea level, as forwarded by IPCC, would be observed in the coastal areas of Bangladesh.

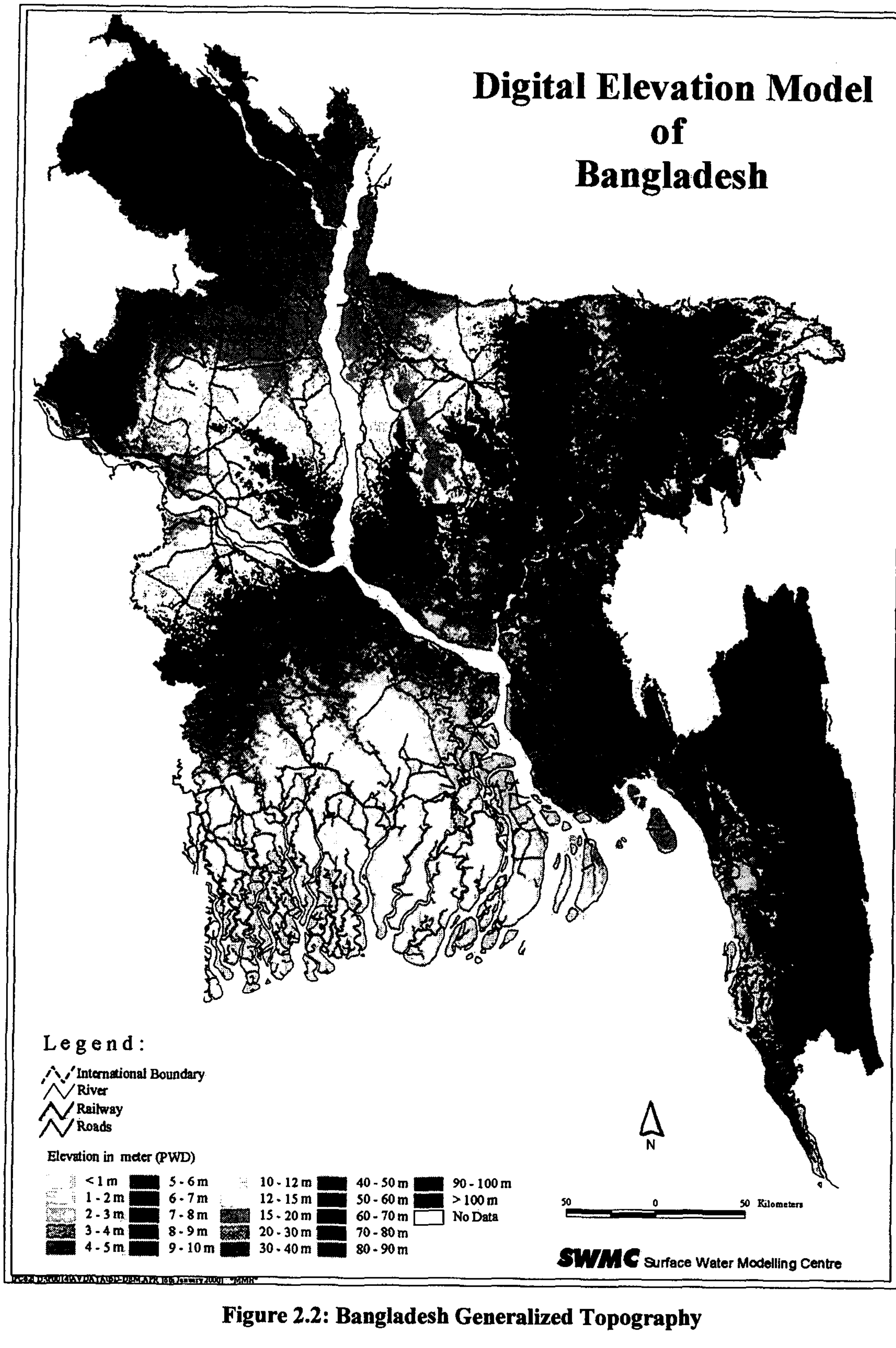


Figure 2.2: Bangladesh Generalized Topography

It should be noted that the IPCC rates of change of sea level, as presented in Table 2.1, are only indicative. Accurate predictions could not be made due to inherent weaknesses of the models. There is a wide range of variation concerning the extent of such changes in the literature (Wigley, 1998; Yohe and Schlesinger, 1998; Greenpeace, 1999).

Cyclones and Storm Surges

The coastal areas of Bangladesh and the Bay of Bengal are located at the tip of northern Indian Ocean, which has the shape of an inverted funnel, and the Bay itself is quite shallow. The area is frequently hit by severe cyclonic storms, generating long wave tidal surges. These surges are amplified when they traverse shallow waters, and have a disastrous effect on the coastal areas of Bangladesh.

Usually cyclones are generated in the deep sea when sea surface temperature reaches the threshold value of about 27 °C. With increasing temperature, barometric pressure drops and the additional energy is dissipated in the form of high-speed winds. In Bangladesh, cyclones are observed twice a year: during late April and early May (early summer), and between late October and early November (late autumn/fall).

A storm surge[2] during a cyclone inundates coastal areas and offshore islands, which causes most of the loss of life and property. Information on storm surge height is very scarce in Bangladesh. Available literature provides a range of 1.5 to 9.0 meter high storm surges during various severe cyclones (Haider *et al.*, 1991). However, a SMRC report shows the surge height for 1876 cyclone was 13.6 m at Bakerganj and the surge height for 1970 cyclone was 10m.[3] Locations of these surge heights are not known. Therefore, it is difficult to compare maximum wind speed and corresponding surge heights. Displacement of water surface during a cyclonic storm surge also depends on the height of tide, which is a function of lunar attraction and wind-factor. There is considerable difference in tide-height depending on the season and position of the moon relative to the sun.

Another important factor is the path of cyclones. Due to its geographic location, cyclones hitting the Khulna region in the south west, have comparatively lower storm surges than those hitting the Meghna estuary. The paths of a few recent cyclones that hit Bangladesh are shown in Figure 2.3. These include the recent 1997 cyclone.

From time immemorial, cyclones have visited the delta and caused extensive damages to the lives and properties of millions of people in the coastal districts of Bangladesh. In 1584, about 200,000 people were reportedly killed in Barisal by a cyclone storm surge. Another cyclone that hit in 1822 killed more than 70,000 people in Barisal and 95 percent population of the Hatiya Island. Considering the much smaller populations during those times, the numbers of deaths give an indication to the severity of the cyclones. A cyclone in November 1970 hit the southern districts of Bangladesh (the then East Pakistan) forcing a 9 m high storm surge and killing approximately 300,000 people (Haider *et al.*, 1991). The cyclone of 1991 caused 138,000 lives. In more recent

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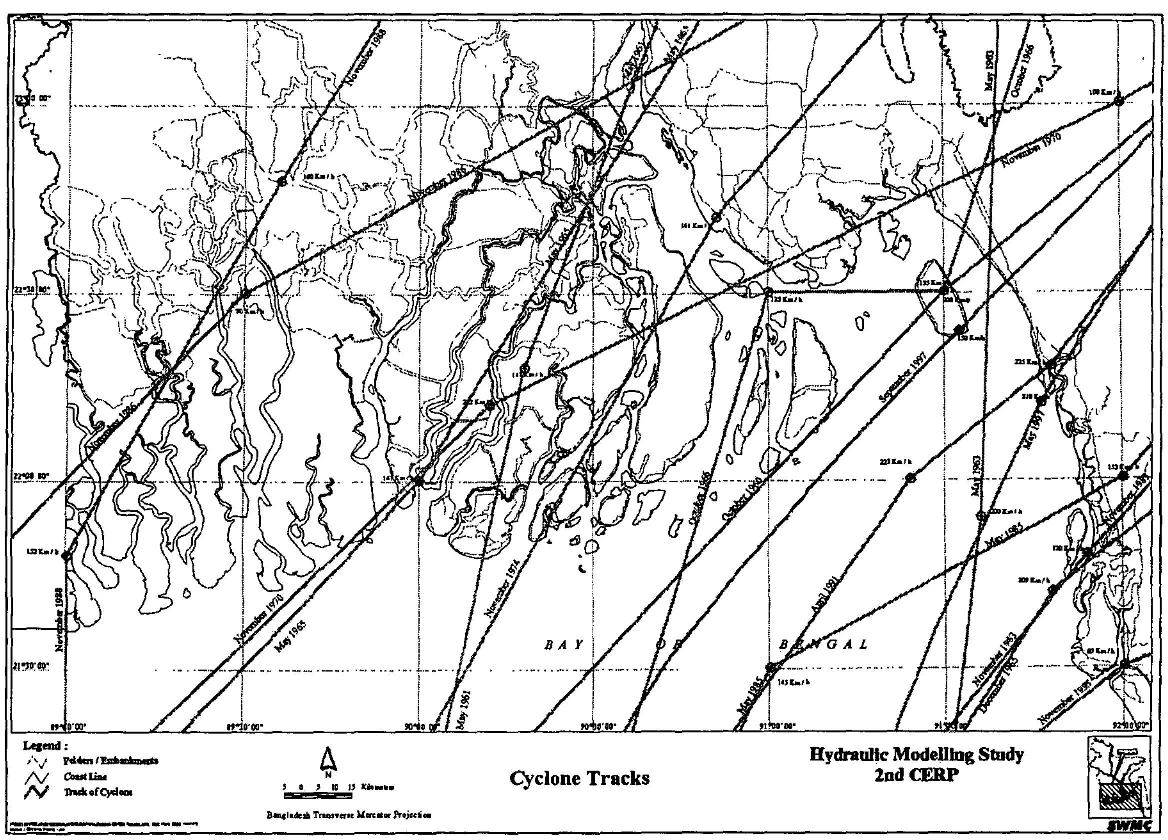
[2] Ali (1999) is very clear regarding the use of the misnomer "tidal surge" when referring to storm surges. Tides are created by gravitational forces where as the "surge" we describe here are caused by cyclones, or weather related activities.

[3] Note from Mir Hammadul Azam, SWMC, June 2000

years, however, number of deaths caused by the cyclones with severe intensity have declined due to the growing successful institutional arrangements for disaster management and the fact that there are now over 2000 cyclone shelters spread along the coast (which are being utilized during the cyclones).

In terms of climate change, warmer sea surface temperatures are correlated with tropical cyclone activity. Some studies have concluded that a 1°C increase in sea surface temperatures could increase tropical cyclone intensity by 10 percent (e.g., Henderson-Sellers and Zhang, 1997).[4] Lal *et al.*, 1995b have found that higher temperatures may not increase tropical cyclone activity. However, even with similar intensity, the destructive effects of cyclones would be intensified by sea level rise induced increased water depths in the shallow continental shelf of the Bay of Bengal. Assuming there is a positive correlation between sea surface temperature and tropical cyclone intensity, Ali (1996) calculated the effect of a repeat of the 1991 cyclone with a 10 percent increase in intensity and sea level rise. He concluded that this could result in storm surge 2 m higher and inundating 13 percent more land than the 1991 cyclone. Ali (1999) in a more recent Bangla publication mentions that during the years 1877-1995, 365 cyclones were recorded in the Bay of Bengal which died before hitting the coast. He suggests that: in a warmer world, some of such cyclones could actually hit the land. Therefore, even if the total number of cyclones do not increase, the number of cyclones hitting the land, with resulting damages, may increase. He reiterates the point on increased intensity of cyclones under climate change.

Figure 2.3: Path of Cyclones in Bangladesh



4 The increase of surge intensity with climate change be could further investigated with upgraded computer models on the basis of recent bathymetrical data and calibrated cyclone wind field.

Source: Surface Water Modelling Centre, February 2000

Cross-boundary River Flows

It is expected that climate change induced alterations in temperature would affect the timing and rate of snow melt in the upper Himalayan reaches. As a result, the hydrological aspects of the eastern Himalayan rivers and the Ganges-Brahmaputra-Meghna (GBM) river basins could change significantly. GBM river systems would begin to swell early, while increased precipitation in monsoon would generate additional volumes of runoff. With only 7 percent of GBM catchment area, the country receives over 90 percent of the water discharged through the GBM river systems, and already suffers from repeated floods. Problems concerning drainage congestion will aggravate further with increasing volumes of water coming through the cross-boundary rivers during the monsoon.

During the winter period, however, flows in the GBM rivers might decrease because of lower rainfall and higher surface evaporation. Developments and climate change induced moisture stress in the upstream areas of the river basin will result in an increase of the rate of water withdrawal for agricultural, domestic and industrial activities. This might lead to even lesser availability of water flow in the cross-boundary rivers in Bangladesh during the winter months.

There are 57 cross-boundary rivers in Bangladesh, 54 are shared with India and the rest are shared with Myanmar. Bangladesh is the common lower riparian for all these cross-boundary rivers. In December 1996, the governments of Bangladesh and India came to an agreement on sharing the low Ganges flows. Discussions on sharing of cross-boundary river flows need to include contingencies for changes in runoff, and demand due to climate change.

El Niño and La Niña

Although no direct correlation has been found between the Southern Oscillation and consequent temperature anomaly in the oceanic systems and the extreme weather events in Bangladesh, some studies report that the El Niño Southern Oscillation (ENSO) events influenced the record-breaking floods of 1987, 1988 and 1998 (Chowdhury, 1998). The rapid transformation of La Niña from El Niño phase in early monsoon in 1998 is said to have influenced high rates of precipitation over the entire GBM catchment basin. As a result, after a prolonged dry season, the wettest monsoon came along with extremely high levels of precipitation eventually resulting in the deluge of the century. Such global events could therefore intensify some of the extreme climate change related weather events even further.

2.2 Sectoral Impacts: Impact on the Coastal Zone

2.2.1 Description of the Coastal Zone

The landmass of Bangladesh is connected to the Indian Ocean through a 700 km long coastline. The coastal region is marked by a vast network of river systems, an ever dynamic estuary, interaction of huge quantities of fresh water that are discharged by the river systems, and a saline waterfront --penetrating inland from the sea. In addition to the coastal plains, there are a number of small islands that are subject to strong wind and tidal interactions throughout the year, and are inhabited by a large number of people. As described in the earlier section, the coastal areas are highly prone to cyclone induced storm surges.

The eastern coastline is extended from the Big Feni river to Badar Mokam, the southern tip of the mainland. This part is more or less unbroken, characterized by flat beaches comprising of clay and sand. Karnaphuli, Matamuhuri, Sangu and Naf rivers discharge fresh water through the plains.

In the southwestern coastal areas of Bangladesh, the Sundarbans, a large patch of naturally occurring mangrove forest is located. The Sundarbans stretches further west into the southeastern part of the state of West Bengal in India. It occupies a total area of about one million hectares, about 62 percent of which is situated within Bangladesh.

The central region of the coastline is situated between the eastern and western coastal areas. Most of the combined flow of the GBM system is discharged through this low-lying area. The lower Meghna river is highly influenced by tidal interactions and consequential backwater effect. Heavy sediment inputs from the rivers result in a morphologically dynamic coastal zone. Cyclones and storm surges bring about the most catastrophic damages here.

The 1991 census recorded the size of the population of the coastal districts as approximately 24 million (BBS, 1991) whereas in 1901, the population of the coastal districts was only 7.2 million. Coastal districts have a population density of 959 inh/km^2, compared to the national average of 861 inh/km^2.[5]

Between 1901 and 1991, 20 to 22 percent of the total population lived in the coastal area. This illustrates two issues. First, factors which have contributed to the rapid population growth throughout Bangladesh have also affected the coastal zone. Second, even though the coastal districts are vulnerable to natural disasters, choice of living in the coastal area has not changed over the years. Based on the assumption that the rate of increase of the population in the coastal districts will remain similar to those for the whole of Bangladesh, the coastal population may increase to 45-50 million[6] by 2050. The population projection of the UN estimates a coastal population size of about 60-67 million (United Nations, 1988).

A predominant linear type settlement pattern in the coastal districts has been identified in the west and central districts, where an extensive network of rivers and canals exist, and water is the principal mode of transportation (MCSP, 1993). Linear settlements have also been found along the coastal embankments, especially on the islands, and along the roadsides and riverbanks in the eastern districts. Other patterns of human settlements in the coastal areas include nucleated, scattered, and mixed type settlements. Nucleated human settlements have been formed on the plains and foothills in the eastern districts. In the central districts (with its high density of population), scattered settlements are especially pronounced in the newly formed *char* lands.

Coastal plains are mainly used for crop agriculture and for grazing of livestock. Regular or periodic inundation and saline water intrusion has been a problem for agricultural activities in the coastal areas. Since the seventeenth century, construction of small embankments or dikes has been a common practice in this country. In the 1960s, the government of the then East Pakistan undertook an organized program to build a series of dykes under the coastal embankment project.

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5 Taken from a part of the earlier draft section of this report *A case study on coastal resources* by Dr. Monirul Q. Mirza, 1998

6 The projection of the population of the coastal districts is based on the following assumptions. Growth rate 1990-2000 same as 1980-1990 rate; growth rate 2000-2005 is 1.25 percent; and growth rate for 2020-2050 is 1.0 percent as assumed by the Bangladesh Planning Commission.

The main purpose of the project was to protect coastal agricultural land from flooding and intrusion of saline water during high tide, and thereby to increase cultivable areas in the coastal region as well as yields in the already cultivated areas (GOB, 1992). Sluices were provided to facilitate drainage from the empoldered land.

Recent practice of shrimp culture inside the embankments, despite its adverse environmental and ecological effects and serious social problems, has been boosting the national economy. Major shrimp culture activities are centered around Satkhira, Khulna and Bagerhat districts in the western zone and Chokoria, Cox's Bazar and Moheskhali upazilas under the Cox's Bazar district. Salt producing pans and relevant industries are located primarily in the Cox's Bazar district.

Coastal water resources not only support agriculture and industrial activities but also provide extensively used navigational routes. There are two sea ports in Bangladesh: Chittagong and Mongla. They support most of the international trade of Bangladesh, and might provide a good headway for Nepal and Bhutan's international trade in the future (especially if Bangladesh is connected to the proposed Trans-Asian road network).

Industrial activities concentrate in the Khulna and Chittagong districts. In Anwara upazila, adjacent to Chittagong city, an export promotion zone has been established. An estimated 400 industries of different sizes are in operation in this area. Another export promotion zone is likely to be established in Chittagong, and a third in Bagerhat near the second seaport at Mongla.

The newly emerging energy (primarily natural gas) production and distribution activities are located in Chittagong and offshore areas. Subject to adequate financing, new power generation plants will be located in Bhola, Khulna and Chittagong so that projected energy demands can be met. It is likely that new industries will also emerge in those areas fueled by higher availability of power and other infrastructure.

Even though the country has excellent locations with beautiful beaches, serene islands and lakes, tourism in Bangladesh has never fulfilled its potential. There are some facilities in Cox'sBazar, Rangamati and Kuakata. However, existing infrastructure for tourism is less than adequate to support even domestic demands. It is expected that new infrastructure will be built in the near future to promote international tourism.

2.2.2 Description of the Coastal Resources

Coastal Bangladesh is rich with natural resources; including both renewable and non-renewable resources.

Geological Resources

In recent years, coastal areas received international attention due to high potential for the exploration of in-shore and off-shore natural gas. In the southeastern Sangu valley, a large natural gas field was discovered and subsequently put into commercial operation in 1998. Offshore drilling is also underway to explore untapped fossil fuel resources found in the coast. This has opened up new possibilities for installation of gas-based power plants in theBhola Island and in Bagerhat, which would promote export promotion zones, and rapid industrialization. Natural gas is well- recognized to be cleaner than other green house gas emitting fossil fuels such as coal. Besides natural gas, commercially important minerals such as monazite, ilmenite, rutile, zircon and ceseum have been found in the sandy beaches along Cox's Bazar. These resources are yet to be exploited for commercial use.

Mangrove Forests

The coastal region houses several mangrove ecosystems, including the Sundarbans. These mangroves forests are transitional zones between fresh and marine waters, and are rich in marine and terrestrial flora and fauna. While sundri (*Heretiera fomes*), gewa (*Excoecaria agallocha*) and goran (*Ceriops decandra*) are the most abundant species found in the forests, many other flora species exist in these areas. Dicotyledonous tree species are represented by 22 families and 30 genus, and *Rhizophoraceae* is represented by all the 4 known genera and at least 6 species. There are also 12 species of shrubs, 11 species of climbers, 13 species of orchids (epiphytic parasites) and 7 species of ferns in the Sundarbans. In addition, the forests support a total of 425 species of wildlife including mammals (49 species), birds (315 species), reptiles (53 species) and amphibia (8 species) (Rashid *et al.*, 1994). Among fish resources, the water bodies within the forest ecosystems provide 53 species of pelagic fish, 124 species of demersal fish, 24 species of shrimps, 3 species of lobster, 3 species of turtles, 10 species of sea snakes and 7 other snake species (Acharya and Kamal, 1994). The forests also provide basic ecological support systems as nursery for many species of marine invertebrates including the fresh water shrimps (*Macrobrachium rosenbergii*) and brackish water prawn (*Penaeus monodon*) that are exported (Ali, 1998a).

The Sundarbans was declared a World Heritage Site. It is known as the single largest stretch of productive mangrove forest in the world, and is inhabited by one of the most elegant creatures of nature, the Royal Bengal Tiger (*Panthera tigris tigris*). The dimensions and richness of biodiversity in the Sundarbans is also proven by the availability of 3,033 ton of fish, 375 ton of mud crab, 3,600 ton of oyster shells and 35 ton of gastropod shells which are obtained from the forest every year (Chantarasri, 1994). In addition, about 1,500 million tiger prawn fries are collected per year from the forest and its adjacent areas. The forest contains a total of 10.6 Mm^3 standing tree volume, 64 percent of it is occupied by the most commercially important species sundri (*H. fomes*). The most important non-wood forest product is *Nypa fruiticans*. Leaves from this plant are widely used for thatching of roofs of houses and boats, and also for fencing the houses of millions of families around the coastal districts. The Sundarbans provides livelihood and employment to wood cutters, fishermen, honey and wax collectors, shell collectors, timber traders and workers, workers of fish-drying industries, etc. The only newsprint paper industry is located close to the forest, and raw materials for the industry are collected from the Sundarbans. Overall, it is estimated that the forest ecosystem provides employment for a total of 0.5 to 0.6 million people in Bangladesh. In addition to natural resources, the forest provides opportunities for tourism, outdoor recreation, biological research and conservation education.

Land Resources

For the local inhabitants, the flat plains in the coastal areas are the most important resource that supports crop production, livestock rearing, salt manufacturing from the sea water, shrimp culture activities, ship manufacturing, harbor activities and different types of industries. Section 2.2.1 provided an overview of the activities in the coastal zone.

Water Resources

Coastal areas are endowed with both fresh and brackish water resources. During monsoon, fresh water there is abundant fresh water, whereas during the winter, water becomes a scarce resource. Due to reduced flows in the rivers in winter, the surface water systems suffer from saline water intrusion, making the resource unsuitable for agricultural, domestic and industrial purposes. The groundwater aquifers in the coastal districts are under growing stress of salinization resulting from over-extraction (*Janakantha*, Dec. 15, 1999). Sea level rise and low river flows would substantially contribute to that stress. Winter agriculture in the coastal areas is dependent on groundwater. Rural water supply almost entirely depends on fresh water source.

Embankments provide protection against flooding from smaller surges but are not designed to prevent inundation by severe surges (GOB, 1992). In addition to the protection against regular inundations and salt water intrusion, the embankments can reduce the tidal dynamics. This has an adverse effect on the drainage conditions (siltation due to reduced tidal volumes) and the ecosystems (water logging and stagnant waters). These negative effects have already been visible in parts of the coastal area, such as the Khulna - Jessore region (EGIS, 1998).

Beaches

The beach along the southeastern coastal areas is continuous and flat. Although it stretches 120 km along the shore, there are only a few patches of sandy beaches, the rest are muddy. There is another important sandy beach in Kuakata in the central coastal area. Production of salt and *shutkee* (dried fish) is done in the beach areas. A long sandy beach of about 145 km runs from Cox's Bazar to Badar Mokam. Most of these sandy beaches offer good tourism opportunities, however, at present have rudimentary facilities to attract foreign visitors.

Fisheries

Although the Extended Economic Zone of Bangladesh covers an area of 70,000 km^2, effective fishing areas for marine fish and shrimp have been estimated at about 10,000 km^2 and 5,000 km^2 respectively. Total annual marine fisheries catch is estimated at 0.23 million ton which is around 28 percent of all fish produced per year (BBS, 1997).

Coral Reefs

Bangladesh has a tiny island at the tip of its southeastern reach, namely Narikel Zinzira, where coral colonies are located. Existing environmental conditions around the coral island are poor due to several reasons including: frequent spillage of bulge waters from sea-going vessels, increasing turbidity of coastal waters because of deforestation followed by land erosion in the hilly reaches of Chittagong Hill Tracts, and exploitation of corals by local traders. Without immediate and adequate conservation activities, the already endangered ecosystems of the coral island are likely to suffer further degradation.

2.2.3 Impacts on the Availability of Coastal Resources

Coastal zone resources highly endangered by the climate change include land and water resources, as well as the mangroves forests. More specifically, the impacts would be:

- ◊ changes in water levels and induced inundations and water logging;
- ◊ increased salinity in ground and surface water, and corresponding impacts on soil salinity; and
- ◊ increased coastal morphological dynamics (erosion and accretion).

Water Levels, Inundations and Water Logging

Any rise of the sea level will propagate upstream into the river system. In Bangladesh, this backwater effect will be more pronounced because of the morphologically dynamic rivers, which will adapt their bed levels in a relatively short time period (Huq*et al.*, 1996). This whole process will lead to decreased river gradients, increased flood risks and increased drainage congestion.

Since most of coastal plains are within 3 to 5 meters from the mean sea level, it was previously thought that a significant part of the coastal areas (as high as 18 percent of the country) would be completely inundated by rising sea waters (Huq *et al.*, 1995; Houghton *et al.*, 1996). Such a speculation was made based on two major approximations: (a) the coastal plains are not protected and (b) the seawater front with follow the contour line. In reality, however, it is found that most of the coastal plains in the central regions are protected[7]. Due to the backwater effect, embankments further land inwards may be topped and areas flooded. This could still turn most of the seaward polders into islands.

Drainage congestion may become an even more serious threat than higher flood risks. Due to the siltation and the poor maintenance of the drainage channel network in many parts of the coastal zone, drainage congestion is already a grave problem (EGIS, 1998), and the problem is expected to increase considerably.

Proper emphasis should be given to the fact that: protection measures against inundation by embankments interrupt the natural processes of land sedimentation and delta formation. This implies that subsidence and sea level rise will not be compensated by sedimentation, and the risks of inundation and drainage congestion will be even greater in the future. These amplifying effects are particularly alarming, and indicate that quite a different approach may be required to face the problems in especially the seaward parts of Bangladesh.

Unlike the densely populated seafront areas, the Sundarbans is not protected and is heavily influenced by tidal effects. A rise in sea level will tend to inundate the mudflats of the forest and reduce the land area of the forest. The forest floor, however, may be experiencing a natural uplift at a rate similar to the anticipated rate of sea level change. Whether natural uplift is strong enough to counterbalance sea level rise is very uncertain, and present research continues to emphasize the vulnerability aspects of the Sundarbans.

Saline Water Intrusion

The effect of saline water intrusion is highly seasonal in Bangladesh. Saline intrusion is at its minimum during the monsoon (June-October) when the GBM rivers discharge about 80 percent of the annual fresh water flow. In winter months the saline front begins to penetrate inland and the affected areas rise sharply from 10 percent in the monsoon to over 40 percent. Climate change would increase saline intrusion through several means:

- ◊ directly pushing the saline / fresh waterfront in the rivers through higher sea levels;
- ◊ lower river flows from upstream, increasing the pushing effect from the sea;
- ◊ upward pressure on the saline / fresh water interface in the groundwater aquifers (every cm of sea level rise will result in a thirty-fold rise of the interface because of the hydrostatic pressure balance);
- ◊ percolation from the increased saline surface waters into the ground water systems;
- ◊ increasing evaporation rate in winter, leading to enhanced capillary action and subsequent salinization of coastal soils; and

[7] The ongoing Coastal Embankment Rehabilitation Project and its predecessor the Priority Works Program apply design criteria based on the once in a 100 year storm surge (past event) and 0.5 m overtopping, i.e. 5.00 m^+ crest elevation, 1:7 sea-facing slope and afforestation on the embankments and foreshore.

◊ increasing storm surges which carry sea water.

All these effects would have significant adverse impacts in the coastal areas. Climate change induced extreme weather events, especially low flow conditions in winter will accentuate the saline intrusion in the coastal areas (Habibullah *et al.*, 1998).

Coastal Morphology

The morphological dynamism of deltaic Bangladesh is manifested in the coastal zones. The coastal areas have experienced natural erosion and accretion in the past, as well as anthropogenic accretion and subsequent erosion in more recent years. Although current literature suggests that coastal land is in the process of slow accretion at an approximate rate of 8 km^2/year during the past 210 years (Allison, 1998, Martin and Hart, 1997), much of this may be attributed to cross dams that have been built to reclaim land from the shallow continental shelves. Nevertheless, due to climate change induced alterations in thermal energy at the ocean-terrestrial interface and the expected changes in the inflow of riverine sediments, the dynamics of coastal morphology appears to be highly uncertain. Furthermore, new embankments for reclaiming additional land would affect the morphological dynamics of the coast.

2.2.4 Impacts on the Use of Coastal Resources

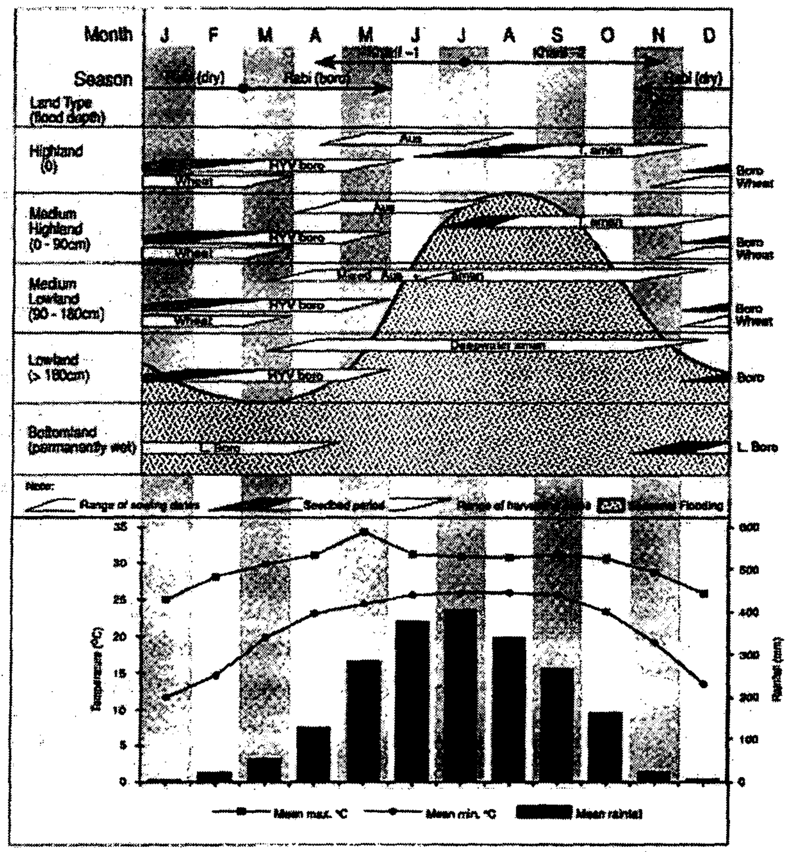
In addition to the above described impacts on the coastal resources (drainage congestion, saline water intrusion and coastal morphology), the occurrence of cyclones and storm surges reduce the economic potential and employment opportunities in the coastal areas[8]. For example, high intensity storm surges might jeopardize the expansion of energy-recovery activities in the coastal areas and supporting industries, especially in the off-shore areas. Salinity intrusion, without climate change induced effects, has already inhibited growth of industrialization in the coastal districts. A number of industries in Khulna, including the only newspaper producing industry in the country have been facing shortage of fresh water during the dry season. As a consequence, no new heavy industry has emerged in the recent years despite increasing infrastructure facilities (sea-ports, etc.) in the coastal areas.

Agricultural activities will suffer greatly from impacts of climate change. Increased salinity levels will reduce fresh water availability for irrigation, while growing drainage congestion problems will result in longer periods of flood inundation. The relation of cropping patterns, climate and seasonal flooding is illustrated in Figure 2.4[9]. This will reduce the areas suitable for rice production. In addition, increased coastal morphological dynamics will contribute to the existing problem of loss of valuable agricultural land due to erosion.

[8] Storm surges are associated with cyclones when high-speed winds interact with shallow waters in the seafront and produce several meters high waves. Such waves may overtop the protective embankments and inundate coastal lands with tremendous destructive power. Throughout history, the tidal boars have wrecked the coastal areas, causing deaths of millions of people, livestock and wildlife, distracting standing crops and vegetation; washing away saltpans and shrimp ponds; and demolishing infrastructure. Climate change is expected to increase the intensity of cyclones and the penetration of storm surges further inland, causing higher damages. In recent years, over two thousand cyclone shelters have been built in the coastal areas to save human lives. But no such infrastructure has been built for livestock, foodgrains and other perishable items. In absence of similar infrastructure these resources remain under the threat of cyclone destruction.

[9] The temperature and rainfall data shown in the figure relate to Dhaka.

Figure 2.4: Cropping Patterns in Relation to Climate and Seasonal Flooding



Source: Brammer *et al.*, 1996

Public health in the coastal areas greatly benefited in the last decades from the massive shift from surface to groundwater sources for domestic water supplies. However, in addition to reduced availability of safe drinking water with arsenic pollution, people now have to deal with saline groundwater especially at the end of the dry season.

A rise in sea level would also inundate some of the pristine sandy beaches along the Chittagong coastline. Islam *et al.* (1998) reported that about 5,800 ha area along the shoreline would be lost in 2030, while 11,200 ha would be recessed in 2075 due to sea level rise. It would affect the prospect of tourism development in the coastal areas. Submergence of low-lying areas would also reduce areas used as salt pans, especially along the coast of Cox's Bazar and its islands.

Northward penetration of the salinity front would result in salinity induced succession problems in the Sundarbans and as a result, the symbiotic process in the entire ecosystem would change completely. It is expected that high value timber species would make way for low value shrubs. Since the rate of these changes are much higher compared to the rates at which forest species migrate to suitable places, the size of the (actual) forest will be less compared to its present size (Ahmed, 1998a).

2.3 Impacts on Fresh Water Resources

This section addresses the availability of fresh water resources (including floods, droughts, sediments, and drainage issues) and the demand for fresh water (in irrigation, fisheries, navigation, domestic and industrial usage). In the first section, relevant climactic factors are discussed. A comparison between water availability and water demand is then provided. The section aims to present the most pressing expected effects of climate change. Due to the uncertainty in present predictions, the scale of the effect remains difficult to estimate.

2.3.1 Description of the Fresh Water Resources

Availability of fresh water in Bangladesh is highly seasonal. Based on rainfall patterns, four seasons can be distinguished. About 75 percent of the annual rainfall occurs during the monsoon (June – September). Annual rainfall ranges from 1,400 mm in the western Rajshahi region to over 5,000 mm in the northeastern Sylhet region (Taskforce, 1991). In the post-monsoon (October – November) and winter period (December – February) only 10 percent of the annual rainfall is available, making agriculture highly dependent on remaining soil moisture and irrigation from surface and groundwater. In the subsequent pre-monsoon period (March – May), on an average, there is 15 percent of the annual amount of rainfall. Rainfall is extremely unreliable in this period.

Table 2.2: Comparison of Average July Rainfalls in Major River Basins to Total Rainfall in 1998

River basin	July 1998 rainfall (mm)	Average July rainfall (mm)	Percentage increase 1998 to average
Ganges	510	427	19
Brahmaputra	591	487	21
Southeastern Hill Basin	898	616	46
Meghna	1,745	641	172

Source: Flood Information Centre, BWDB, 1998.

Seasonality is reflected in river discharges as well. Table 2.3 presents comparisons of average July-rainfall in major river basins with respect to total rainfall in 1998. Approximately 85 percent of the mean dry season streamflow is found in the GBM rivers. Smaller regional rivers carry the remaining 15 percent. In terms of water availability, March is a critical month in Bangladesh. The Brahmaputra accounts for 67 percent of the flow measured within the country, whereas the share of the Ganges is only 13 percent. The Meghna discharge contributes only 2 percent of the total measured discharge in Bangladesh during the month of March. It is estimated that the ratio between the discharges of the dry and monsoon seasons for the Ganges River is 1:6 (Mirza and Dixit, 1997).

Climactic factors, both natural and anthropogenic, which change the water availability through their impacts on such primary physical effects as floods, droughts and salinity intrusion, are:

- ◊ precipitation and evaporation;
- ◊ upstream (cross-border) river flows; and
- ◊ sea level rise, which results in higher flood levels; rise in river bed levels; and salt water intrusion.

Most climate models (GCMs) estimated increased annual precipitation over Bangladesh (Table 2.3). Increases were more pronounced particularly during the monsoon period.[10] Some models (e.g., Geophysical Fluid Dynamics Laboratory 1 percent transient model) show potential for a wetter monsoon and a drier winter (Ahmed and Alam, 1998). In Appendix F, results are given of recent calculations (prepared for this study) of changes in peak discharges of the main cross-border rivers due to climate change.

Potential evapo-transpiration (PET) is the largest determinant in the water requirement for crops. Brammer *et al.* (1996) provided possible increases in PET in five meteorological stations in Bangladesh. The results indicate 4 mm, 3 mm, and 2 mm increases in PET in the Ganges, Brahmaputra, and Meghna basins, respectively in the month of March for a 1.1 degrees celcius rise in monthly mean temperature. On average, the GCM results show similar or slightly higher changes in mean annual temperature.

Sea level rise will affect river water and riverbed levels, and will increase saline intrusion as well. Backwater effects, induced by higher sea levels, occur over the whole year. This eventually will lead to higher bed levels in the main rivers which in turn will lead to higher water levels. One modeling study shows that a 50 cm instantaneous increase in sea level in the Bay of Bengal may raise the bed level of the lower Padma river by 22 cm over a period of 100 years (Halcrow, 1992). There are many limitations of the study (for example, the study assumed a fixed riverbed and the current rate of sediment flow in the river), but it might be expected that a rise in sea level would have significant impacts on the morphological behavior of the major rivers in Bangladesh (BCAS/RA/Approtech, 1994).

Flooding

Analysis of past floods suggests that, about 26 percent of the country is subject to annual flooding and an additional 42 percent is at risk of floods with varied intensity (Ahmed and Mirza, 1999). Box 2.1 briefly describes the effects of the floods of 1987, 1988, and 1998. A 10 percent increase in monsoon precipitation in Bangladesh could increase runoff depth by 18 to 22 percent, resulting in a sevenfold increase in the probability of an extremely wet year (Qureshi and Hobbie, 1994). Since it is found that monsoon precipitation will increase by 11 and 20 percent, surface runoff will increase in the order of 20 to 45 percent, respectively (Ahmed and Alam, 1998). Alam *et al* (1998) reported that, by the year 2030, an additional 14.3 percent of the country will become extremely vulnerable to floods, while the already flood-vulnerable areas will face higher levels of flooding. It is also reported that, even if the banks of the major rivers are embanked, more non-flooded areas will undergo flooding by the year 2075. Mirza and Dixit (1997) estimated that a 2°C warming combined with a 10 percent increase in precipitation would increase runoff in the GBM rivers by 19, 13, and 11 percent respectively. Increased depth of flooding will be pronounced in the lowlands and depressions in the Faridpur, southwest Dhaka, Rajshahi-Pabna, Comilla, and Sylhet-Mymensingh greater districts. Figure 2.5 shows the areas likely to be flooded by the year 2030, even after completing about 60 percent of the flood protection schemes considered under the Flood Action Plan (Alam *et al.*, 1998).

[10] Before 1995, GCMs did not account for the effects of sulfate aerosols. The models consistently showed increased precipitation over Bangladesh (because land was warming more than ocean, deepening the monsoon low pressure system). Inclusion of sulfate aerosols showed the possibility of reduced monsoon precipitation. For example, Mitchell *et al.* (1995) estimated that sulfate emissions from South Asia would result in less cooling of land than of the ocean. This would weaken the low pressure system and the monsoon. Some other GCM estimates with sulfates, though, have still shown a stronger monsoon.

New work undertaken by this study (and referred to previously) reported that an increase in precipitation over the GBM basins of about 5 percent combined with a temperature increase of around 1°C could result in small changes in peak discharge, but up to a 20 percent increase in area flooded (Kenny *et al.*, 1998). (see Appendix F)[11] Additional area flooded would tend to have small flood depth (flood category F_0), but would still cause additional destruction compared to current floods. Severity of extreme floods, such as the 20-year flood event, is estimated to increase marginally.

Box 2.1
Floods in Bangladesh

Flooding occurs annually in Bangladesh. While other floods have resulted in a larger loss of life, magnitude and duration of the 1998 flood earned it the distinction of being the country's worst in living memory. The origin and wide-ranging impacts of the 1998 flood, which began in July and ended in September, are summarized below.

Origins of the Flood

The magnitude and duration of the 1998 flood can be explained in large part by the simultaneous realization of the impacts from three factors:

◊ Heavy rainfall/snowmelt in India and Nepal (which increased the flow in the rivers entering Bangladesh).

◊ Increased July rainfall within critical river basins in Bangladesh (Ganges, Brahmaputra, Meghna, Southeastern Basin).

◊ Elevated tides in the Bay of Bengal.

The first and second factors help explain the magnitude of the 1998 flood. In this respect, it is worth noting the extent to which the 1998 July rainfall totals within some of Bangladesh's critical river basins exceeded the typical July average (see Table 2.3).

The third factor, elevated tidal levels in the Bay of Bengal, with possible back water effects, reduced the Bay's capacity to receive the floodwaters. This, in part, contributed to the duration of the flooding.

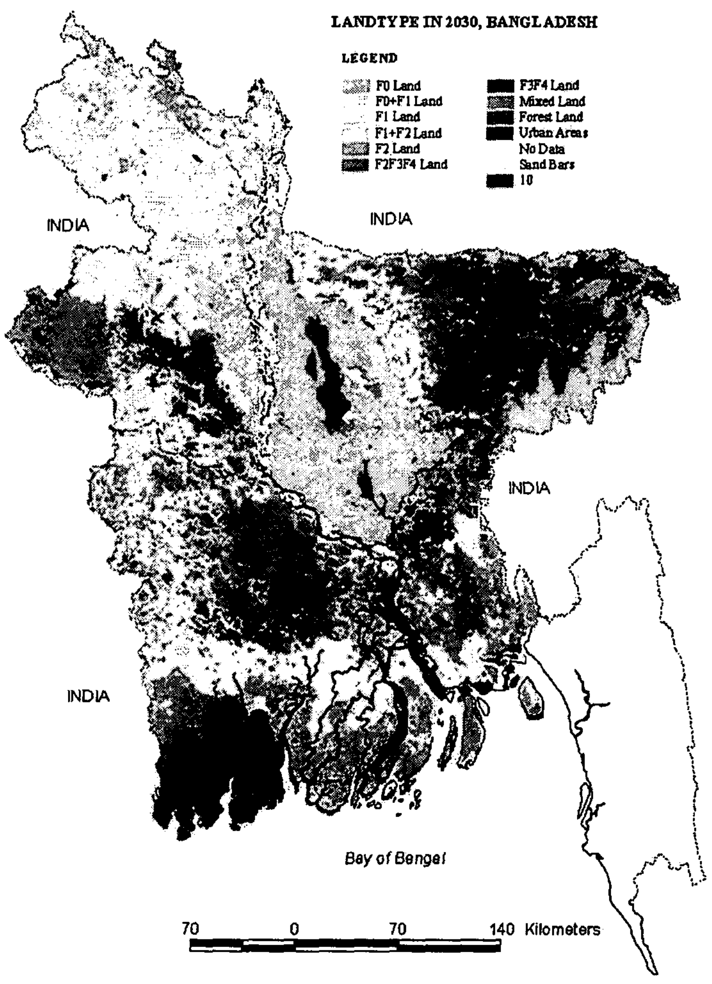
Before 1998, two of the worst flood years in Bangladesh's recent history were 1987 and 1988. The 1987 flood was primarily attributable to elevated rainfall within Bangladesh, and the 1988 flood was primarily the result of increased rainfalls in the upper reaches of these river basins in India and Nepal, increasing the flow of water into Bangladesh. Those two floods were each primarily attributable to the impacts of one of the above three factors. Simultaneous impacts of the three factors made the 1998 flood the worst one in living memory.

Extent of Flooding

According to government sources, the 1998 flood inundated about 100,000 km^2. In contrast, the 1987 flood had inundated about 57,000 km^2 and the 1988 flood inundated 89,000 km^2. The 1998 floods affected 68% of the country, and seriously impacted the livelihoods of 30 million people. Overall damage was estimated at two to three billion U.S. dollars. Final estimates showed that 51 districts and 307 thanas were inundated, about 1400 people were killed, 1.77 million houses were damaged, and 23,45,8713 Bangladeshis became homeless. While the 1987 and 1988 floods inundated three-quarters of the country, and killed more people, they receded after three weeks. The 1998 floods lasted for over 10 weeks (MDMR/UNDP 2000)

11 The study was done using BDCLIM. This is not a predictive tool, but rather a tool that allows for assessment of sensitivity and uncertainty, as related to possible effects of climate and sea-level change. The results should be considered as indicative of change, but not as a prediction.

Figure 2.5: Areas of Bangladesh Likely to be Flooded by 2030



Prepared by: Natural Resources Information Centre, BCAS

Source: Alam *et al.*, 1998.

Drainage Congestion and Sediments

Flooding would be exacerbated by climate change induced sea level rise, which would limit runoff discharge due to enhanced backwater effect, as was seen in the floods of 1998 (Ahmed and Mirza, 1998)[12] Moreover, due to prolonged discharge of floodwaters, the rate of sedimentation will increase. As a result, both the river bed and the bed of the adjacent floodplains will rise leading to further drainage congestion, and possibly more intense flooding in the following years. Such a cyclic course of events would intensify flood problem in the already flood prone areas of the country.

[12] When seas were higher than normal because of the pull of the moon, and southerly winds

Major sources of the sediments carried by the region's rivers are in the upstream areas in India, China, Nepal, and Bhutan. Sediments generally originate in the mountainous areas. In recent years, increased deforestation in the mountains have exposed top soil, and eventually might have increased the sediment load in the rivers (Goswami, 1985). Increased rainfall runoff in the vast GBM region, comprising a total catchment area of 1.41 Mkm^2, also contributes to enhanced sediment flows along the GBM river systems. This is likely to increase the rate of bed level rise in the channels and the floodplains. Moreover, instead of fertile silt, if infertile sand or coarse sediments are deposited with flooding of the Brahmaputra, it will severely reduce productivity of the top soil. Climate change induced higher sedimentation rates will, therefore, have serious social and economic implications for the future.

Effects of drainage congestion may differ in different parts of the country. This study distinguishes between the coastal zone and the flat riverplains of the GBM basin (see also Figure 2.1). Further detail is beyond the scope of the present study.

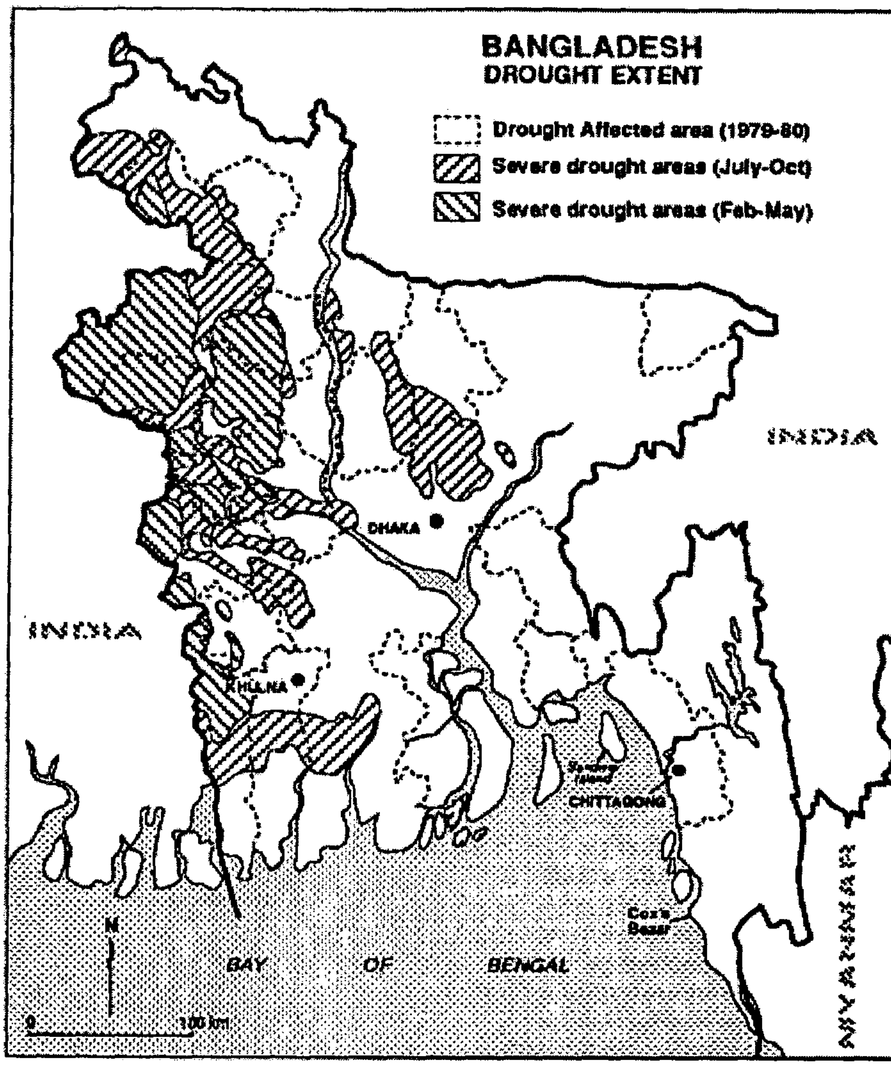
Low River Flows

As mentioned earlier, lower precipitation in combination with higher evaporation will lead to increased withdrawal of surface water. Low flow conditions of the rivers will be subsequently accentuated. This will also reduce the cross-boundary river flows, and the availability of fresh water for irrigation, livestock and people.

Droughts

Bangladesh will also be at higher risk from droughts (see Box 2.2). Karim *et al.* (1996) reported the effect of climate change induced moisture stress and resulting phenological drought impacts. A geographical distribution of drought prone areas under climate change scenarios shows that the western parts of the country will be at greater risk of droughts, during both the Kharif and pre-Kharif seasons. The extent of 1979-80 drought is graphically represented in Figure 2.6. It is found that, under a moderate climate change scenario, Aus production would decline by 27 percent while wheat production would be reduced to 61 percent (Karim *et al.*, 1998). Under a severe climate change scenario (with 60 percent moisture stress), yield of Boro might reduce by 55~62 percent. Moisture stress might force farmers to reduce the area for Boro cultivation.

Figure 2.6: Extent of the 1979-1980 Drought



Source: Erickson et al. 1996

In case of a severe drought, forced by a change of temperature by +2°C and a reduction in precipitation by 10 percent, runoff in the Ganges, Brahmaputra, and Meghna rivers would be reduced by 32, 25, and 17 percent respectively (Mirza and Dixit, 1997). This would limit surface irrigation potential in the drought-vulnerable areas, and challenge food self-sufficiency programs of the country.

Box 2.2

Droughts in Bangladesh

Like floods, Bangladesh is also vulnerable to recurrent droughts. Two critical dry periods are distinguished (Karim *et al.*, 1990).

- *Rabi* and pre-*Kharif* drought (January/ May), due to: (i) the cumulative effect of dry days; (ii) higher temperatures during pre-Kharif (>40 degrees celcius in March/May); and (iii) low soil moisture availability. This drought affects all the Rabi crops, such as HYV *Boro*, *Aus*, wheat, pulses and potatoes especially where irrigation possibilities are limited. It also affects sugarcane production.
- Kharif droughts in the period June/July to October, created by sub-humid and dry conditions in the highland and medium highland areas of the country (in addition to the west/northwest also the Madhupur tract is drought prone). Shortage of rainfall affects the critical reproductive stages of transplanted *Aman* crops in December, reducing its yield, particularly in those areas with low soil moisture holding capacity.

Western regions are particularly vulnerable to droughts. In the Rabi season, 1.2 million ha of cropland faces droughts of various magnitude. A very severe drought can cause more than 40 percent damage to broadcast Aus. During the Kharif season, drought causes significant damage to transplanted Aman crop in about 2.32 million ha area annually. Apart from loss to agriculture, droughts have significant effects on land degradation, livestock population, employment, and health.

Between 1960 and 1991, droughts occurred in Bangladesh 19 times (Mirza and Paul, 1992). Very severe droughts hit the country in 1951, 1961, 1975, 1979, 1981, 1982, 1984, and 1989. Past droughts have typically affected about 47 percent area of the country and

53 percent of the population (Task Force, 1991). Figure 2.6 provides a general spatial distribution of drought prone areas in Bangladesh.

River Erosion and Accretion

Rivers in Bangladesh are morphologically highly dynamic. The main rivers are braided, and forms islands or chars in between the braiding channels. These chars, of which many are inhabited, "move with the flows" and are extremely sensitive to changes in the river conditions. Erosion processes are highly unpredictable, and not compensated by accretion. These processes also have dramatic consequences in the lives of people living in those areas. A four year study concluded in 1991 reported that: out of the 462 administrative units in the country, 100 were subject to some form of riverbank erosion, of which 35 were serious, and affected about 1 million people on a yearly basis (REIS, 1991).

A study by EGIS (1997), analyzing remote sensing images from 1973 to 1996 of the 240 km long Brahmaputra-Jamuna River between the Indian border, and the confluence with the Ganges concluded that the river has been widening at an average rate of about 130 m per year. This corresponded to a loss of about 70,000 ha in 23 years, while only 11,000 ha had been accreted. With the exception of 10 percent of stable charlands, which were more than 20 years old, the average age of a given area of charland was found to be only four years. The same EGIS study concluded that the observed erosion during the flood years 1987 and 1988 was 8,000 ha per year, against an average of 3,000 ha per year during the mentioned 23 year period -- this gives some indication of how sensitive these processes are.

Changes in the river flows and sediment transport due to multi-dimensional impacts of climate change are expected to increase the dynamics of these rivers even more. While the consequences are highly uncertain, they give rise to major concern especially given the related loss of land and property.

2.3.2 Demand for Fresh Water

In Bangladesh, the largest demand for both surface and groundwater is to support irrigation in the dry months. However, in setting priorities for allocating water during critical periods, the National Water Policy gives this sector a relatively low priority and sets the following order: domestic and municipal uses, non-consumptive uses (e.g., navigation, fisheries and wild life), sustenance of the river regime, and other consumptive and non-consumptive uses including irrigation, industry, environment, salinity management, and recreation (WARPO, 1999).

By 2018, demand for irrigation may reach 58.6 percent of the total supply. Demand for other sectors is estimated to reach 40.7 percent for navigation, salinity, and fisheries, and 0.7 percent for domestic and industrial uses (MPO, 1991). It should be noted that these estimates do not take into account the effects of possible changes in climate. The following paragraphs discuss the possible influence of climate change in the estimation of the water requirements for the various sectors.

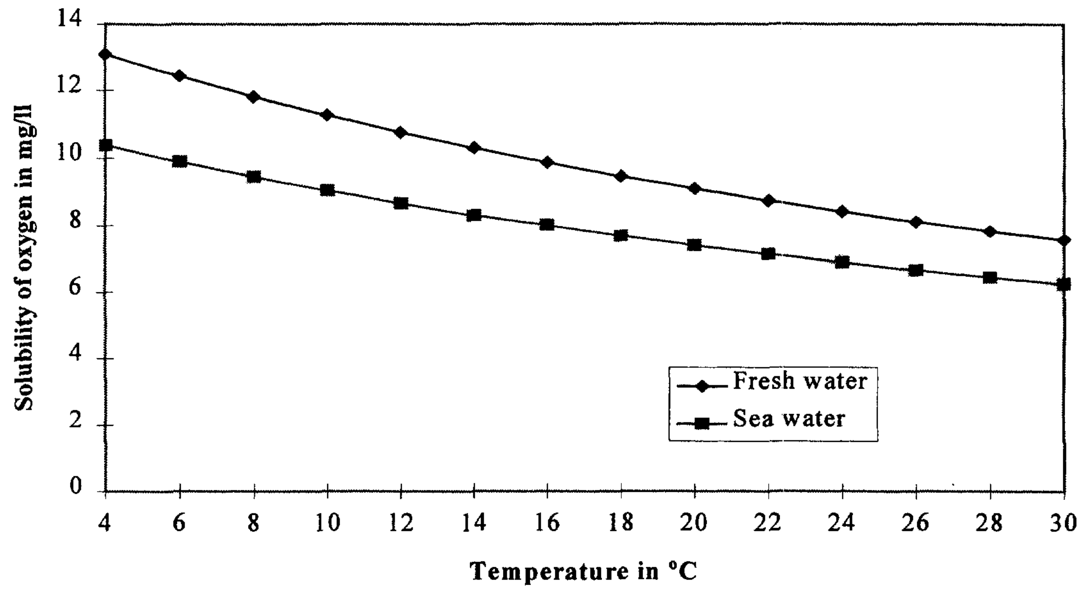
Irrigation

A large portion of the increased demand is expected to be from expansion of irrigation. Currently, 7.6 Mha out of the total cultivable land of 9.03 Mha used in agriculture are suitable for irrigation, and about 3.99 Mha are irrigated (PC, 1998). MPO (1991) estimated that the irrigated area would reach 5.5 million hectares by 2005 and 6.9 million hectares by 2020 (WB and BCAS, 1998). Changes in climate may affect irrigation requirements for all the three cropping seasons: Rabi, Kharif-I, and Kharif-II. Increase in temperature will lead to escalating irrigation demands by 200 Mm^3 for March only (Brammer *et al.*, 1996).

Fisheries

Currently, the irrigation and fisheries sectors compete for water. In determining water demand for fisheries, various factors need to be considered. As shown in Figure 2.7, the solubility of oxygen in water decreases with higher temperature, which could be a problem for fisheries. If river flow is reduced during the dry season, this problem will be worse.

Figure 2.7: Solubility of Oxygen in Fresh Water and Sea Water at Different Temperatures



Source: Stirling and Philips, 1990.

Fresh water migratory fish hatchlings will face a survival problem in the southwestern part of Bangladesh because of increased salinity from sea level rise. Fish hatchlings from the Ganges and the Padma (combined Ganges and Brahmaputra rivers) migrate to the southwest region through the Gorai and Arial Khan rivers. With sea level rise, the saline-water front will move farther inland. Migratory fresh water fish hatchlings cannot survive even in moderately saline (2,000 mmhos/cm) water (EGIS-II fisheries expert, personal communication). With declining number of hatchlings in the dry season, one may expect that the overall fish production in the floodplains will decline significantly.

Navigation

Inland navigation plays an important role in the Bangladesh economy. It carries 31 percent of the country's freight and 15 percent of its passengers (DHV, 1989). This estimate does not include the contribution of country boats in the rural areas. Shawinigan Lavalin (1993) reports that there are about 850,000 country boats in Bangladesh, with a carrying capacity of 3 million tons. This estimate is 20 times the capacity of trucks in Bangladesh. The boats carry almost 16 billion tons-km per year, twice as much as all the formal modes (rail, road, and formal IWT) combined (IFCDR, 1996).

A few years ago, the Bangladesh Inland Water Transport Authority (BIWTA) prepared a long list of navigation routes in Bangladesh (MPO, 1986). It also estimated required draft or water depth for some of the navigation. While many of the routes are not navigable throughout the year, some 8,000 km are currently navigable by larger mechanized vessels during the wet season, and this is reduced to about 4,800 km in the dry season (DHV, 1989).

Over the years, water depth in many navigation routes in Bangladesh has deteriorated. There are two principal reasons for this deterioration. Supply of water in the dry season has decreased, and siltation has accelerated due to an increase in sediments in the major rivers and in other cross-border rivers. While the Ganges, Brahmaputra, and Meghna rivers supply 1,151 million tons of water; their share in terms of supply is 48, 51, and 1 percent respectively (IFCDR, 1996). Due to siltation, many regional rivers such as the Gorai River have lost their connection with their perennial water source in the dry season (Mirza, 1997a). Therefore, lower river flows, rising bed levels, and increased morphological dynamics will likely deteriorate further the flow conditions of the smaller channels as well as their navigability in winter.

Domestic and Industrial Water Demand

Water resource requirement for the domestic and industrial sectors is minimal in Bangladesh because of low per capita demand for domestic purposes, and a low level of industrial development. According to an estimate of the MPO (1991), water demand for domestic and industrial sectors constitute less than 1 percent of the total demand. Despite a projected increase of over 50 million people by the year 2018, the same study estimated that the demand of water for domestic and industrial uses would remain below 1 percent.

Implications of climate change to future urban and rural water supply could be manifold. First, in summer, increased urban temperatures may increase the demand for water for drinking and bathing. Second, increased temperatures may increase the demand for industrial cooling water as well as cooling water for transportation. These increased demands may aggravate the current conflict between domestic and industrial water supplies in the urban areas. Third, in the rural areas. Higher temperature may increase the rate of evaporation in standing water bodies. Therefore, ponds that are for example used in rural areas for bathing (by people and for livestock) may dry up even more quickly than now. Shortage of water in the standing water bodies will also generate pressure on hand tubewells (HTWs), depleting further the groundwater table as they may not be fully replenished. If monsoon droughts escalate, domestic water supply in rural areas will suffer, and current conflict with irrigation water supply will worsen.

Currently, only one-half of the urban population has access to reasonably safe water; the remaining half depend on contaminated traditional sources (UNDP/World Bank, 1994). In rural areas, the usage of ground water for the last few years was encouraged as a safe alternative to contaminated surface water. However, popularity of hand tubewells as a provider of "pure" potable water has been facing tremendous challenges in recent years due to wide-scale contamination of shallow groundwater tables with arsenic. Many people are already suffering from chronic arsenicosis, and it is feared that almost half the population of the country will have to fight against arsenic disorders in near future (Ahmed, 1998b). If the farmers depend on increased number of STWs, the rate of groundwater abstraction from the shallow water tables will be much higher leading to increased arsenic abstraction in areas where the groundwater is contaminated and there may be possible impacts on crops. More research is needed on the issue of arsenic contamination of the food chain before a possible climate change impact can be assessed.[13]

[13] Comments from Nadim Khouri, core team member of Bangladesh Arsenic Mitigation-Water Supply Project, project design team.

Climate change induced low flow and high evaporation will reduce availability of surface water in the water bodies including rivers, artesian wells and ponds -- and thereby accentuate the prevailing crisis of drinking water in the dry season.

Water situation in the capital city, Dhaka, requires special attention. The rate of population growth in the city is estimated to be the highest in the world (McClean *et al.*, 1997), and the urban population in Dhaka is projected to create a demand of 700 Mm^3/year of water, against a supply of 300 Mm^3/year (World Bank, 1996). Of the total current supply, groundwater constitutes 98 percent of the supply, and the remaining 2 percent comes from surface water. Scarcity may arise because of mining of groundwater caused by over-pumping.

2.3.3 Water Balance

Changes in water supply and demand caused by climate change will be overlaid on top of changing water use due to growths in both population and income. Currently Bangladesh withdraws 22,500 million m^3 of water (WRI, 1998). According to the MPO (1991), the total requirement for water consumption in 2020 will be 24,370 million m^3, and supply will be 23,490 million m^3. Thus, there would be a shortage of 880 million m^3. Agriculture is estimated to constitute 58.6 percent of demand; navigation, salinity and fisheries 40.7 percent, and municipal and industrial demand will be only 0.7 percent. It is also estimated that on a yearly basis, about 77 percent of water supply comes from surface water sources.

Although monsoon availability of water will increase under climate change, it is highly likely that the winter water availability will decrease, and more water will be required for irrigation in winter. Keeping the projected shortfall in mind, one may infer that irrigation will be more dependent on groundwater withdrawal. While the ground water is fully replenished every year, the availability of (shallow) groundwater in the dry season is finite. Under such a condition, it would be quite difficult to control salinity intrusion, to keep navigational routes functional, and to ensure environmental and ecological harmony in various places -- especially in the Ganges, Atrai and Teesta dependent areas of the country.

2.4 Impacts on Agriculture

Agriculture is a major sector of Bangladeshi economy, providing about 22 percent of total GNP. Perhaps more important is the fact that almost two-thirds (65 percent) of the labor force is employed in agriculture (Faruquee, 1998). Rice is by far the major crop in Bangladesh. In 1992-1995, average annual production was 18 Mmt. In contrast, only 1.2 Mmt of wheat was produced annually in the same period (BBS, 1998).

Farmers in Bangladesh are quite poor, even in comparison with its neighboring countries. The average size of farms is very small. A recent estimate shows that over 70 percent of farm families have less than 1.0 hectares (2.5 acres) and 80.3 percent has less than 2 ha (5.0 acres) land. The farms are undercapitalized, and lack the usual inputs of quality seed, fertilizer, pest control etc. (Ahmad and Hasanuzzaman, 1998). In addition, Bangladeshi farmers have little mechanized agricultural tools. For example, in the early 1990s, there were 5,300 tractors in Bangladesh, whereas Pakistan with about twice the area for agriculture had more than 54 times the number of tractors (WRI, 1998).

Published sources on the effect of climate change on rice yields tend to show minor negative to positive effects at low temperature changes associated with slight CO_2 fertilization effect. For example, Karim *et al.* (1996) estimated that an increase of 2°C with unconstrained water supplies (no moisture stress) would increase rice yields only slightly.[14] A temperature increase of 4°C (higher than projections for 2050) results in mixed yield changes. Rice yields for 2020 and 2050 were calculated based on the results of Karim *et al.* (1996) and assuming no moisture stress, and relatively strong CO_2 fertilization effect. The results, presented in Table 2.4, show a small positive change in yields.[15] Wheat yields are projected to decrease at both temperature changes, even with optimistic assumptions on the CO_2 fertilization effect.

Table 2.3: Percent Change in Rice Yields (Chittagong)

Scenario	Aus	Aman	Boro
2020: +0.7°C; 410 ppm CO_2	+3	+2	+4
2050: +1.5°C; 510 ppm CO_2	+9	+4	+11

Notes: Calculations are based on Karim *et al.*, 1996, but without considering moisture stress.

Previous agricultural yield estimates were based on information published on the positive effects of higher atmospheric carbon dioxide levels on plant growth at the time the studies were carried out. Recent analyses have shown that increased CO_2 levels essentially help to attain higher leaf-area index, and do not contribute to increased rice yields (Abrol, 1998). These results have supplemented the findings of Walker and Steffen (1997). It may be too early to come to a conclusion regarding the direct effects of climate change on food-grain production. There are, however, indirect effects in relation to induced changes in floods and salinity.

At present, western parts of Bangladesh are periodically being affected by droughts in winter months (see also Box 2.2). Since the temperature will rise, and there exists a strong possibility that the winter precipitation will decrease further, it is likely that the moisture content of topsoil would decrease substantially leading to severe moisture stress. Higher temperature would, furthermore, induce higher rates of evapo-transpiration leading to acute (phenological) drought conditions in winter months. Consequently, a late Kharif II drought in December would adversely affect Aman crop at the ripening stage, while an early Rabi drought would more severely affect wheat and Boro crops at both germination and vegetative growth stages (Karim *et al.*, 1998). Furthermore, increasing moisture stress in early Kharif I would affect Aus production significantly. Increased drought will increase capillary action and salinity build up in the top soil as well. Detailed processes of salinity build up are explained in Karim *et al* (1990).

On an average year, increased salinity not only causes a net reduction of about 0.2 Mmt of rice production, but also diminishes potentials ofBoro and wheat cultivation in saline affected soils of the coastal areas. With the possibility of increasing soil salinity under climate change scenarios, it is highly likely that food-grain production in those areas would be extremely vulnerable. It is reported that, the effect of soil salinity on Aus production would be detrimental, and Aman, when grown under a severe climate change scenario, could also suffer over two-fold yield reductions (Habibullah *et al.*, 1998).

[14] Lal *et al.* (1998a), however, found that rice yields would decline 5 percent under a 2°C warming and a CO_2 doubling, and that wheat yields would increase substantially.

[15] It should be noted that these results assume a relatively strong CO_2 fertilization effect. With assumptions of a smaller CO_2 effect (based on Walker and Steffanee, 1997), there would be a small decrease in yields

Together with the possible reduction in Aman rice area (as a result of greater spread of flood waters, and longer duration of flooding) and a reduction in the Boro rice area (which will be limited by available surface and groundwater for irrigation), the total area suitable for rice production may in the future stagnate or possibly decrease.

Another influence on the total available area for agriculture is that: climate change is expected to disturb the sediment balance. It is difficult to forecast whether there will be net accretion or erosion. However, it is important to remember that newly accreted land along the coast may take up to 15 years to develop full production potential, whereas land lost to erosion is in most cases valuable agricultural land. Despite this fact, average accretion in Bangladesh is close to one thousand hectares per year of valuable agricultural land. At present this land is 'state-owned'. A coherent land use policy with appropriate support services (for example, access to information) for this state-owned land is urgently needed to avoid (the often illegal) settlements before the soils have developed their full productive capacity.

Floods affect agricultural production significantly. The 1988 flood caused reduction of agricultural production by 45 percent (Karim *et al.*, 1996). Similarly, Aman production potential of some 2 to 2.3 Mha could not be realized due to the devastating floods in 1998, that lasted for about 67 days. Since seedlings could not be planted in the flood affected areas, the resulting estimated shortfall of foodgrain production exceeded 3.5 Mmt. Higher discharge and low drainage capacity, in combination with increased backwater effects would increase frequency of such devastating floods under climate change scenarios. Prolonged floods would tend to delay Aman plantation, resulting in significant loss of potential Aman production, as observed during the floods of 1998.

Considering all the direct and induced adverse effects of climate change on agriculture, one may conclude that crop agriculture would be even more vulnerable in Bangladesh under a warmer world.

2.5 Impact on Human Health

Human health conditions in Bangladesh is quite poor. Average life expectancy is 58 years, which is lower than in its neighboring countries. Two-thirds of children under five are underweight in the country, and infant mortality rate is 78 per thousand, three times higher than the average for all of Asia (WRI, 1998). Major health hazards are communicable diseases (cholera, dysentery, diarrhea, measles, tetanus etc) caused by poor nutrition and sanitation status. Prevalent parasitic diseases include malaria, dengue, filariasis, and helminthiasis. Most diseases are found in rural areas (Heitzman and Worden, 1989), where access to health care is limited. There is only one doctor for every 12,884 people and one nurse for every 11,549 people. Ratio of individuals to doctors deteriorated between the early 1980s and the early 1990s. Only 48 percent of the population has access to adequate sanitation (WRI, 1998).

Existing literature does not provide an assessment of climate change impacts on human health in Bangladesh. Although there is a significant seasonal variation in temperature ranging from 10 to 38°C, heat stress mortality may be observed among elders, especially during mid-April and mid-August. Due to high temperature and humidity, the elders and malnourished children will face dehydration related problems. A temperature increase of 1~2°C would perhaps not cause a significant change, but higher intensity of extreme events (patches of very hot days etc.) may intensify heat stress and associated health hazards.

There are some indirect implications of climate change to human health. It is reported that elevated temperatures would create favorable conditions for vector-borne pathogens (McMichael *et al.*, 1996) and directly influence prevalence of vector-borne diseases. Bangladesh is already exposed to diseases such as malaria and dengue. Many people suffer from malarial diseases each year. Salmonela is a common pathogen that causes large-scale outbreaks of typhoid fever in most parts of Bangladesh. Warmer and wetter conditions would increase the prevalence of such deadly diseases.[16] A study on the number of weeks in a typical year in which dengue could be transmitted in Calcutta, India, found that the length of the period could increase from 44 weeks a year to all year long under a 2°C warming (Jetten and Focks, 1997). Since the general weather and environmental conditions of West Bengal and Bangladesh are similar, a similar change might be observed in this country.

Mosquito is a menace almost everywhere in Bangladesh. It is also a common vector for the malaria parasite. Stagnant and filthy water bodies are the best breeding grounds for mosquitoes. Since higher temperature and prolonged rainless days during January and February help reducing water volumes in standing water bodies, problems associated with mosquitoes are at its peak during winter months. Under climate change, higher prevalence of mosquito-borne diseases can be expected.

Effect of climate change on other sectors could adversely influence the health situation in Bangladesh. Floods increase the risks associated with diarrhea and cholera -- diseases also associated with high temperatures (Colwell, 1996). Any adverse impact on food production systems would increase the risk of further malnutrition. Increases in the number of tropical cyclones, or flood intensity, or frequency could pose additional risks to human life.

2.6 Impacts on Ecosystems and Biodiversity

The potential risks of climate change to ecosystems, such as the Sundarbans, and to species diversity (including forests and fisheries issues) are addressed in this section.

Sea level rise poses a severe threat to the Sundarbans. A possible 45 cm sea level rise by the year 2050 could inundate 75 percent of the Sundarbans (Qureshi and Hobbie, 1994). While the sea level rise may be counterbalanced by natural uplift, the extent of uplift is highly uncertain. It is also reported that, climate change induced higher evapo-transpiration, and low flow in winter would increase salinity. As a result, growth of fresh water loving species would be impaired. Eventually, the species offering dense canopy cover would be gradually replaced by non-woody shrubs and bushes. It is also feared that the overall productivity of the forest would decline significantly (Ahmed, 1998a). Once the quality of the forest is degraded, one may conclude that the rich diversity of forest flora and fauna would also face degradation in a warmer world.

The Sundarbans is home to the Royal Bengal tiger as well as marine turtles, crocodiles, frogs, and fresh water dolphins. With the loss of the Sundarbans, habitat for these species would also be lost. Whether these valuable species could survive elsewhere is not known.

[16] One of the more acute risks from climate change is that the potential range of infectious diseases such as malaria and dengue will spread to high altitude and higher latitude areas that are currently not at significant risk of outbreak of these diseases (Martens *et al.*, 1997).

The Royal Bengal Tiger finds its Home in the Sundarbans

Official estimates reveal that about 17.8 percent of the total land in Bangladesh is currently covered by forests and woodlands (BBS, 1997). However, the area under forest cover is shrinking rapidly due to over exploitation of forest resources and gradual conversion of forest lands for other uses. Results of available studies of climate change impacts on vegetation are inconclusive. In Neilson (1998), the IPCC reports that under some scenarios of climate change for late in the 21st century, Bangladesh would remain a savanna/woodland, whereas under other scenarios, conditions would become wet enough to support tropical broad-leaf forests (such as those now found in Assam and Meghalaya). The modeling results are inconsistent on whether the density of vegetation will increase or decrease. Studies on vegetation changes in Bangladesh under scenarios corresponding to the first half of the next century are not available. It is, however, reported that climate change induced additional flooding would adversely affect the *Artocarpus* species (Ahmed *et al.*, 1998a) especially *Artocarpus heterophyllus* (jackfruit, the tree bearing the national fruit of Bangladesh). Similarly, other flood vulnerable species including *Azadirachta indica, Cajanus cajan, Leucaena leucocephala* would be affected. It is also expected that the Sal forest ecosystems in the Madhupur and the Barind Tract areas would face additional moisture stress. Further water stress due to increased groundwater demand for irrigation would have compounding effects on the regeneration process of the species in those areas. Tea production in the Sylhet region might also decline due to uneven rainfall in winter and due to extreme weather events.

Bangladesh contains 18 threatened species of mammals, 30 threatened bird species, and 24 threatened plant species (WRI, 1998). A change in climate could lead to the extinction of these specie, although such risks have not been assessed for the country. Sea level rise may inundate the habitat of many of these specie, whereas drier conditions could reduce moisture supplies. Huq *et al.* (1996) concluded that the Haor wetlands would also be at risk from climate change.

Bangladesh has a relatively large fishing industry. During 1993-95, the country annually produced 250,000 metric tons of fresh water fish from aquaculture. During that period, a total of 713,000 metric tons of fresh water fish and 389,000 metric tons of marine fish were caught (WRI, 1998). Fisheries is also one of the important sectors for Bangladeshis in terms of supply of protein and foreign exchange earning. More than 80 percent of the animal protein intake of Bangladeshis comes from the consumption of fish.

Impact of climate change on the fisheries sector of Bangladesh has not been researched well. Ali (1998b) attempted a speculative assessment that revealed that fish growth and production might face some adversities under climate change. Low-flow conditions in the winter would reduce wetland areas and might cause declining fish stock in the remaining wetlands. Sea level rise could also push saline waters further into the GBM delta, reducing habitat for fresh water fish. Increased water temperature could cause reduction in the concentration of dissolved oxygen, thereby decreasing the habitat suitability for the fish, especially for the hatchlings. As mentioned earlier, figure 2.7 shows how solubility of oxygen in fresh water decreases with increased temperature. Increased risk of cyclone induced storm surges in the coastal areas would reduce fisheries activities including culture fisheries.

2.7 *Indication Impacts for Climate Change*

Table A-1
Sea Level Rise Impacts

Sea Level Rise	Land below sea level	Storm Surge	Salinity
2020 — 10 cm	2% of land = 2,500 km^2.		Increase
2050 — 25 cm	4% of land = 6,300 km^2.	1991 cyclone happens again with a 10% increase in intensity, wind speed increases from 225 to 248 km/h; storm surge, with 0.3 m SLR, goes from 7.1 to 8.6 m	Increase
2100 — 1 m (high end estimate)	17.5% of land = 25,000 km^2. Patuakhali, Khulna, and Barisal regions most affected.	Storm surge, with 1 m SLR, goes from 7.4 to 9.1 m.	Increase

Table A-2
Water Resources

Scenario	Runoff	Flooding	Drought
Current Climate	During monsoon, rivers flow at 140,000 cm/sec; dry season, 7,000 cm/sec.	60% of country is flood prone; 20% of land inundated in normal years. 1988: 60% of land inundated. 1998: 70% of land inundated	A severe drought can affect yield production in 30% of the country, reducing national production by 10%.
2020	Based on Mirza and Dixit (1997), a +0.7°C increase in average temperature results in a +7% increase in annual precipitation (a mid-range scenario for 2020) and increased runoff in the Ganges, Brahmaputra, and Meghna of 17%, 12%, and 9% respectively.	5% increase in rainfall results in a 20% increase of areas subject to flooding in average year.	Mirza and Dixit (1997) calculated that +0.5°C, -5% annual precipitation (the driest scenario identified for 2020) *reduces* runoff in the Ganges, Brahmaputra, and Meghna by 14%, 11%, and 8% respectively. Under 12% reduction in runoff, percent of population living in severe drought-prone areas goes from 4% currently to 9% under moderate CC (discharge of rivers decrease by 12% in winter).
2050	Based on Mirza and Dixit (1997), a +1.5°C temperature rise results in +12.5% annual precipitation (a mid-range scenario for 2050) and increased runoff in the Ganges, Brahmaputra, and Meghna by 29%, 19%, and 16% respectively.	Flooding increases, With 10% increase in rainfall, probability of extreme wet year increases sevenfold 20% increase in flow decreases return period for 55,000 m^3/s from 2.54 years to 1.26 years; i.e., probability of this magnitude flow in a year changes from 39% to 79%. Sea level rise could increase flooding in Meghna and Ganges floodplains.	Droughts increase, Probability of dry year, such as 1972, increases 4.4 times Based on Mirza and Dixit (1997) +1.3°C, -9% precipitation (driest scenario for 2050) *reduces* runoff of Ganges, Brahmaputra, and Meghna rivers by, respectively, 27%, 21%, and 15%. If runoff drops 22% in Kharif season, drought-prone areas switch from just NW to central west and SW. No wheat cultivation in south central and SW.

Table A-3

Agriculture

Scenario	Crop Yields	Sea Level Rise	River Flooding
Current Climate			In 1988, yields were down 45% because of flooding.
2020	Based on interpolation of published data to be consistent with climate change scenarios; rice yields have increases of up to 5%. With less optimistic assumptions about the CO_2 fertilization effect, generally have yield change -5% to +1%.	Based on interpolation, a 0.1 m SLR would inundate 0.2 MMT of production < 1% of current total.	Monsoonal floods increase yield loss.
2050	Based on interpolation of published data to be consistent with climate change scenarios; rice yields have increases of up to 10%. With less optimistic assumptions about the CO_2 fertilization effect, generally yield changes from few percent increase to 10% decrease. Pests and crop disease could reduce yields further.	0.3 SLR inundate 0.5 MMT of production ~ 2% of current total.	Monsoonal floods increase yield loss.

Table A-4
Human Health

Climate Change (warmer and wetter)	Indirect Effects
Potential increase in heat stress mortality. Change in distribution and increase in period when disease can be transmitted for malaria, dengue, bilharzia, leishmaniasis, and schistosomiasis.	Schistosomiasis spreads with irrigation (contrary to popular belief, some cases of the disease have been recorded in the country under climactic conditions). Drought and floods facilitate transmission ofdiarrheal diseases (e.g., cholera).

Table A-5
Ecosystems

Climate Change	Potential Impacts
Sea Level Rise	Interpolation: 10 cm SLR inundates 15% of Sundarbans. Interpolation: 25 cm SLR inundates 40% of Sundarbans. 45 cm SLR inundates 75% of Sundarbans. Interpolation: At 60 cm, Sundarbans would be lost. 1 m SLR, Sundarbans would be lost. Species like sundri (*H. fomes*), main economic species in Sundarbans, would be replaced by less valuable goran (*ceriops decandra*) and gewa (*E. agollocha*). Also affects *Excoecaria agallocha* (moderately saltwater zone) and *Ceriops decandra* (saltwater zone) specie. Human habitation possibly prevents inland migration. Loss of the Sundarbans and other coastal wetlands would reduce breeding ground for many estuarine fish, which could reduce their population. Sea level rise would result in saline waters moving farther into the delta. This would reduce the habitat for freshwater fish, although it could increase the habitat for estuarine fish.
Warmer and Wetter	Effects are generally uncertain. Increased runoff could increase pollutantloadings in rivers, possibly harming fish. If additional flood protection measures are taken (such as expanding embankments), there could be additional negative effects on fish.
Warmer and Drier	Reduced runoff combined with higher water temperatures and reduced dissolved oxygen levels could harm fisheries. On land, warmer and drier conditions would adversely affect plants and animals needing moisture.

Climate Change Adaptation in Bangladesh

Victims of Climate Related Disasters Waiting for Relief

Discussions in chapter two show that Bangladesh is highly vulnerable to climate change. Faced with the indicated impacts, the next issue is: whether and how Bangladesh can adapt to those changes. This chapter is divided into two segments: the **first** part (3.1) is shorter. It presents: i) a brief overview of how one can think about adaptation to climate change, ii) identifies four key threats (critical impacts) to the greater goal of sustainable development, and iii) describes some of the socio-economic causes of vulnerability to climate change, such as level of development, and examines how different development paths may affect the country's ability to cope with climate change.

The **second** part (3.2-3.7) of the chapter describes possible measures and policy changes for Bangladesh that could be used to adapt to climate change. Such adaptations should be considered complementary to the efforts for sustainable development, aiming to protect the country's natural resources and environment by *reducing its vulnerability to climate change.*

More specifically, sections 3.2-3.6 are organized by the sectors identified in Chapter 2: *coastal resources, fresh water resources, agriculture, human health, and ecosystems / biodiversity.* Key risks for climate change in each of these sectors are summarized separately, and more specific adaptation possibilities are sketched out. In this context, tentative assessment on the effectiveness and feasibility of possible adaptations per sector are provided, and limitations in implementing the identified adaptations are briefly discussed. While specific adaptations remain tentative, the study aims to provide directions on how the potential effects of climate change and adaptation options can be factored into policy making. Specific examples are given, that cannot be the solution in themselves, but can be part of a strategy to deal with the impacts of climate change. Thus, the study tries to identify strategic adaptations to climate change for policy makers and aims to give a practical demonstration of adaptation measures that could become part of a worked out strategy.

Strategic crosscutting adaptations are presented in section 3.7. These adaptations will affect a number of sectors at a time; they refer to: *coordinated institutional response*, *information management and dissemination,* and *international activities.*

Overall, this chapter covers many key risks and possible adaptations. These are written to help stimulate thinking among development and other experts, climate sensitive sector planners in the GOB, the Bank, and the rest of the donor community. The chapter shows that there are feasible ways to adapt to climate change. What is important to remember is: climate change should be a consideration when development and other decisions that affect the capacity of climate sensitive systems to cope with this phenomenon are being made. The lesson of the climate change(CC) threat for Bangladesh is not that costly adaptations have to be introduced to deal specifically with CC. However, there are compelling reasons as well as possibilities to reduce the country's vulnerability to the future and current threats of climate change (including fresh water availability, drainage, floods and coastal storms). This process should begin immediately.

3.1 Why Adaptation is Needed in Bangladesh?

Those involved in planning and decision making to overcome problems with poverty, health, education, and environment in Bangladesh may wonder whether it is worth diverting any financial resources to adapting to climate change. However, there are several strong reasons to adopt an *anticipatory* rather than a *reactive* strategy. These include (Smith, 1997):

- *Some impacts of climate change are gradual, long term and may be irreversible.* Changes in long term trends may lead to deaths, species extinction, or loss of valuable ecosystems, which cannot be reversed. Anticipatory measures strive to ease or change these trends.
- *Some impacts of climate change increase the intensity of extreme events, such as cyclones and floods.* While reactive measures are used to respond to the latest events, anticipatory measures would mainly aim to increase the effectiveness and efficiency of such reactive measures.
- *Long-term performance of some decisions and investments may be affected by the impacts of climate change.* Major infrastructure works such as dams are designed to last several decades. If their design does not take climate change into consideration, their effectiveness in providing services might be under stress in the future.

These reasons therefore relate to two types of impacts: (i) gradual long term changes; and (ii) changes in the frequency and intensity of extreme events. Anticipatory measures to adapt to these types of changes will have to be taken in a very different context. While Bangladesh is already suffering from major extreme events, and is relatively well-equipped in disaster response (with the continuous process of improving on its capacity to mitigate the impacts of cyclones and riverine floods etc), the country lacks the capacity and mechanism to account for long term changes. There remains a serious lack of real time data in monitoring and preparing for these events. Given the overriding importance of the coastal and water resources in the development of Bangladesh, such vulnerability remains a key threat to the country's potential for sustainable development.

Table 3.1: Sectoral Needs for Anticipatory Measures in Bangladesh

Impacted sectors and key issues	**Are anticipatory measures needed because of:**	
	Long term changes and irreversible effects	**Increased intensity of extreme events**
Coastal resources		
Drainage congestion	Y	
Saline water intrusion	Y	
Coastal morphology	Y	Y
Storm surges		Y
Water resources		
Flooding		Y
Drainage congestion	Y	
Droughts and low river flows	Y	Y
Sedimentation of flood plains	Y	
Erosion and sedimentation	Y	Y
Water balance	Y	
Agriculture		
	Y	
Public health		
	Y	Y
Ecosystems / biodiversity		
	Y	

Table 3.1 (a repeat of section III in the Executive Summary) gives an overview of the importance of both types of changes for risks facing the various sectors. For example, anticipatory measures in the coastal zone are needed because of long term changes in the drainage congestion, saline water intrusion, and coastal erosion and accretion processes, while an increased intensity of extreme events plays an important role in morphological processes and storm surges. Climate change impacts on agriculture, public health and ecosystems/biodiversity, are mainly of concern because of their long term changes and related irreversible effects.

The table shows the relative importance of long term changes on the prioritized sectors. For its development in the near future, Bangladesh will make important decisions on major investments. Expected long term performance of these investments provides a strong reason to account for impacts of climate change. For example, in addition to the proposed Ganges Barrage, the Brahmaputra Right Bank Protection, the Coastal Embankments and the Padma Bridge, and other similar investments may be related to the expected development of the energy sector in the coastal zone.

Box 3.1.1 Critical impacts of Climate Change in Bangladesh: The study identified the following critical impacts that Bangladesh will face, and which are the key justification for anticipatory adaptation measures.

▲ ***Drainage congestion problem*** will be a major impact of climate change. The combined effect of higher sea water levels, subsidence, siltation of estuary branches, higher river bed levels and reduced sedimentation in flood protected areas will gradually increase drainage and water logging problems, and impede drainage. This effect will be particularly strong in the coastal zone, but will also be felt in riverine flood plains further upstream. The problem will be aggravated by the continuous development of infrastructure (e.g. roads) reducing further the limited natural drainage capacity in the delta and the flood plains. One of the key effects of drainage congestion is that it will increase the period of inundation, and will expand wetland areas. This may hamper agricultural productivity, and also threaten human health by increasing the potential for water borne diseases and holding back food production. Drainage congestion will thus affect several sectors including agriculture, and human health[1].

▲ ***Reduced fresh water availability*** will become a serious constraint to development due to growing demands stimulated by climate changes (through increased evapo-transpiration), population growth and economic development. Low river flows and increased evapo-transpiration in the dry period will reduce the availability of fresh water. In the coastal zone, the additional effect of saline water intrusion in estuaries and into the groundwater stimulated by low river flow and sea level rise will be significant. [2]Pressure of the growing population and economic development will result in over-abstraction and salinization of groundwater aquifers, and further reduce fresh water availability.

▲ ***Disturbance of morphological processes*** will also become a significant problem under climate change. Bangladesh' riverine and coastal morphological processes are extremely dynamic, partly because of the tidal and seasonal variations in river flows and run-off. Climate change is expected to increase these variations, with two main (related) processes involved:
(i) *Increased bank erosion and bed level changes of rivers and estuaries.* Theory suggests an exponential increase in morphological activity with increased river flow, implying that bank erosion might substantially increase in the future. Experience with the latest severe floods in Bangladesh support this prediction. Yearly erosion of river and coastal banks incurs the loss of valuable land and homesteads of hundreds of thousands of people, which is not fully compensated by the accretion of new land.
(ii) *Disturbance of the balance between river sediment transport and deposition in rivers, flood plains and coastal areas.* Disturbance of the sedimentation balance will result in higher bed levels of rivers and coastal areas, which in turn will lead to higher water levels. Continuous protection of rural areas against inundation will further reduce the sedimentation in the flood plains, which might increase both the river bank erosion and the drainage congestion / risks for flooding.

▲ ***Increased intensity of disasters (extreme events)*** including cyclones/storm surges, floods and droughts will become evident with climate change.[3]Though the country is relatively well equipped in one aspect of disaster management i.e. disaster response, there remains a serious lack of real time data (especially in terms of lead time) in monitoring and preparing (through proper dissemination) for these events. Additionally, increased intensity of the disasters imply major constraints to the country's social and economic development. The study shows that Bangladesh is particularly vulnerable to climate change in its coastal zone, covering about 30 percent of the country. Private investment in this area is likely to be affected by the risks of cyclones and increased flooding.

Box 3.1.1 above presented a summary of the four identified key threats (critical impacts) to the social and economic development of the country. Three of them: drainage congestion, fresh water availability and morphological dynamics are related to the availability of land and water resources. Disasters refer to an increased intensity of storm surges, floods & droughts, and have a

1 There may be some benefits for fisheries, for *Boro* production etc however the net affect, and whether they outweigh the dis-benefits (aman crop loss, health affects), and cover the equity concerns remains highly questionable

2 Groundwater recharge and surface storage could improve increasing availability in some areas particularly in the late monsoon and early rabi seasons. However, higher E-T will increase water use, which calls for increased water use efficiency.

3 Scientists from SPARSSO support this school of thought

major impact on the people living in affected areas and on the prospects for overall economic development.

The critical impacts actually combine different effects of climate change, and are generally not linear with, for example, an increase in sea level, or a reduction in the amount of precipitation in the dry period. To illustrate, chapter two stated that small changes in peak discharge might result in about 20% increase in area flooded and in a manifold increase in the probability of an extremely wet year. All these impacts combined -- may develop into really disastrous conditions. Examples refer to: the combination of more intense storm surges and higher sea water levels; higher sea levels which hamper drainage and at the same time increase siltation of tidal channels further hampering drainage; and low river flows from upstream which reduce the fresh water availability and at the same time strongly enhance salt water intrusion (further driven by sea level rise), leading to a dramatic development of salinization of surface and groundwater.

Vulnerability to the effects of climate change, and in particular for the mentioned long term issues, threaten the country's potential for sustainable development. It should be emphasized that rather than being mutually exclusive, adapting to climate change should be part of and complementary to a sustainable development strategy. This is discussed in more detail in Appendix A.

3.1.1 Problems Facing Anticipatory Adaptation

As mentioned earlier, disaster management in the country focuses on reactive management and not on anticipatory measures. The need for disaster oriented anticipatory measures and the required focus on long term changes meets special institutional and technical problems.

1. *Proper attention to long term issues requires well defined planning structures and procedures.* Many development activities aim at quick yielding results to meet the immediate needs of the growing population. This mechanism is enhanced through project oriented donor funding. Long term concerns with respect to sustainable use of water and land resources is typically the responsibility of the national government. However, Bangladesh lacks the institutional, planning and decision making structure to carry out this function. Donor involvement is also less effective in this respect since their involvement responds to donors' political priorities which tend to focus on visible results within limited political time horizons.

   Another important bottleneck is: planning agencies have not been created by law, but by administrative decision. Thus, planning in Bangladesh is not mandatory, and bureaucratic inefficiencies hamper the decisiveness of institutional systems in Bangladesh. Therefore, planning and implementing development schemes often prove to be problematic.

2. *Management of resources requires integration.* Related to the above is Bangladesh' focus on project planning instead of resource planning. Long term changes mainly affect the availability of resources. Integrated management is required to account for such changes with appropriate coordination of all management agencies involved. Bangladesh is poorly equipped in this respect, and developments in this direction are only at an initial stage.

   Possibilities for *integrated water resources management* are enhanced by the recent establishment of a National Water Council, the formulation of a National Water Policy and the specification of responsibilities of the Water Resources Planning Organization (WARPO).

   Coastal resources management is another area that remains fractionated. Coordinated efforts for integrated management in the past resulted in useful studies but the recommendations were not implemented. A new Integrated Coastal Zone Management (ICZM) approach, coordinated by the Ministry of Water Resources and supported by the

World Bank, seems more promising especially since institutional issues receive more attention (ICZM, 1999).

Integrated environmental management is a difficult issue in many countries, and it can not be expected that Bangladesh, which only recently started with concerted actions in this respect, will have an effective environmental management structure in the near future. The Ministry of Environment is now in a process of being strengthened through the implementation of the National Environmental Management Plan (NEMAP, 1995).

With respect to *land use planning*, the report on the issues for the National Water Management Plan states (WARPO, 1999): "physical planning capacity in Bangladesh is weak, and the last attempt to look at national planning issues, and those for major urban areas, date back to 1985 or earlier." Physical planning should be at the basis of any resource oriented planning as it defines, and depends on the spatial distribution (and intensity) of the use of the land and water resources.

3. *Adaptation needs coordination between central and local levels of management.* Bangladesh' system of planning and management is strongly centralized. Adaptation to long term changes will require a combination of measures on a national level, and changes in behavioral patterns on a local level. The need for this "vertical" integration is widely recognized, and steps are being taken to establish sustainable local institutional arrangements. When established, these arrangements could spearhead the implementation of climate change related policies. Moreover, government organizations are sometimes found reluctant to work together with CBOs, NGOs and local beneficiaries of a project. This attitude can considerably affect projects that are designed to promote changes in land use through participation of end users and beneficiaries.

4. *Traditional planning techniques are inadequate.* Planning which would account for adaptation to climate change faces at least two methodological problems. First, impacts may not occur in the near future (i.e. within the next decades), and thereby would be beyond the normally adopted planning horizons for intervention. Second, uncertainties about changes in the regional climate and the corresponding impacts are still significant.

5. *Awareness with planning agencies and the public is still low.* Previous studies on the effects of climate change in Bangladesh (e.g.: BCAS/RA/Approtech, 1994) following the IPCC (1992) conference had drawn political support. In Bangladesh, an Interministerial Government Review Committee on Climate Change was established, but this initiative has slowly faded and public awareness on the issue is still low.

6. *Information* about climate change related issues is *scattered* and sometimes *difficult to access*. Policy and development planning depends on accessible accurate information and on coordinated research. However, the required political focus to establish a knowledge base for climate change is missing.

3.1.2 Possibilities for Adaptation to Climate Change in Bangladesh

The goal of anticipatory adaptation measures is to reduce vulnerability by: i) minimizing the negative impacts of climate change, or ii) enabling reactive adaptation to come about more efficiently. Reducing vulnerability is directed towards making the system (both resources and users) more robust and flexible to changes. A system is **robust** if it continues to function under a wider range of conditions. For example, building larger flood protection works would enable a system to withstand a greater flood. A system is **flexible** if it quickly repairs or adapts itself. For example, lifting price support on crop production could induce farmers to switch crops more rapidly in response to climate change (Lewandrowski and Brazee, 1993). Additionally, institutional arrangements in place for planning and management ensure timely anticipatory actions.

A country's vulnerability to climate change depends also on its level of development. Generally a poor country has:

- fewer financial resources to cope with climate changes;
- its population is less "educated and technically competent" to understand changes in practices or new technologies necessary to cope with climate change (the quality of information dissemination and research network will also be of poor standard).
- less healthy population, and inadequate health care system--making people more vulnerable to extreme events and outbreaks of diseases.

To conclude, however, that only social and economic development would make the country less vulnerable to climate change, is too simple or even a wrong conclusion. For example, continuous investments in infrastructure and industrial developments could all the same lead to an increased vulnerability to extreme events, or to salt water intrusion. An important aspect of development is of course the level of awareness and the financial possibilities to implement adaptation measures. However, without adequate institutional arrangements, these aspects would not necessarily contribute to reduced vulnerability.

This study aims to focus on concrete and practical possibilities to decrease the country's vulnerability to climate change by distinguishing the following types of adaptation measures.

7. *Adaptations of climactic factors* such as negotiating water sharing arrangements and participating in international deliberations on the mitigation of greenhouse gas emissions.
8. *Physical adaptations* (protection and enhancement) in the human made or natural systems, such as: planting of mangroves, raising of dikes, construction of tidal basins.
9. *Institutional adaptations* would facilitate the various types of adaptation. These may also include socio-economic measures such as changing the use of resources through non-structural measures, such as, crop diversification and sustainable shrimp cultivation, changing planning procedures and increasing awareness level etc.

Who Should Adapt

The identified measures would involve a range of possible actors. International committees are already involved in discourse on greenhouse gas emissions, while scientific organizations on both international and national levels could conduct research on new crops, or on regional climate changes. Physical adaptations can be implemented on national, regional and local levels, while institutional adaptations tend to relate strongly to those levels as well as individual behavior of e.g. farmers or industrial companies.

In general, reactive measures dominate on the individual level while more aggregated levels (national, international) seem better equipped for planning approaches. This implies that the focus for the introduction of anticipatory measures would first be on national planning organizations. These organizations can be reached through development plans/activities such as the Integrated Coastal Zone management plan, or the Agricultural Research Management Project. In contrast, public awareness building is more appropriate in changing behavioral patterns on an individual level.

3.1.3 Identification and Selection of Adaptation Measures

A process is proposed (based on Smith, 1997) for analysts to use in identifying policy areas where adaptation to climate change could and should be considered by i) identifying options for anticipating climate change, and by ii) distinguishing which of these policy areas are most in need of anticipatory adaptation. The following steps are recommended:

1. *Analyze the Sensitivity to Climate Change*

   The first step is to analyze the sensitivity of sectors to climate change. The assessments should identify whether climate change could cause significant negative impacts. If a sector appears not sensitive to climate change, policymakers should move on to the next step. If a sector appears to be insensitive to climate change, policymakers could study other sectors they operate in, or need not proceed any further. This report does not address methods for assessing climate change impacts, but the IPCC's *Technical Guidelines for Assessing Climate Change Impacts and Adaptations* (Carter et al., 1994), the U.S. Country Studies Management Team's *Guidance for Vulnerability and Adaptation Assessments* (Benioff et. al., 1996), and the UN Environment Programme's *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies* (Feenstra et al., in press) could be consulted for guidance on methods to assess climate change impacts.

2. *Select High Priority Sectors*

   If a sector is sensitive to climate change, policymakers should examine whether it should be given priority in anticipating climate change. Priority should be given if: climate change could result in irreversible or catastrophic impacts, current trends make adaptation more difficult, or decisions are for the long term. If high priority anticipatory adaptation is justified, policymakers should proceed to the next step. If not, they should examine other high priority areas under their jurisdiction.

3. *Analyze Current Policies on Climate Change*

   The next step is to analyze whether current policies are flexible enough to allow for adaptation to climate change in a cost-effective manner. To do this, one should first identify the objectives of current policies. If analysis of the current policy shows that their effectiveness is reduced under climate change, alternative policies are examined.

4. *Examine the Relative Effectiveness of Anticipatory Adaptation Policies*

   The final step is to analyze whether alternative policies are more effective in meeting the policy objectives under current climatic conditions, and under climate change. A number of tools are available to analyze the effectiveness or relative effectiveness of anticipatory adaptation policies. Among them is benefit-cost analysis (e.g., Smith et al., 1997), which has the advantage of assessing whether a project's benefits are greater than its costs, but has the disadvantage of the difficulty in application. Another option is cost-effectiveness analysis. Adaptation Decision Matrix (ADM; Smith et al., 1996) enables users to subjectively assess benefits of adaptation policies and compare the results to costs. Another methodology is developed in BCAS/RA/Approtech, 1994, which develops a quantitative comparative indicator representing changes in vulnerability.

3.1.4 Assessment of Adaptation Measures

The study finds that adaptation measures should be tested and prioritized on their cost-effectiveness rather than on their cost-benefit relations. Any cost-benefit analysis will be complicated by the fact that the climate changes and their impacts are expected to occur gradually, and might emerge only after a long period which make them "negligible" in traditional economic terms (that aim at short term benefits). Cost-effectiveness should be broadly interpreted with the objective of prioritization of anticipatory adaptation measures. The following general framework of main criteria will be used:

- *Effectiveness* to reduce the vulnerability of key sectors through the reduction of key risks (drainage congestion, lower fresh water availability, morphological dynamics, and more intense disasters). This aspect suffers from the methodological problem of different time horizons. A possible solution could be: expected climate changes are superimposed on alternative development options and a comparison among options is made of the changes between conditions with and without climate change scenarios. This would result in an indication of more and less vulnerable options for development.

- *Feasibility* for implementation, which should not only consider cost aspects, but also technical, social and institutional aspects. Costs of measures should consider all costs involved, including investments, costs for environmental mitigation and compensation, O&M costs, and administrative costs. Institutional aspects relate to all management and legal issues involved in the planning, implementation and maintenance of adaptation measures.
- *Current state of implementation & requirements for improvement* refers to how the suggested adaptation measures are being practiced in the country with or without consideration of climate change.

The above mentioned criteria also relate to the mitigating impacts of the overall potential for sustainable development. An important consideration in this discussion is: whether adaptation requires continuous support and maintenance, such as maintenance dredging of silted drainage channels. Consideration should also be given to the relative importance of climate change in comparison to other exogenous developments and to possible positive or negative by-effects of the proposed measures on other sectors.

By taking into account the efforts needed for the implementation of the proposed measures, the above framework would mainly serve a comparative assessment of these measures (for example, in terms of which measures are expected to contribute more or less to the reduction of the country's vulnerability).

The above criteria then lead to a tentative assessment of prioritizing future action programs which are indicated by HIGH, MEDIUM, or LOW priority[4]. To emphasize, an adaptation measure if it has not been tried before could be identified as high priority as long as it is effective, technically feasible, socially acceptable, and can be implemented under the **existing or an improved** institutional and legal framework in Bangladesh. Such a program would **not** be high priority **only if** one is convinced that in the Bangladesh context, it is not possible at least in the next fifty years.

It should be noted that the proposed framework only provides a general guideline of "tentative assessment of climate change adaptation" in order to provoke the thinking process of policy makers. The framework is based on the best judgment of the authors and those consulted[5] for this study, and does not claim to be a prescribed policy framework for Bangladesh. However, for every sector, <u>guidelines to incorporate climate change in long term planning</u> should be considered as an essential institutional adaptation. In addition to the descriptive part later in the chapter, section V of the Executive Summary presents the framework in tables.

4 A proposed adaptation measure may be deemed high priority even if it scores are medium on average (if it has not been tried properly or extensively in the country)

5 Appendix F of the main report provides a complete list of those consulted in the review workshops.

Socio-Economic Scenarios / Sensitivity to Climate Variability and Change & Adaptation Possibilities for Bangladesh

To demonstrate how different socio-economic scenarios can affect the vulnerability of Bangladesh to climate change, an attempt is made to analyze development paths for the country and their effect on the country's sensitivity to climate change. These developments are complementary to the discussion on adaptation strategies. Development of Bangladesh is aimed mainly at accelerating economic development, increasing wealth, and reducing poverty. Adaptation to climate change is an important consideration in this regard. Should Bangladesh remain one of the poorest countries, its vulnerability to the effects of climate change may be very great. It is beyond the scope of this report to address how Bangladesh can achieve a higher GDP growth path and improve its health and education systems. However, given the tremendous sensitivity of the country to current climatic variability, it is hard to imagine that sustainable development paths can be achieved without addressing the country's vulnerability to climate change. In other words, for Bangladesh to be included in the ranks of developed countries, it must reduce its vulnerability to devastation from droughts, cyclones, monsoon floods, and various critical impacts of climate change.

The first development path is based on published projections of population and income. This is referred to as a "best guess," although projections of population and particularly income for decades into the future are highly uncertain. The population projections are from WRI (1998), and the income projections are derived from the IPCC's IS92a projections for GDP. The IS92a is often referred to as a "business as usual" projection.
The population, GDP, and GDP/capita projections are displayed in Table A.

Table A: "Best Guess" Macro Projections for Bangladesh

	1998	2020	2050
Population (milions)	124	168	218
GDP (billions)	$28.6[1]	$72.2	$180.0
GDP/capita	$220	$430	$825

1. 1995 value.
Source for 1998 data: WRI, 1998.

The second development path is based on a vision for Bangladesh developed by the World Bank and the Bangladesh Centre for Advanced Studies (World Bank and BCAS, 1998) and is referred to as the "optimistic" scenario. The report describes this vision as follows:

By 2020, if not earlier, the hope is that the basic needs of the population of Bangladesh will have been met, when everyone will be properly fed and adequately clothed, shod and housed, able to read and write, have access to basic health care and have their basic rights respected — both men and women, old and young. Furthermore, the expectation is that all of this can be ensured on a sustainable basis without dependence on foreign donors, and without damaging the environment. Nothing would be done today which would in any way compromise the well-being of future generations.[6]

The report envisions that population will achieve replacement levels by 2010, and that per capita GDP will be $1,200-$1,300 by 2020 (it also envisages annual rates of 7% to 8% for the next two

6 WB and BCAS 1998. *Bangladesh 2020: A Long-Run Perspective Study*. pg 1

decades). Extrapolating from those trends, projections of population, GDP, and GDP/capita were developed under the optimistic scenario as shown in Table B below.

Table B: "Optimistic" Macro Projections for Bangladesh[1]

	1998	2020	2050
Population (millions)	124	165	165
GDP (billions)	$28.6[1]	$206.3	$1,485.0
GDP/capita	$220	$1,250	$9,000

1. 1995 value.
Source for 1998 data: WRI, 1998.

More recently, the National Water Management Project planning has developed some projections[7] based on a more modest growth rate of 5.5% to 6% per year (similar to the recent levels in Bangladesh). However they have not projected GDP/capita up to the year 2050. So, it is not included here.

Would these different development paths affect Bangladesh's vulnerability to climate change (i.e., the ability of the country to absorb and respond to changes in climate) as well as its capacity to take proactive action to reduce risks of climate change? To try to answer this, some countries (with current GDP/capita close to the projected GDP/capita for each scenario) were selected as **analogues** for future conditions in Bangladesh.

These analogues are not perfect predictors of a future Bangladesh especially since political/economic, income distribution, social, and cultural differences among the various countries. The analogues also do not account for changes in technology in the future, which could have a significant effect on vulnerability. Nonetheless, the analogues could be useful indicators of future development paths. The results are displayed in Tables C and D.

As noted earlier, sustainable development will help reduce vulnerability to climate change and increase capacity to take proactive action for the following basic reasons:

1. ***Higher per capita income*** will typically mean that financial resources to make adaptations to climate change, such as building sea walls (though not a recommendation of this study -- note from SASRD, World Bank), or coping with people forced to migrate, are more readily available.
2. ***Percentage of the economy in agriculture*** is an indicator of the vulnerability of an economy to climatic variability and changes. The lower the percentage, the more of the economy is likely to be in sectors such as industry and services, which are less sensitive to climate change than agriculture and related sectors (e.g., forestry, fisheries).
3. ***Higher education levels*** typically mean that a society can adopt new technologies and practices as necessary to cope with climate change. Literacy rates could perhaps be used as a proxy for education.
4. ***Better health care systems*** would result in reduced vulnerability to the outbreaks of infectious diseases like cholera, or other health problems complicated by climate change. Life expectancy, and percentage of population with access to health care could be proxies for the quality of the health care system.

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7 More recently, the National Water Management Project planning has developed some projections based on a more modest growth rate of 5.5% to 6% per year (similar to the recent levels in Bangladesh) (National Water Management Plan Project. *Draft Development Strategy*. Vols 2 & 8. August 2000)

Tables C and D display the GDP/capita, the percentage of the economy in agriculture, life expectancy, percentage of population with access to health care, and literacy for the analogue countries today.

Table C: Vulnerability Indicators for 2020[8]

	1998 Bangladesh 	2020 Best Guess for Bangladesh	2020 Optimistic for Bangladesh
Analogue Country		Pakistan 	Kazakhstan 
GDP/Capita	$240	$460	$1330
% of Economy in Agr	30%	25%	12%
Life Expectancy in Years (1995-2000)	58	64	68
% Pop w/ Access to Health care	45%	55%	N/A
Literacy[9]	38%	39%	98%

In 2020, if Bangladesh grows to the present level of development in Pakistan,[10], under the best guess scenario, there will be some moderate improvement in its ability to cope with climate change. Pakistan generally ranks higher than Bangladesh on the indicators, except for literacy. Thus, Pakistan may have a marginally greater capacity to cope with climate change. Still, Pakistan is a poor country today with significant vulnerabilities to climate change. Therefore, if Bangladesh follows this path: it too could be expected to have significant vulnerabilities to climate change in 2020.

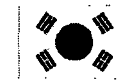
In contrast, the optimistic scenario for 2020 results in Bangladesh with a GDP/capita slightly lower than the current level in Kazakhstan. The latter's per capita income today is about five times higher than Bangladesh's today, it has a much lower share of the economy in agriculture, and it appears to have much better health and education systems. Based on the indicators, Kazakhstan appears to be substantially less vulnerable to climate change than Bangladesh (although its agriculture and water systems may have considerable vulnerabilities (Mizina et al., 1996)). If this optimistic scenario is realized, Bangladesh's vulnerability to climate change could be substantially lower.

8 Sources: WRI, 1998; literacy rates from CIA 1998

9 The latest data show a literacy rate of 62%.

10 The GNP/capita projection for Bangladesh is also close the current GDP/capita of Bhutan, which as a GDP/capita of $420. Even though it has a higher GDP/capita than Bangladesh has now, Bhutan has a higher percentage of the economy in agriculture and a lower life expectancy than Bangladesh has now (WRI, 1998).

Table D: Vulnerability Indicators for 2050[11]

	1998 Bangladesh 	2020 Best Guess for Bangladesh	2020 Optimistic for Bangladesh
Analogue Country		Bolivia 	South Korea 
GDP/Capita	$240	$800	$9700
% of Economy in Agr	30%	17%	8%
Life Expectancy in Years (1995-2000)	58	62	73
% Pop w/ Access to Health care	45%	67%	100%
Literacy[12]	38%	83%	98%

The two scenarios for 2050 present a more dramatic contrast. The best guess scenario results in Bangladesh achieving a per capita income similar to Bolivia. Although Bolivia is still a poor country, based on the macro indicators of vulnerability, it appears to have more financial resources, better health care, and a better education capacity to cope with climate change. Since it is a poor country, Bolivia can still be considered to have a limited capability to cope with climate change. So, Bangladesh would be better off than today in its ability to cope with climate change, but would still be vulnerable to climate.

The optimistic scenario for 2050 results in Bangladesh's GDP/capita closely reaching the level of today's South Korea. Indicators for South Korea, which recently joined the Organization for Economic Cooperation and Development (placing it in the ranks of developed economies), are dramatically more favorable for Bangladesh. If the Bangladeshi economy, health care, and education system were similar to South Korea, it would be significantly less vulnerable to climate change. It would have the financial capability to cope much better with changes in flooding, drought, and cyclones. The risks of infectious disease and other health problems from climate change would also be lower. There would be much greater capacity to adopt new technologies and practices.

Thus, it appears that much healthier economic development, with its concomitant improvements in health care and education, could significantly reduce Bangladesh's vulnerability to climate change. As noted earlier in this chapter, different development paths can still result in significant differences in vulnerability. If institutions and infrastructure are developed assuming no changes in climate, they might fail or limit the capacity of the society to adapt to climate change.[13]

The issue of population growth deserves further attention. Population growth, particularly rapid growth, increases pressure on the limited land and resources. Higher population growth will likely result in lower GDP/capita compared to lower population growth, limiting per capita income growth for reducing vulnerability to climate change. Particularly in rural areas, larger population is likely to result in increasing numbers of people living in flood, erosion, and cyclone

[11] Sources: WRI, 1998; literacy rates from CIA 1998

[12] The latest data show a literacy rate of 62%.

[13] An additional factor that can affect vulnerability is the distribution of income. If development benefits only upper income members of society, the vulnerability of the poor to climate change may not be reduced at all. In fact, if the poor people lose their land, their vulnerability would increase. However, if the benefits of development are spread across incomes, then all income groups will have greater financial capability, improved health, and improved education and technical skills to cope with climate change

prone areas. Thus, efforts to reduce population growth will also limit the country's vulnerability to climate change. Fortunately, projections of population growth for Bangladesh have dropped significantly in recent years. In 1995, the United Nations (UN, 1995) projected Bangladesh's population in 2050 to be 195 to 289 million, with the median projection of 239 million. In 1998, the World Resources Institute (WRI, 1998) projected Bangladesh's population in 2050 to be 218 million. However, even this lower rate of growth is an increase of 75% over current levels, in an already very densely populated nation. The optimistic scenario assumes population stabilizing at 165 million after 2010. Such a reduction in population growth could substantially improve Bangladesh's socioeconomic conditions and limit its vulnerability to climate change.

Ericksen et al. (1996, p. 269) offer "some likely outcomes" for Bangladesh 50 years from now. This includes:

- intensified migration from high to low density rural areas and to cities
- increased urban expansion and settlements
- increased service and manufacturing sectors of the economy
- a larger proportion of the population belonging to the upper and middle classes, but the poor and disadvantaged continuing to be the majority
- modernization of traditional rural attitudes and adaptive methods for coping with natural hazards
- increased landless population, which will be absorbed in the nonagricultural sectors of the economy
- improved education and health care, but only small improvement in living conditions for the poor.

These "forecasts" highlight the importance of distribution aspects of development, i.e., if development mainly benefits the rich and middle classes, the poor will be left behind. However, a more rapid pace of economic development may help alleviate many of the problems listed by Ericksen et al.

Broad Sectoral Adaptations

3.2 Coastal resources (risks & adaptation)

3.2.1 Key Risks

Box 3.2

Key Risks to Coastal Resources

- Drainage congestion due to higher water and bed levels, and increased sedimentation in the flood plains.
- Salinization of land and water resources due to lower river flows and higher relative sea levels (including subsidence) aggravated by subsidence.
- Erosion of rivers and coasts due to changing dynamics, not compensated by accretion of land of equal quality.
- More intense cyclones and storm surges, with higher risks because of higher water levels and lower land levels in protected areas.

The fact that most of Bangladesh is in the lower (coastal) part of the deltaic floodplains, where the major rivers meet with the Bay of Bengal, is one of the primary reasons of its vulnerability to climate change. The critical impacts (Box 3.2) affect all coastal activities. Continuous threat of disasters and erosion added to the limited availability of fresh water and local drainage problems seriously constrain the region's economic development. Agriculture and human health will be strongly affected as well, while important ecological areas such as the Sundarbans will suffer from salinization and other effects. The risks are described in more detail in Chapter 2.

3.2.2 Vision of Coastal Resources at Low Risk to Climate Change

The vision of a coastal zone at low risk to the impacts of climate change and sea level rise includes provision of sufficient protection against storm surges and flooding so that the homes, and livelihood of Bangladeshis become relatively safe. In this vision, adaptations in the coastal zone would be directed towards protection of special urban and industrial areas and the population-- with well designed coastal embankments, community managed new regulators, tidal basins, landfills etc. Additionally, good and flexible management of mangrove belts and other inter-tidal areas would reduce vulnerability from disasters, and at the same time enhance the accretion of new land.

An efficient forecasting and warning system would prove beneficial for all people potentially affected by storm surges and floods, enabling them to take reactive adaptations such as evacuation. There should be enough shelters in the rural areas to accommodate all individuals, livestock, food and other assets. Such a safe environment is an important condition for industrial development of the coastal zone with optimal utilization of its energy potential. Another important condition for this development is access to sufficient fresh water. A partial shift from agricultural to industrial activities would reduce the zone's dependence on agriculture, and increase the employment and income of the local population. This would also reduce pressure on fresh water availability. The scarce fresh water could be allocated with priority to domestic and industrial users, and used for an ecologically sound management of the Sundarbans. Other possible adaptations could include changes in agricultural practices with a shift to paddy cum shrimp cultivation (with due consideration of the environmental and social implications of introducing shrimp culture), while proper groundwater management would prevent aquifers from becoming saline.

Problems related to drainage congestion could eventually lead to pumped drainage for high value land uses such as urban and industrial uses, replacing the present practice of drainage under gravity. Before pumped drainage finds more application in rural areas (which requires substantial capital investments), the actual problem can be eased through a proper maintenance of the drainage network (dredging), requiring an operational organization with a substantial annual budget. A proper functioning O&M arrangement including establishment, and support of local water management is an integral part of that vision.

Integrated Coastal Zone Management plan (ICZM) under the Coastal Zone Development Program is an important step to create the conditions for sustainable social and economic development of the coastal zone under the serious constraints and limitations of its natural resources.

3.2.3 Adaptations

As stated in section 3.1.4, the study has developed an overview of possible adaptations based on a general framework. The framework assesses which adaptations are expected to contribute more or less to the reduction of the country's vulnerability, taking into account the efforts needed for their implementation.

Discussion on each of the sectors (as presented in this chapter), provides an overview of possible adaptations. A first *tentative* assessment for each sector based on the above criteria are also provided in tables in section V of the Executive Summary. The assessments are meant to evoke discussion, and indicate which directions (strategic) adaptations may take. The assessments do not claim to be complete or absolute. Since Integrated Coastal Zone Management (ICZM) is perceived as the necessary condition for placing the various adaptation measures in perspective, this issue is treated separately in Section 3.2.4.

It should be noted that, given the risks already faced by the country from coastal erosion, cyclones and the other key risks, most adaptations imply significant benefit for the actual conditions even in a future with very moderate (low end) climate change.

♦ Specific recommendations for adaptation to **drainage congestion** include *physical interventions* and *institutional measures*. Physical adaptation includes increasing drainage capacity of infrastructure, new regulators, tidal basins, and pumped drainage; whereas institutional adaptations include guidelines to incorporate climate change, proper O & M arrangements including establishment, and support of local water management, and design criteria for drainage capacity of infrastructure.

Physical adaptations aim at improving the run-off from land after flooding, which requires mainly two steps: (i) bringing water from the land into the main drainage system; and (ii) draining water to the sea. Step (i) presently is done under gravity, mostly through regulators which open during low tides. When higher water levels impede this process, pumping remains the main option. Step (ii) requires a well maintained drainage network, and continuous dredging. Experience in Bangladesh, for example, in the Khulna – Jessore area (EGIS, 1998), has shown the dramatic effects of delayed and neglected dredging, which resulted in strongly progressive and heavy siltation in dead-end channels. Increasing the *drainage capacity of existing infrastructure* such as roads seems a feasible and effective way to reduce drainage congestion where drainage is hampered by culverts, bridges, regulators etc. This study also considered *new regulators* and *tidal basins*[14] as alternative physical interventions to solve the drainage problem. Tidal basins stand out as a preferred option from an environmental and maintenance perspective (since tidal basins would substantially reduce the maintenance dredging and bring sediments to

[14] In the tidal basin approach, the dynamics of the tidal system is maintained, fixed major structures such as regulators are avoided as much as possible, and applied only on a local scale

the beel areas). More specifically, the *tidal basin* experience in Khulna-Jessore Drainage Rehabilitation Project should prove the feasibility of this approach in south-west Bangladesh. Disadvantage of *regulators* in contrast, is that they generally need active maintenance dredging in the downstream entrance channels. *Pumped drainage* seems a last and expensive resort especially when the outside water levels become too high for drainage under gravity.

Possibilities for reducing drainage congestion through *institutional measures* include guidelines to incorporate climate change in long term planning. Establishing*proper O&M arrangements* for the maintenance of drainage channels and infrastructure could be an effective approach, but has medium feasibility. Effectiveness of water management associations is limited because of the fact that drainage congestion is caused by factors outside their control. Developing*design criteria for drainage capacity* (both for infrastructure and embankments) is feasible but not very effective in the coastal zone.

♦ Specific *physical adaptations* for the **salinity** problem should focus on increasing surface water flows from upstream, resuscitation of river networks, increasing local storage capacity of fresh surface or groundwater, and desalinization plants and equipment. The Gorai River Restoration Project is an example of*diversion project* for diverting water from the Ganges river[15] towards the southwest. Effectiveness of such measures can be high, but feasibility is low because of high cost. *Resuscitation of river networks*, in spite of the physical constraints, could be meaningful in the short-term especially in the south-west (e.g. Satkhira). Possibilities for *increased local storage* of surface and groundwater in the area itself are low as well. *Desalinization plants and equipment* are very expensive. This method could be applied only in specialized activities such as domestic water supply in coastal areas through distillation etc.

Institutional adaptations for salinity include maintenance and operation of sluices and other regulators, groundwater management, land use practice, extension services, and water saving techniques. The first two are management options. Improving *maintenance and operation of sluices* and other *regulators* to hold water in areas that are under increased stress from salinization score low on feasibility, but high as priority for incremental future action since they need to be implemented. Establishing effective *groundwater management* may be effective but scores low on feasibility. In Bangladesh, there still remains a tendency to consider water as common property. Groundwater management and regulator operations should therefore incorporate and make use of the difference between the dry and wet seasons in Bangladesh.

Land use practice can be influenced by incentives to change agricultural practices so that agricultural demand for fresh water goes down. Therefore, a cohesive approach is necessary with an intensification of *extension services* to promote changes in land-use and farm management techniques. For example, there could be door-to-door service in providing access to, and information of weather extremity tolerant crops to the farmers. Promotion of research and development of *water saving techniques* could improve the present state of implementation of this method. All these measures face implementation challenges because of the institutional aspects involved.

♦ For the impact of **increased morphological dynamics**, several methods can be adopted. *Physical adaptations* to the threat of increased **erosion** would include mangrove greenbelts, cross dams and/or river training works. *Mangrove greenbelts* in the foreshore areas and along the coastal embankments, and *cross dams* at the same time enhance accretion. *River training works*, e.g., through bank protection or strong holds are confined to the estuarine river branches. All these measures are effective. The main challenges for cross dams and river training works are in

[15] Of course, the flow in GRRP depends on the Ganges flow

terms of feasibility. While costs of cross dams and river training works are progressive, the latter requires long term maintenance -- making it basically unsustainable. The high effectiveness and feasibility of *mangrove greenbelts* are well acknowledged.

Institutional adaptations would aim at protecting mangroves & wetlands, and land use arrangements (including land tenure laws) & policies. The value of growing *mangrove* greenbelts is closely related to the effectiveness, feasibility and sustainability of protecting mangroves in existing forest areas (through a combination of enforcement of existing legal provisions, and awareness raising among the coastal population). *Protection of wetlands* is assessed in a similar way, and wetlands can serve as a buffer against coastal storms and erosion. Another promising approach may be found through community-based adaptation where the community decides on how to share the limited common resource.

Although loss of land, and the creation of new land are common phenomena in Bangladesh, there does not appear to be a functional legal and administrative system for addressing these issues. At present, taking **accreted** land into culture for either forestry or agriculture falls under the jurisdiction of different ministries The loss of land, and relocation of displaced people needs to be addressed seriously (Freestone *et al.*, 1996), while mangrove belts should be managed in a much more flexible way than the present practice. For example, the belt could be allowed to shift seaward, taking land gained on the landward side into culture. Due to the lack of coordination among various ministries, such ideas meet implementation challenges. Therefore, changing *land tenure laws and policies,* though potentially effective, will meet serious institutional limitations. A sustainable adaptation to the reality of climate change forces us to search for reforms in these policies.

♦ In terms of more intense **natural disasters,** *physical adaptations* include construction of new infrastructure such as cyclone shelters and / or coastal embankments and landfills[16] modification of existing infrastructure combined with improved warning systems, and mangrove greenbelts. In addition to *cyclone shelters* for people, adequate provisions should be made for livestock, foodgrains and other perishable items. In the past, evacuation shelters for coastal storms have helped mitigate risks from cyclones. The size and adequacy of the shelters should be re-examined in the light of increased number of people at risk and the increased cyclone intensity as well.[17] Construction *of coastal embankments and landfills* should be coordinated, and should focus on special areas such as urban centers and concentrations of industrial activities. Design of new high value infrastructure (roads, sluices and embankments) could be altered with consideration of climate change. Additionally, *modification of infrastructure* focuses on the most valuable existing infrastructure, such as the new runway at the Mongla airport. New and existing *mangrove belts* (as mentioned earlier) appear to be effective in protecting against coastal storms, and in facilitating sedimentation. For example, mangroves can be an effective barrier against winds and storm surges (Haider, 1992). Such activities in Bangladesh needs to be streamlined by ensuring peoples' participation in maintaining and benefit sharing.

Institutional adaptations in this respect include improving forecasting, warning and evacuation procedures, adapting land use & development policy, and maintenance of existing and future coastal embankments. These responses relate to an improved emergency preparedness for coastal storms/surges etc., and could reduce risks to health and property. In particular, the Disaster

[16] Landfills here refer to land elevated to keep up with the flood levels, that can be used on a multi-purpose basis, e.g. community usage in the form of a village market place

[17] Past experience have shown that the holding capacity of existent shelters is barely adequate for people, and there is often no room for them to bring in livestock, and other assets, which are vital to the livelihood of the poor

Management Bureau (DMB) should incorporate climate change into its disaster preparedness program.

Improvement of the *forecasting system* seems highly promising, though implementation could be deterred by institutional and communication problems. *Dissemination system* could be improved in terms of alerting coastal residents about the seriousness of storms, and also, for example, making sure they do not confuse the danger signals applicable for "inland river ports" with the signal for "maritime ports" (as experience shows the result of such a mistake could be literally deadly). In addition, the system for tracking storms needs to be improved. Increased lead time in disaster forecasting would help in preparing to meet potential dangers.

Adopting *land-use development policy* seems an effective tool. For example, new coastal development projects might consider new construction to be built at a reasonable distance from high tide to allow for a certain amount of sea level rise. The land in between could be assigned to less investment intensive uses, e.g., agriculture. Required institutional arrangements, however, seem almost unattainable, and therefore this adaptation is low on feasibility. Overall, as priority for incremental future action, this adaptation scores medium.

Embankments need to be maintained on a regular basis. Actual maintenance of the existing coastal embankments is insufficient; a sizeable proportion of the existing coastal embankments is in bad condition, and are already being breached. Therefore, even though *maintenance of embankments* are effective, they do not score high on feasibility because of costs and organization needed to maintain them. For its role in saving lives and property, this has been slotted as a high priority future incremental action

3.2.4 Integrated Coastal Zone Management (ICZM) plan under the proposed Coastal Zone Development Program

Discussion of adaptations in the coastal resources sector shows a set of potential measures, which are closely interrelated. For example, proper mangrove belt management would be instrumental in reducing the impacts of cyclones and storm surges and also in stimulating the accretion of land, while changes in land use policy are needed for an optimal use of these accreted lands. Another example, referred to above, is the coordination needed to manage a shift from the agricultural to the industrial activities.

A proper instrument to deal with these interrelations is ICZM, which aims at an optimal use of the combined potential of all coastal resources. ICZM plans could include avoiding the development of areas vulnerable to inundation, ensuring that critical natural systems continue to function, safeguarding the availability of fresh water for priority users, and protecting human lives and economic activity. The ICZM plan should consider existing and future threats to the coastal zone in relation to climate change and adaptation possibilities (CZMS, 1990). Different responses may be appropriate for the very flat central region and the hilly Chittagong region.

Developing an ICZM will require extensive coordination of land use planning at the national, regional, and local levels. It is important that ICZM plan development includes input from the public at the local level. This will build stakeholders' confidence in the plan and take advantage of local knowledge on adaptation. The ICZM is an evolving program based upon a concept note prepared by GOB. According to Sept-Oct Aide Memoire (ICZM, 1999) the first three years of the proposed ICZM activity would be devoted to the development of an ICZM Plan which will be prepared by a small, highly professional program development office (PDO) (also see Appendix E on the proposed Coastal Zone Development Program). Along with the PDO, the proposed

Technical Committee, and the inter-Ministerial Steering Committee, the various agencies that could have some responsibilities for the different sectors include:

- Ministry of Water Resources for overall planning and management of the water sector through its Directorates:
- Water Resources Planning Organization (WARPO), for strategic planning of water resources
- Bangladesh Water Development Board (BWDB), for coastal & river embankments, river training works, barrage construction, irrigation and drainage
- Ministry of Environment and Forest; and Forest Department for coastal afforestation
- Ministry of Agriculture; BARC, DAE for agricultural research and extension
- Department of Fisheries (DOF), for marine and coastal fisheries
- Ministry of Local Government and Rural Development; LGED for local level small-scale water sector projects, etc.
- Ministry of Energy and Mineral Resources; PDB, REB.
- Ministry of Communication; Roads and Highways
- Bangladesh Inland Water Transport Authority (IWTA), for shipping and navigation
- Ministry of Land
- Ministry of Public Works, Public Works Department
- Ministry of Education; Facilities Department for coastal multi-purpose cyclone shelters
- NGO Affairs Bureau, for coastal multi-purpose cyclone shelters
- Chittagong and Mongla Port Authorities, for port facilities in Chittagong and Mongla, respectively
- Ministry of Aviation – Chittagong and Barisal Airport Authority
- Bangladesh Tourism Authority (Parjatan Corporation), for tourist facilities at Cox's Bazaar and Kuakata.

The latest draft Bank concept note[18] on the proposed CZDP has evolved from the subsuming of the proposed Integrated Coastal Zone Management Project (planned as a FY 04 project) and the former CERP II which was held up recently at the Project Concept Document stage because of concerns over Coastal Embankment System sustainability issues, lack of progress with BWDB institutional reforms and the need for a longer term strategy for development of the coastal zone. The proposed program would address all these concerns by adopting a longer term approach with earlier activities concentrated on i) well informed investment planning, ii) development of appropriate strategies underpinned by extensive community consultation, and iii) appropriate institutional reform. Substantial investments would come later and be conditional on substantive advances in these three areas, which would be identified from the outset and constitute trigger points to allow progression from one phase of the program to the next. The underlying concept would be that GOB access to increasing levels of funding would be directly related to the adoption and successful implementation of increasingly significant institutional reforms/ strengthening and community-based investment planning and implementation.

Since the program is expected to continue beyond 7 years, within the next three years, CZDP could implement some specific components such as i) complete preparation of the Integrated Coastal Zone Management Plan involving wide-ranging community consultations; ii) explore and develop financial and administrative arrangements for a proposed disaster repair and rehabilitation fund for emergency and urgent works, etc. The overall development outcome of the evolving CZDP would be i) substantial and sustainable reduction in the risk of loss of life, and damage to property and economic assets; (ii) restored and sustainable natural ecosystem functions

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and services; and (iii) equitable improvements in farm and non-farm employment and income. This issue is elaborated in Appendix E as well.

3.2.5 Possibilities and Limitations

Limitations of the proposed adaptations have been partially discussed in the previous paragraphs. Possibilities for adaptation to drainage congestion and salinity intrusion seem constrained either by limited effectiveness, or by high costs of required institutional arrangements. As mentioned before, ICZM/CZDP is a proper mechanism to consider all these risks in their interrelation and proper context, and optimize the use of the increasingly scarce resources. Mangrove belts and their proper management seems possible and effective in terms of accretion and protection. The role of cyclone shelters and improved warning systems has been confirmed as highly effective against the risks of increased disasters. Bangladesh already has a good record in this respect, which merits to be strengthened where possible.

In a densely populated developing country like Bangladesh, there are a number of limitations concerning implementation of adaptations. The high population density limits the efficacy of imposing setbacks. Given the long history of people living on and farming coastal lands, it is not clear that a setback policy would be acceptable or enforceable. BCAS/RA/Approtech (1994) concluded that retreat from sea level rise is not an acceptable option for Bangladesh. Thus setbacks are likely not to be feasible either.

Bangladesh' institutional, planning and decision making structure lacks mechanisms for long-term planning, This significantly hampers the development of integrated programs and the coordination of the existing projects. Another important obstacle is the lack of institutional and financial capacity for O&M in Bangladesh. Many existing infrastructure already urgently require maintenance.

Physical interventions such as building coastal defenses can be expensive. Huq *et al.* (1995) estimated that the cost of defending against a 1 m sea level rise would be US$1 billion. It should also be noted that hard coastal defenses such as sea walls[19] can have negative effects on beaches and on biodiversity. Sand beaches often disappear when sea walls are built, and hard structures can block the inland migration of wetlands (Titus, 1991). In contrast to these infrastructure interventions, major shifts in the development approach may be needed. Changes in land use and a greater focus on industrialization to reduce the zone's dependence on agriculture may be called for. Scarce fresh water should be allocated with priority to domestic and industrial uses, and properly utilized for sound management of critical ecological areas such as the estuaries and the Sundarbans. Key development activities to realize adaptation may include: *Coastal Greenbelt Project, the proposed Integrated Coastal Zone Management Plan and/or the proposed Coastal Zone Development Program, Khulna-Jessore Drainage Rehabilitation Project.*

[19] As stated elsewhere, building sea wall is not a recommendation of this study- note from SASRD, World Bank

3.3 Fresh Water Resources (Risks & Adaptation)

3.3.1 Key Risks

As noted earlier, water resources in Bangladesh are at risk from reduced water availability in the dry season and from more severe floods and drainage congestion in the aftermath of the floods. Moreover, induced by changing river and sediment flows, riverbank erosion is expected to increase, while the incurred losses of land will not be compensated by accretion or by land of equal quality elsewhere. Most of the expected impacts on the water resources will be more pronounced because of infrastructure developments, such as extension of the road communication networks and the construction of flood protection works. This implies in principle a kind of a multiplier effect, for example, by building embankments and protecting areas against increased flood levels, the flood problem is increased which requires more or higher embankments. Similar multiplier effect would be implied by withdrawing more groundwater in response to increased drought conditions, which would enhance the same conditions. Box 3.3 lists the key risks to the fresh water resources sector.

Box 3.3
Key Risks for Fresh Water Resources

- Increased pressure on fresh water availability, due to increased droughts (less precipitation and more evapo-transpiration) and lower river discharges and increased demand.
- Drainage congestion, due to higher water levels in the main drainage system and increased sedimentation in the flood plains.
- Increased riverbank erosion, due to higher peak flows, not fully compensated by accretion of equal quality land elsewhere.
- Increased flood levels with longer duration due to higher peak flows, aggravated by increased drainage congestion.

3.3.2 Vision of Fresh Water Resources at Low Risk to Climate Change

In terms of fresh water resources, adaptations would aim to substantially reduce the risk of drainage congestion, erosion and drought, explicitly addressing water management issues in both the wet and dry seasons. Water supplies would aim to be of sufficient quantity and quality to support growing uses in the country such as domestic, industrial, irrigation & navigation uses, and would support existing ecosystems. During winter, sustained fresh water flow would maintain the base flows in channels, especially in the smaller channels. Possibilities to increase water-use efficiency would be utilized as much as possible.

Proper allocation of the increasingly scarce resources requires an integrated approach to water resources planning and management. Such an integrated approach is expected to greatly contribute to reducing the vulnerability of Bangladesh' water resources to climate change. Important components of integrated planning and management include land-use planning, coordinated construction and operation of regulating infrastructure, monitoring and evaluation, demand oriented management, and participatory approaches focusing on the various water user groups.

3.3.3 Adaptations

The adaptations suggested here might help Bangladesh to reduce the risk of climate change impacts on fresh water resources. Moreover, many of these adaptations have significant benefits even if climate change does not materialize, or occurs at a much slower rate than currently predicted.

Planning for adaptations in fresh water resources is perceived as the necessary condition for putting the various adaptation options in perspective. It is treated separately in Section 3.3.4.

The structure of the suggested adaptation distinguishes between physical and institutional response. Section V of the Executive Summary provides a tentative assessment of the proposed adaptation measures.

- Possibilities for *physical adaptations* to **reduced fresh water availability** mainly refer to increasing surface water availability through *additional inflows from upstream*, or *increase of storage of water* in the area itself. Increasing drainage capacity of infrastructure scores high as a priority for incremental future action. Increase of inflow, e.g., by diversion of rivers is in itself effective but seems not so feasible because of the conflicts with upstream users even within the country. If groundwater is not fully replenished, storage can be increased through recharging groundwater aquifers or through special operation of regulators (by closing regulators at the end of the wet season to store fresh water for the dry season). However, effectiveness and feasibility of this mechanism are not promising, mainly because of physical limitations related to the aquifer conditions. There is also the potential of causing harm to the livelihoods of a substantial number of farmers. Another way of storage would be through rain water harvesting, excavation of ponds etc which could be a promising alternative.

On the user side, there may be possibilities for more efficient water application techniques. *Institutional adaptations* aim to increase the fresh water availability through *reducing water demands* with various incentives. For example: groundwater extraction, which is basically uncontrolled, could be better regulated and monitored; or farmers could be trained to increase water use efficiency through farm practices. Again, market concepts could be introduced (by having consumers pay for water use, or allowing trading of water rights) which may help ensure that water goes to the most efficient applications. Pricing groundwater could make groundwater use more efficient, and can be more extensively applied to government-owned surface water irrigation schemes and possibly to publicly-owned deep tube wells. However, it may be impractical and socially undesirable especially where farmers use low lift pumps and shallow tube-wells to draw on a common resource (which is the case in most of the irrigated area). This issue needs further investigation because at present, though many poor farmers cannot afford the cost, some of them are forced to pay money for water usage from a middle-person (the one that owns the pump) instead of the government. The middle person, since not liable to pay taxes, continues with indiscriminate over-abstraction of the water, which is in itself an environmental externality.

Another important and promising institutional mechanism to increase the flexibility to adapt to climate changes are proper *arrangements for (participatory) operation and maintenance of water resources infrastructure.* This relates, for example, to more sustainable sluice operations which would allow storage of fresh water and support a more fish-friendly management.

- In terms of adaptations to **drainage congestion,** *physical adaptations* are directed towards helping to drain the water after flooding, thus improving the land and water conditions for agricultural practices and human health. Typical traditional examples to increase the capacity of the drainage network are: the *restoration of channels* through dredging and river training; *flushing* to prevent drainage channels from siltation; and *increasing the capacity of openings* in roads, highways and regulators to discharge the required volume of water. Flushing capacity enhancement is assumed to be reasonably effective, but has a low feasibility because of the poor maintenance organization in Bangladesh, and the scarcity of water for flushing. The maintenance requirement in itself implies low sustainability.

Controlled sedimentation and *land fills* favor the drainage network. However, as new concepts, they need more understanding. *Pumped drainage* seems unavoidable in some high value parts of Bangladesh. This worked, for example (partly) in Dhaka during the flood of 1998. General feasibility of this measure is still low, but might increase as the economic development of the country continues.

Institutionally adaptation could consider improved *design criteria* for openings in drainage blocking structures, such as culverts and bridges in roads and community involvement in the operation and maintenance of the water resources infrastructures. Both are considered to have low to medium effectiveness and feasibility, however score high as a priority for incremental future action. *Participatory management of water resources infrastructure* is a high priority institutional adaptation measure.

- Adaptations to **increased morphological dynamics (erosion & accretion)** also includes physical and institutional aspects. *Physical adaptations* would focus on *protection against bank erosion* and *dredging* of navigation channels which suffer from increased sedimentation. *River training* and bank protection have long been practiced in Bangladesh, in particular on a local scale. More recently efforts are being taken on a national level to harness the main rivers (e.g., the Right Bank Protection of the river Jamuna). Careful analysis is needed on what solution is known to work in a particular situation. Their effectiveness and feasibility are not always high in the morphologically dynamic environment of Bangladesh. The scale of the rivers in this context is also significant, and the priority of such measures is low.

On the *dredging of navigation channels*, the study on the morphological dynamics of the Jamuna River (EGIS, 1997), showed a continuous increase in river width, which is partly compensated by a decrease in river depth. Dredging activities could be intensified, but they have low feasibility, and medium priority.

Institutional adaptations (which includes improved monitoring and forecast of changes, relocation of victims of erosion, and navigation management and information), at present face limitations in implementation. *Monitoring* and *predicting morphological changes* become more and more important to prepare for anticipatory measures to protect the increasingly important infrastructure (such as the Jamuna bridge). Knowledge and experience to analyze the morphological behavior of the rivers in Bangladesh is growing (supported by the international scientific community), but still inadequate for proper management and has to incorporate the impacts of climate change.

Other institutional arrangements include programs to *relocate the victims of erosion.* At present, erosion victims often move to low lying lands that are hardly gained from accretion. An *institutional and regulatory framework* is necessary to relocate the victims in government owned *Khas* lands, which may be supplemented by NGO-driven micro-credit programs to facilitate income generation activities in those areas. This highly effective and sustainable mechanism may however have a low feasibility. Navigation would greatly benefit from proper and real time *information about the navigability* of rivers during the dry season and demarcation of navigation channels. This is again effective and sustainable but has low feasibility. Overall priority for this measure is high.

- Adaptation to **increased flooding** in terms of fresh water sector-- is discussed next. *Physical adaptations* first of all include *full flood protection embankments*. These are widely practiced in Bangladesh in areas where full flood control is economically needed and justified. Although effective, their feasibility is medium because of the O&M requirements and the long term accumulating effects of flood storage reduction, and the unwanted side effects of prevention of sedimentation, effect on fisheries/biodiversity in the floodplains (which can cause these interventions become unsustainable in some cases). Considerable experience has been built up with *submergible dikes* in the northeastern part of the country.

Controlled flooding in combination with compartmentalization has been practiced under the FAP project (FAP 20) and deserves more attention. A special case of controlled flooding is green rivers, which consists of an offset full flood protection embankment, and a strip of land around the riverbed for seasonal flooding. The advantage of offsetting flood protection is that it is less exposed to erosion, and sedimentation is enhanced. The major disadvantage is the limited land use allowed in the floodplains, and the advanced arrangements needed for proper management. Therefore, in terms of feasibility, controlled flooding scores low, as priority it scores medium.

Landfills or flood shelters*(elevated land)* and *flood refuge areas* focus directly on the affected people and assets rather than on limiting or managing the excess floodwater. In response to the need for increased dredging operations in Bangladesh, introduction of larger scale landfill (as defined before) operations could be considered. Most of the pucca schools and the elevated roadsides are now considered flood refuge areas. These measures are quite effective, and feasible. *Institutionally, improved flood warning and forecasting* is needed. Flood warning should not only predict water levels in rivers, but also give an estimate of the depth and duration of floods -- which is much more useful to farmers. Improved forecasts need to be combined with proper dissemination mechanisms and techniques. Improved damage assessment techniques would then support efficient and effective relief measures.

Discouraging future development in high-risk areas seems to have lower feasibility in Bangladesh. Although Bangladesh is not particularly known as an industrialized country, many of its medium to small sized industries are located in the floodplains just to avail facilities of water-borne transportation. Limiting such developments may impose costs in lost opportunities of land use for housing, industry or other uses. This "opportunity cost" should be balanced against the reduced risks to lives and property from flooding.

Involving local community in maintaining flood protection embankments should be a priority both as physical and institutional adaptation. Finally, programs could be developed for the *evacuation of flood vulnerable people and their valuables.* This is likely to extend into an important aspect of disaster management as more urban and industrial areas become protected. While effectiveness is high, feasibility of such adaptations is medium to low, because in Bangladesh it may be extremely costly to evacuate people (the numbers are in millions), and also for the poorest it is a difficult issue (with very few material belongings, and no insurance—evacuation can mean losing their lives' savings, and means of livelihood). Still, considering saving of human lives as the "principal" objective, this is a high priority option.

3.3.4 Planning for Adaptations in Fresh Water Resources

Planning is an essential mechanism for the implementation of anticipatory adaptation measures. Two planning issues merit mention: integrated (resource) planning and the incorporation of climate change issues in the design of major infrastructure.

Integrated Water Resources Management (IWRM) is a proper mechanism to account for the many aspects of water supply and demand, and to properly consider long term issues of sustainable resource management. Through integrated management, different sectoral interests are coordinated and important links are made with land use and environmental planning and management (see also crosscutting adaptations in Section 3.7). Recently, structured through the formulation of a National Water Policy and the reformulation of WARPO's mandate, Bangladesh developed a planning approach which aims to prepare and support integrated water management, focusing on resources management rather than project management. The National Water Management Plan (NWMP), which is in the process of being formulated, will be revised on a periodic basis. WARPO is intended to become the coordinating agency at a national (macro) level for all water-related sectors.

Design of major infrastructure such as barrages and river training works in the main rivers should consider climate change scenarios such as those contained in this report. Given that infrastructure can have a lifetime of decades or more, and that it can be cost-effective to marginally alter the design of infrastructure before it is built, planners should evaluate the effect of climate change scenarios. The potential for increased flooding can be incorporated in the design and location of roads and bridges. In addition, planners should consider whether climate change will affect the functioning infrastructure. Protocols could be developed giving directions on how to incorporate climate change in the design of infrastructure.

3.3.5 Possibilities and Limitations

River training, dredging and bank protection have long been practiced in Bangladesh, in particular on a local scale. More recently, efforts are made on a national level to harness the main rivers (e.g., the Right Bank Protection of the Jamuna). Careful analysis is needed on what solution is known to work in what situation in the highly morphologically dynamic Bangladesh.
Main limitations refer to those adaptations depending on institutional coordination, changes in land use and the participation of local communities. Implementation of such adaptations should be carefully assessed since their success often depends on rather lengthy and well-coordinated processes.

Costs involved and required in institutional arrangements often pose another set of serious constraints. Protection works are often expensive. Proper coordination and management require operational procedures which are often lacking in Bangladesh, and are hard to finance.
Although evacuation of flood affected people from high-risk zones could be relatively doable, making adequate provisions for flood affected people is almost impossible. With the high population density, it will be difficult to take land out of culture, only on the basis of*potential* damage to users.

Key adaptations, in terms of fresh water, would aim to substantially reduce the critical impacts by explicitly addressing the management of water resources both in the wet and in the dry seasons. As water demand rises steadily for domestic and industrial usage, fisheries (flood plain, riverine, estuarine and marine), irrigation, navigation, and ecosystem regeneration needs--incentives to promote conservation in the dry season will be needed. This requires an integrated approach to water resources planning and management that will also coordinate the design, operation and maintenance of major infrastructure and embankments. Climate change impacts should be taken into account in both the design criteria and the location of the infrastructure. Key projects to realize adaptation include: *National Water Management Plan, River Bank Protection Project, and Small-Scale Water Resources Management Sector Project.*

3.4 Agriculture (Risks & Adaptation)

3.4.1 Key risks

As mentioned in chapter 2, Bangladesh is highly sensitive to climate change impacts on the *agriculture sector*. Considering the agriculture based subsistence economy, and almost two-thirds of the population employed in that sector, adaptations to climate change impacts are vital in achieving sustainable development. Box 3.4 lists the key risks from climate change to agriculture. Agriculture is closely linked to freshwater resources, and the success of adaptations in that sector. Moreover, the agriculture sector has the difficult task to meet the ever-increasing demand for food.

Box 3.4
Key Risks to Agriculture

- A greater incidence of droughts in the Western and North Western parts of the country, reducing areas suitable for rice production.
- Due to drainage congestion and more extensive flooding, the duration of floods, crops will be damaged and yields of e.g. Aus and Aman crops reduced (see Figure 2.2).
- Soil and surface and groundwater salinity will increase in the coastal zone, adversely affecting fresh water availability and agricultural production.

3.4.2 Vision for Agriculture at Low Risk to Climate Change

The vision for a sustainable agriculture sector firstly aims at increasing the productivity so that agriculture remains a key source of economic development, and employment. Crops would be diversified to become less vulnerable to changes in market conditions and climate. Due to successful adaptation, the production of major grains (C3 and C4 crops) would not be threatened by climate change. Yields could be improved, and land that is now used for agriculture can be gained for forestry, or returned to their original state.

The vision for the Bangladesh' agriculture sector at low risk to climate change also draws on the visions for coastal and water resources sectors. As mentioned earlier, agricultural activities in the coastal areas could be at certain places replaced by industries, while throughout the country agricultural lands would be protected from severe floods. In the drought sensitive areas, in particular in the western and northwestern parts, proper allocation policies and priorities would be developed and implemented to reduce the vulnerability to droughts. Introduction of new varieties (including research) and corresponding dissemination of these varieties and their cultivation would be taken care of by the responsible authorities.

3.4.3 Adaptations

Agriculture depends to a great extent on the availability of freshwater. Therefore, its vulnerability depends on the success of adaptation for fresh water resources as well as coastal resources sectors.

While this chapter provides details on specific sectoral adaptation (including the agriculture sector), it should be emphasized that, most of the adaptations provide benefits even with the lower end of climate change scenarios, such as improved irrigation efficiency or strengthening the extension services to farmers. A table with tentative assessment of the proposed adaptation measures is provided in section V of the Executive Summary.

Physical adaptation measures to reduce **drought** impact on agriculture will mainly focus on improved irrigation efficiency, crop diversification, and conjunctive use of surface and groundwater for irrigation. *Improved irrigation efficiency* will become an important adaptation tool. Climate change is expected to result in decreased fresh water availability and reduced soil moisture during the dry season, while the crop water demand is expected to increase because of climate change induced increased evapo-transpiration and the continuous introduction of high yielding varieties. Improving irrigation efficiency would help to reduce water stress. Present day irrigation practices are rather water intensive. Changes in fertilization techniques involving application of granular (or briquettes) urea under field saturation condition may as well result in a significantly reduced water consumption. Although the technical and financial feasibility of such adaptation is promising, it might require adequate training and extension (institutional support). Different irrigation techniques such as drip irrigation can reduce losses of water during conveyance and application. Dissemination of these techniques, and very weak financial capability of the farmers may prove to be the limiting factors in this case. Various forms of *pricing of water* is already in practice in the private irrigation schemes in Bangladesh, and water pricing in public irrigation schemes could be introduced.

Crop diversification with an emphasis on more drought resistant crops in drought sensitive areas should help to reduce vulnerability to climate change. For example, wheat requires significantly less irrigation water compared to Boro paddy. However, social acceptability of wheat is still poor. Diversification towards high value crops is feasible in the medium to long term. Growing crops or varieties that are relatively less water-intensive could also be considered in this context. Overall, crop diversity is a high priority adaptation measure. For a more efficient use of the reduced areas suitable for rice production, HYV varieties, hybrid varieties could be grown. In the future, the Super Rice varieties, being developed by the International Rice Research Institute (IRRI) could possibly be introduced. These are, however, more dependent on water, and may add to the problem of water scarcity.

Adaptation may also be possible by *promoting optimal use of both surface and ground water.* These adaptations should only be applied with great care. In terms of ground water usage, some areas are already under threat of over-abstraction. Availability of groundwater is therefore a very pertinent question where it is necessary to know the rate of groundwater recharge, and the limit where extraction may exceed recharge. Indiscriminate proliferation of Surface Tube Wells has shown detrimental effects on afforestation programs in the Barind Track. Such measures could be investment intensive. Therefore, such adaptations have medium feasibility.

Institutionally, measures to reduce drought vulnerability may consider *development of drought-tolerant crop varieties* and *training and extension, expanding access to credit etc*. More *efficient water* use can also be stimulated. A promising approach could be found through community-based adaptations rather than regulation, i.e. the community deciding on how to share a limited common resource.

Development of drought tolerant crop varieties could be stimulated with the National Agricultural Research System (NARS). Once the desired varieties are developed and tested in the fields, there should be a strong follow-up *training and extension* program to disseminate such developments. Institutionally these adaptations are feasible, and much will depend on the success of dissemination of information about new and improved varieties.

Adaptations to the effects of **increased depth and duration of flooding** in the agriculture sector will be important under the climate change scenario. *Physical adaptations* have been considered as part of 'adaptation to drainage congestion' in earlier sectoral discussions. *Institutional adaptations* should focus on research towards development of *faster growing or stronger and less* *inundation sensitive crops or varieties.* As mentioned before, once such crop varieties are developed, *extension* services have to be provided to disseminate the technology at the grassroots level. Given the institutional strengths and operation capacity of the NARS institutes, and also recognizing the willingness of the poor farmers to adapt to adversities, feasibility of such adaptation appear to be high.

Adaptations to effects of **increased salinity in soil and groundwater** in the agriculture sector will be another challenge in a warmer world. While *physical adaptations* have been listed in the coastal resources section, *institutional adaptations* could be research and training in combination with the various specific adaptations mentioned above. Various adaptations concerning *changes in agricultural practices* have been proposed in Habibullah *et al.* (1998). These adaptation measures are particularly well known under arid and semi-arid conditions. Their applicability to (the coastal zone of) Bangladesh is more uncertain. These adaptations include:

- planting on raised beds in double row in combination with irrigation;
- reduction of turn around time after Aman harvest in combination with rapid and deep tillage; and
- heavy pre-plant irrigation.

Although such methods for reducing soil salinity are known among the research community, it appears that the farmers are little aware of the existence of such adaptations. It is necessary to disseminate these ideas among the farmers in the southern areas through the existing network of the Department of Agriculture Extension.

Expanded access to credit requires institutional support, and is a high priority for the agriculture sector. Another high priority institutional adaptation measure, as in other sectors, is guidelines to incorporate climate change in long term planning.

3.4.4 Planning for Adaptation in Agriculture

Reduction of vulnerability of agriculture for impacts of climate change through the suggested adaptations require coordinated actions, proper planning and a financial context. Typical planning mechanisms or activities would include the following issues:

Incorporate climate change in long-term planning for agriculture. The potential impacts of climate change on agriculture should give directions to the Agriculture Research Management Project (ARMP) which is now being initiated.

Implement research and development on new crops suitable for impacts of climate change. Research and development efforts should include crops better suited to grow under climate change conditions. Crop varieties that are more resistant to extreme weather events will be needed under climate change. Reviewing the literature, Reilly (1996) concluded that it might take 8 to 15 years to develop new varieties and 3 to 14 years to adopt them. Thus research on new crop varieties needs to begin now. Further analysis of potential climate change and crop attributes needed to offset the effects may be initiated without delay. A climate change adaptation unit may be established at BARC in coordination with other National Agricultural Research System (NARS) institutions. Since many nations face the same risks and adaptation needs from climate change, localized research efforts should be coordinated at both regional and global levels.

Improve the outreach and information dissemination network, and corresponding extension services. Agriculture is a relatively flexible economic sector because farmers can change crops and practices on an annual or more frequent basis. However, for these changes to occur quickly and efficiently, farmers need to be aware of changes in crop varieties, crops, practices, or technologies that will help in coping with climate change. Farmers can often make the changes themselves, mostly based on indigenous knowledge. In other instances, training and demonstration may be necessary. The capacity of the outreach and information dissemination networks involving public and private sectors should be examined and institutional weaknesses should be adequately dealt with.

Expand free market reforms in agriculture. Lifting price supports on crop production could induce farmers to switch crops more rapidly in response to climate change (Lewandrowski and Brazee, 1993). Subsidies or restrictions on the types of crops that can be grown will either distort the market signal (a subsidy may indicate that it is still profitable to grow a certain crop when it may not be), or inhibit farmers from changing practices or crops. Removal of subsidies and other restrictions on agriculture will enable farmers to more quickly see the effects of changes in climate on the market and act on those changes.

Daily *et al.* (1998) note that "evidence suggests that open societies harboring secure property rights (be they private or communal) and avoiding flagrantly distorting fiscal policies are not only desirable in themselves, they would also appear to be good for the sustainable management of the natural resources base." The gains of market reforms in terms of efficiency of the market need to be balanced against the social costs of a free market society.

While market driven solutions offer opportunities for adaptation, when it comes to long term planning needs, the market is perhaps not the best way to deal with such planning issues. It is argued that government should have a central role in at least identifying the problem and setting in motion the solution (which can include market-oriented solutions).

Expand access to credit and crop insurance. For the agriculture sector to adapt quickly to climate change, farmers need ready access to credit for financing the purchase of new equipments, adopting new technologies and for investment in alternative crops. This has been proven to be a successful approach in recent years of severe flooding. An accessible, reliable, and honest credit system will help farmers expand their production capabilities under current climate, and in response to climate change, and is a high priority future action. The state operated Krishi (agricultural) Bank and private and non-government sector micro-lending institutions (Grameen Bank and other NGOs) could play a vital role to provide timely and safe credits to the poor farmers. Feasibility of such adaptation is high and already proven. In addition, there may be possibilities for farmers to participate in a crop insurance system. Feasibility of such approaches needs to be re-examined given the disaster proneness of the country, and its fragile agro-ecosystems.

3.4.5 Possibilities and Limitations

Limitations of the agriculture sector in adapting to climate change are encountered even under the present no climate change scenario. Access to capital and inputs at proper time are the major impediments to the improvement of agricultural production in the country (Faruqee, 1998). If the situation does not improve, it would also limit climate change adaptation possibilities. The high number of small land holdings in the country makes the situation more difficult. There remains a great need for an effective and efficient outreach network, similar to the one offered by the Local Government Engineering Department (LGED).

Climate change also touches upon the issue of land availability. In an ideal condition, if there were large patches of fallow land in the country for distribution, agricultural areas could be relocated from lands at most risk to less vulnerable lands. However, in the densely populated and resource-constrained Bangladesh, such relocation cannot be made without getting into conflicts with other land-uses. Taking newly accreted land into culture is a possible response to increased morphological dynamics.

Overall, since agriculture is expected to remain a key sector of the rural economy, Bangladesh is very sensitive to climate change impacts on the agricultural sector. These risks are particularly pronounced in the coastal zone where agricultural activities will likely be in conflict with industrial development. The study highlights the need for further research on the adaptation of agriculture sector under climate change scenarios. Key development activities to realize adaptation include: *Command-Area Development Project, National Water Management Plan.*

3.5 Human Health (Risks & Adaptation)

3.5.1 Key Risks

Bangladesh is already vulnerable to outbreaks of infectious, waterborne or other types of diseases. Chapter 2 highlighted the increased potential for these diseases and the adverse impacts of climate change on public health. The growing pressure on the availability of safe water during droughts and the increasing reliance on groundwater, with growing problems of arsenic contamination and salinization, pose an additional threat. Other risks include increased frequency and extent of natural disasters, and the pressure on agriculture that may result in reductions in food production. The key risks to human health are listed in Box 3.5

> *Box 3.5*
> *Key Risks to Human Health*
> - Increased potential for cholera and other waterborne and diarrheal diseases such as dengue or dysentery
> - Pressure on drinking water availability
> - Increased intensity of extreme climate events, e.g. cyclones and floods cause greater number of deaths and injury
> - Loss of agricultural production poses a threat to food production resulting in malnutrition.

3.5.2 Vision for Human Health at Low Risk to Climate Change

The sustainable vision for human health in Bangladesh is one in which the population is healthy enough to employ their full potential in developing themselves, and the overall living condition of the country in good harmony with its natural conditions. The health care system would be well equipped to deal with waterborne diseases. It is also envisioned that health-related risks to both climate variability and climate change are reduced. Fewer people will be subjected to the dangers of cyclones, storm surges and flooding.

3.5.3 Adaptations

The threat to human health in developing countries is one of the salient risks of climate change. An overview of possible adaptations in Bangladesh are discussed in this section, and a first *tentative* assessment is provided in table in section V of the Executive Summary.

Generally, adaptations for human health focus on improving the health care system (Benioff and Warren, 1996). Thus, they are needed anyway to meet the current health problems. Human health has strong relations with the other sectors as well. Therefore, its vulnerability depends on the success of adaptation in these sectors.

Possible adaptation measures in the human health sector are listed below.

Establishing water treatment facilities to provide quality drinking water from surface water systems could be useful. Due to surface water pollution, Bangladesh increasingly relies on shallow and deep groundwater resources for drinking water. In addition to making Bangladesh more vulnerable to increased droughts and saline intrusion, arsenic hazards in many areas of the country are becoming a serious challenge to the development programs. Returning to surface water use for consumption would require another (and therefore difficult) turn-around in user pattern. If water quality is low, this will have serious health implications as well. Treatment facilities could provide good quality drinking water from surface water, and create the required flexibility in fresh water sources. Considering the high degree of human dispersion, the lack of capacity to collect water almost regularly from a point source and the high capital investment and O&M costs, feasibility of water treatment facilities appears to be low. If, on the other hand, low-cost and easy-to-handle water purification technologies would be introduced at household level, adaptation could be possible. Social acceptability of such adaptation needs to be evaluated and tested.

Sewage treatment facilities are related to this health aspect. Social mobilization needs to be continued to keep the local water bodies clean. Such adaptation is feasible, and highly desirable towards, for example, mitigating the mosquito menace.

In terms of *institutional adaptation,* improved *surveillance and monitoring* of conditions favorable for outbreak of diseases will help predicting and preventing outbreaks of vector-borne diseases. Such programs should be coordinated with the media to issue early warnings and enhanced social response. Institutional feasibility for such adaptation measures is high.*Improved public education especially in reproductive health system* is another important adaptation measure. Continuing to *sensitize* people through greater awareness/*public education* programs about *improved sanitation* needs in the reduction of risks of waterborne diseases such as cholera, dengue fever etc is also very important in the adaptation context

Rational incorporation of *technological/engineering control* is sometimes mentioned as an adaptation measure. In certain cases, technological controls may be useful, such as genetic or biological pest management systems. However, consideration must be given to potential negative environmental consequences of the use of technological adaptation methods. For example, airborne spray of pesticides to eradicate mosquitoes might kill insects and birds, and might have other unforeseen effects on the local eco-system. Feasibility of such adaptations is tentative and questionable.

Strengthening the existing health care system and the access to health care is also important. Only 45 percent of the population has access to health care services (WRI, 1998). This situation needs to be improved urgently.

3.5.4 Possibilities and Limitations

The link of climate change vulnerability and development is evident in the human health sector. Primary education is a vital element in realizing the full potential of nation-wide health care programs. The existing inequity in distribution of land and access to other resources pose threats of further malnutrition to over half the population of the country, and contributes to its vulnerability to climate change. Key projects to realize adaptation in the health sector include: *Third Water Supply and Sanitation Project, and Bangladesh Arsenic Mitigation-Water Supply Project.*

3.6 Ecosystems and Biodiversity (Risks & Adaptation)

3.6.1 Key risks

Of all the sectors vulnerable to climate change, ecosystems and biodiversity sector may be most vulnerable due to the combination of: i) high sensitivity to climate changes and ii) low possibility for anticipatory adaptation measures.

Key risks for Bangladesh are indicated in Box 3.6. Increased stress on ecosystems will reduce their resilience to changes, or climate variability. This would not only be seen in terms of biodiversity loss, but also in terms of lower agro-ecological productivity. Most at threat from climate change are the Sundarbans; the agro-ecology of the north-central and western districts; the Haor wetlands; the Beel wetlands with the associated fish and other aquatic lives. For example, sea level could rise faster than wetlands can accrete sediments, or climate zones may shift latitudinal faster than species can migrate (Davis, 1989). Human development has in many cases fragmented or reduced habitat and species population. This increases vulnerability and blocks the migration of species. For example, development at the landward edge of the Sundarbans will probably prevent the inward migration of the wetlands in response to sea level rise.

Box 3.6

Key risks to ecosystems / biodiversity

- Low flow in dry season will result in further salinization of the Sundarbans.
- Lower groundwater tables and lower river inflows will result in substantial drought stress and even desertification in some sensitive parts of the country (northwest).
- Higher temperature would accentuate depletion of organic carbon from the topsoils.
- No studies exist as to whether endemic species are at risk of climate change. However it may be assumed that as elsewhere in the world, a rapid change in climate could threaten the existence of some of these species
- Higher water temperatures, change in brackish-fresh water conditions and reduced flows could harm fish productivity.

3.6.2 Vision for ecosystems / biodiversity at low risks to climate change

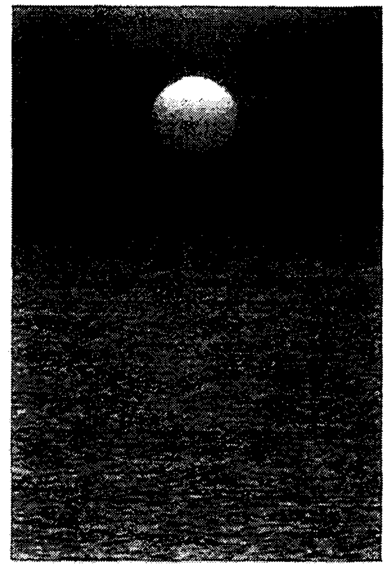
Proper management of natural resources in harmony with the overall ecology, which would also facilitate anticipatory adaptation measures, is already a worldwide concern. However, it is a slow, evolving process laden with many difficulties. Specific measures tend to focus on parts of the overall problem or on isolated ecosystems, which often seem to delay, rather than sustainably prevent environmental degradation, or natural resources depletion. In addition, climate change poses significant risks to biodiversity in itself. In our sustainable vision for biodiversity, the rate of climate change is reduced considerably. This would require substantial reductions in greenhouse gas emissions. International coordination and awareness building are adaptation measures in this context as well.

Beyond that, adaptation measures would aim at sound ecosystems, which is not a synonym for but in many situations implies protective measures. Bangladesh would, for example, protect forests and wetlands through regulations as well as community-based approaches. In addition, development would allow for species migration and buffer zones.

3.6.3 Adaptations

Adaptation measures to protect the threatened ecosystems and biodiversity from impacts of climate change include general activities to protect ecosystems as a whole, as well as activities directed toward protecting a threatened species in particular. Section V of the Executive

Summary provides a table with tentative assessment of the adaptation measures. The following adaptations may be considered as part of sustainable management of ecosystems in Bangladesh:
In considering *protection of the Sundarbans*; in addition to strengthening the ongoing activities under Sundarbans Biodiversity Programme (SBP), Sustainable Environmental Management Programme (SEMP) and Bangladesh Environment Management Programme (BEMP), a sustained *flow of water* is required in the Gorai-Madhumati system of at least 250 m^3/s. This adaptation is connected with freshwater availability. Since the feasibility of the proposed Ganges Barrage is highly controversial, some other techno-economically feasible, environmentally sound and socially acceptable options should be sought. The excavation of the Gorai River has been implemented. However, its effectiveness and downstream effects are still to be thoroughly evaluated. Regular dredging seems to be a requirement. It is not known whether the sediment creates a problem to the important tree species in the Sundarbans, and the brackish water fish species including the tiger prawn.



Coastal greenbelts as an adaptation measure in the biodiversity sector scores high both in terms of feasibility and effectiveness. Present *agro-forestry* development programs could be further expanded .

Adaptation to *conserve the 14 ecologically critical areas* of the country is absolutely necessary to warrant the sustainability of the society and food self-sufficiency. To slow the rate of depletion of organic carbon content from the top soils, efforts should be given to replenish it by adding organic fertilizers (dung, green manure etc.) along with inorganic fertilizers. The Fertilizer Recommendation Guide, periodically published by BARC, could disseminate such ideas with appropriate dosages and application advice. Given the institutional strength and social acceptability, feasibility appears to be high for such adaptation measures. *Introduction of "alien" species/genetically modified organisms* as practiced in the country is highly questionable, and only mentioned here to highlight the need for more research prior their introduction.

Reduction of habitat fragmentation, and development of migration corridors and buffer zones are identified as possible adaptation options. Geographic habitat fragmentation may threaten the ability of species to migrate or adapt to changing climate. Habitat fragmentation could be reduced through incentive programs for multiple-use management, or through the protection of important land parcels from development. Buffer zones around current reserve areas could favor protection. In the outer buffer zones or corridors more uses are allowed (Benioff and Warren, 1996). While development of buffer zones is considered under SBP, climate change considerations remain to incorporated. Some researchers believe this adaptation would not a feasible measure for Bangladesh.

Introduction of integrated ecosystem planning and management reduces the institutional fragmentation and focuses on protecting a variety of species and natural systems in connection with their users. Potential effectiveness of such methods is high, and could be attempted under ICZM or CZDP.

Stimulating *awareness, participation of local communities and users,* and *community based management* are crucial adaptation measures for the ecosystem of densely populated Bangladesh.

Community-based adaptation, i.e. the local community decides on how to share the limited common resource, could be part of the protection of ecosystems, fishing resources and mangrove belts

Breeding of threatened species has been tried successfully in some countries. For example, breeding of (controlled) game-farming enhances biodiversity by incorporating wildlife in traditional ecosystem management practices (Markham and Malcolm, 1996). This has been practiced for certain fish types in the Haor wetlands. Applicability of such adaptation for the different important species of the Sundarbans may be examined.

With the exception of studies on the effects of low flow induced increased salinity in the Sundarbans, there have not been detailed studies on the effects of changes in temperature, precipitation, and climate extremes on endemic species and ecosystems in Bangladesh.*Studies on risks from climate change to endemic species and ecosystems* would facilitate adaptation under a warmer world. More detailed studies should examine whether changes in climate would threaten the survival of endemic species or the continued existence of unique or important ecosystems. These studies could also examine the efficacy of adaptation responses such as buffer zones.

3.6.4 Possibilities and Limitations

Although changes in temperature, precipitation, and other climate change impacts are expected to have an effect on endemic species and ecosystems in Bangladesh, the extent of these effects are still very uncertain. This uncertainty affects awareness building, and the possibility of including threats to biodiversity in management policies. It is important to remember: even without climate change, human development has in many cases fragmented or reduced habitat and species population, and blocked the migration of various specie.

In the densely populated Bangladesh, it will be difficult to realize buffer zones or migration corridors. Removing land from economic production is not socially acceptable. Financial feasibility to preserve or relocate species is low as well. Technical knowledge is also limited. Thus, a concerted effort to protect biodiversity in Bangladesh may require significant infusion of capital, and training from donor agencies.

Furthermore, management of ecosystems only exists as a concept, but its institutional realization is still relatively weak, and the institutions that are involved lack the required capacity. Linking in this issue with existing projects is difficult. A number of location specific initiatives exist that are mainly initiated by NGOs and CBOs. These initiatives need to be strengthened and coordinated with the state-run programs.

Changes in land use, accompanied by increased economic opportunity and investment may be the most important policy objective for climate change adaptation. Key projects to realize adaptation include: *Sustainable Environmental Management Program (SEMP),* Bangladesh Environment Management Programme (BEMP), *Sundarbans Biodiversity Conservation Project, Forestry Sector Project, Forest Resource Management Project,* and *Fourth Fisheries Project.*

3.7 Strategic Cross-cutting Adaptations

The study recommends that Bangladesh's overall adaptation to climate change should produce a coordinated response with specific cross-cutting adaptations that affect a number of sectors at a time. For example, they relate to institutional arrangements for issues such as improved coordination, integrated planning, information management, research and international action. They are considered of crucial importance in the efforts to reduce Bangladesh' vulnerability to climate change. Not only do they prepare or are needed for the implementation of concrete actions, but they also contribute significantly to an increased awareness, which in itself is considered a core crosscutting adaptation. The principal ones are discussed in this section.

A. Coordinated Institutional Response

3.7.1 Coordination of Climate Change Activities in Bangladesh

A coordinated institutional response to climate change(CC) across the Government of Bangladesh (GOB) is needed. Coordination is needed: to analyze climate data; to make projections of climate change; to assess vulnerability to climate change; to develop coordinated research agendas and policies; and to develop guidelines for inclusion of CC impacts in resource and project planning. Without such coordination, there is potential for duplication of effort and formulation of inconsistent or contradictory policies. For example, adaptations in agriculture need to be closely coordinated with decisions in the water and coastal resources sectors. It is also important that the public, NGOs, and the donor community remain involved in coordinated climate change planning activities. In addition to natural resource/ environmental agencies, agencies such as the Ministry of Foreign Affairs should become involved, so that Bangladesh' negotiating positions for the United Nations Framework Convention on Climate Change (UNFCCC) is strengthened. There are several possible avenues for coordinating climate change activities:

The National Councils on Water Resources and Environment (NWRC and NEC). These councils will coordinate all water management and environmental activities and oversee the preparation and implementation of the national planning efforts, including the National Water Management Plan (NWMP) and the National Environmental Management Plan (NEMAP). Both councils are headed by the Prime Minister, and include the secretaries of the Ministry of Water Resources, and the Ministry of Environment and Forest. The general complaint is: these councils meet only once or perhaps a few times each year. Both Councils should be stimulated to put CC issues on their agendas, which could be realized through a more operational Climate Change Committee described below.

The Climate Change Committee (CCC). This inter-ministerial group has been responsible for coordinating climate change activities in Bangladesh since about 1992, when it was created under a climate change vulnerability assessment project supported by the Government of the Netherlands (BCAS/RA/Approtech, 1994). Since then, the CCC has been involved in several other climate change projects, including the US Climate Change Country Study Project (Assaduzzamen *et al.*, 1997) and the Asia Least-cost Greenhouse Gas Abatement Strategy (ALGAS). The CCC is chaired by the Minister of Environment and reports to the NEC. The Secretary of the Ministry of Environment was supported through the CCC when he led Bangladesh's delegation to the Fourth Conference of Parties of the UNFCCC in Buenos Aires in November 1998. However, lately CCC has become inactive. The CCC is an appropriate and operational group to carry out the coordination of adaptation activities and should be revived, strengthened and given the task to address adaptation to climate change issues.

A technical secretariat with a permanent staff dedicated to coordinating climate change adaptation activities. The secretariat could coordinate day-to-day adaptation activities among ministries, and NGOs. The secretariat need not be in the government but could be located at a CBO/NGO.

3.7.2 Integrated Planning

Integrated planning is an important crosscutting mechanism that prepares for integrated actions. Discussions on the sectoral adaptations showed that such integration is needed to reduce Bangladesh' vulnerability to climate change, in particular with respect to the coastal zone and the water resources. Following actions are recommended:

Establish a process of integrated coastal zone management. In March 1999, a Joint Donor Identification Mission structured an approach for integrated coastal zone management in Bangladesh. In a concept note (ICZM, 1999) prepared by the GOB, the proposed institutional structure considers an inter-ministerial steering committee, a technical committee, and a highly professional program development office (which would essentially prepare the ICZM plan in the course of three years). More information on ICZM (subsumed under the proposed CZDP) is provided in Appendix E.

Support and continue to improve the structure and procedures for Integrated Water Resources Planning. Water resources planning, considering changes in supply and demand of water in all seasons due to different non-climate factors such as population and income growth and urbanization, should also consider potential effects of climate change. In addition various initiatives to regulate and divert water either by physical adaptations, or operation control should be coordinated on a (sub-) national level. The NWMP is currently being revised by the Water Research and Planning Organization (WARPO) for the NWRC. The risks of climate change should be a consideration in preparing and implementing the plan. Data should be collected and examined on the dimensions and impacts of climate change on the availability and the demand of water. This is discussed in more detail later.

Community and participatory resources management. Anticipatory adaptation can be undertaken on many different levels with the individual and local level playing an important role in behavioral adaptations, which is a key factor in safeguarding the natural resource bases for human activities. Community management tends to focus on resource management, rather than on management of projects and interventions. Where possible, decisions on the use of resources should be taken on the lowest possible level. Planning of management on higher levels is justified only when impacts and interventions cross the boundaries of mandated areas with economic and financial implications that go beyond the capacity of these individuals and local communities or such planning deal with long term, intergenerational aspects.

In a community based approach, people begin to see their own interests protected by protecting their common interest. For such an approach, a decentralized, knowledge based method will be essential. For example, farmers are best informed about the shallow aquifers they are use on a daily basis, and how to abstract water from it with very economical technologies. For them, the objective is: to gain a deeper understanding of this aquifer as a common property resource that they and domestic users in the surrounding villages and towns are jointly using, and must jointly manage to maximize the benefits for everyone.

Considering the current situation in Bangladesh, this crosscutting adaptation would imply a strong support for all ongoing activities to establish and strengthen local management organizations and community-initiatives in providing them with the proper knowledge, information and legal means for functional resources management. Awareness building should reach these local communities to ensure that climate change considerations become properly embedded in decision making on this level, which is so strongly related to behavioral patterns. Community participation should be part of the planning process, particularly in the most vulnerable areas.

B. Information Needs, Management, and Dissemination

3.7.3 Research and Analysis of Climate Changes

The potential for research has grown significantly in Bangladesh in the last decade, and the participation of Bangladesh' research organizations and individuals in climate change oriented studies has drawn attention worldwide. Bangladesh is well represented in internationalfora, while organizations such as BIDS, BUET, BUP, BCAS, SPARRSO, BARC, EGIS and SWMC have been actively involved in a range of important studies and projects on climate change since the beginning of the 1990s. This is reflected in an impressive series of publications (as evident in the bibliography of this study).

The study strongly recommends that this position of Bangladesh is stimulated and promoted as much as possible. It would not only support planning and awareness building, but also enhance Bangladesh' role in the international negotiations as outlined in Section 3.7.8.

There are several avenues and platforms for incorporating Bangladeshi institutes in the climate change related research. First, existing project such as: ARMP, BEMP and SEMP, and the proposed CZDP could be used to include a more explicit component on research on climate change issues. Secondly, a research agenda may be prepared and presented for a revived CCC. The focus of such an agenda could be on the coordination between different research organizations.

Possible topics for the research agenda are described below.

Estimates of regional climate change. There remains significant variations among the climate change scenarios. In particular, some show increased annual precipitation while others show decreased annual precipitation. There is even more uncertainty on seasonal and local scales. Regional climate data monitoring and recording networks should be maintained and enhanced. In addition, there needs to be sufficient support for analysis of data to examine changes in climate and variability.

A number of developments can help including:

- *More detailed regional models.* One advantage of regional models over the general circulation models is that they have much higher spatial resolution, and thus can better capture regional topographic features.

- *Improved understanding of the role of sulfate aerosols.* Sulfate aerosols can have a very significant effect on the climate of South Asia. Some climate model studies show that when increases in sulfate aerosol emissions are included, precipitation in the region is estimated to drop (e.g., Lal, 1995a). Other climate models show rising precipitation. Resolving this uncertainty about the direction of these meteorological variables, particularly precipitation, would be very helpful in making anticipatory adaptation decisions (i.e., preparing for more floods, more droughts, or both).

Weather and disaster forecasting. Improved short-term (up to one week), medium-term (monthly to seasonal), and long-term (one year to decade) forecasting is needed for several reasons. Among other benefits, this will provide better information to farmers for planting decisions and for emergency response, and to relief organizations to prepare for the aftermath of cyclones and floods.

Demand oriented measures. Little is known on the feasibility of so-called demand oriented measures in Bangladesh. Such measures aim to change the behavioral pattern of individuals and economic activities and are considered important tools in natural resource management and therefore in the anticipatory adaptation for impacts of climate change. Experience has to be built up with measures including water pricing, setting quota, licensing and trading in emission rights. Related is the discussion on market reforms and an enhanced role for the private sector.

Social and economic consequences of climate changes. The identified impacts focus on impacts on the natural systems. Assessment of these impacts, however, is not possible without an improved knowledge of their social and economic consequences. An important related issue is: several of these impacts seem to accumulate in certain regions and concentrate on certain social groups. These effects might combine with other vulnerabilities, for example with pest attacks and earthquakes, which would significantly contribute to the vulnerability of these regions and groups to climate change.

Taking advantage of traditional knowledge. For thousands of years, Bangladeshis have faced common natural hazards of the area, including floods, salinization, and cyclones. They have developed many adaptation techniques and innovations to address climactic variability. These include construction of flood and cyclone shelters for protecting humans and livestock during these natural hazards; using floating rice seed beds to move the seed rice along with the people if they were flooded out of the homesteads (to ensure that they would have some rice seeds to plant after the floods receded); burying dry food (e.g., dried rice and molasses) in sacks underground during cyclones (so that even if the house and its contents get blown away, there would be some food remaining after the cyclone passed).

These adaptations may be useful in coping with climate change. Therefore, it may make sense to not only study and document the existing adaptations that people have already made to deal with climate related phenomena but also to find means of enhancing the adoption of such adaptations that have the advantage of being indigenously developed and hence are far more likely to be adopted by local people than any new or foreign technology.

Proper documentation is important in the IPCC context, which has adopted a policy of only using well-referenced documentation. IPCC work has already been criticized for ignoring the massive experience that exists in the vast area of traditional knowledge. As it moves gradually into the area of adaptation, these experiences become important to document. A study is proposed for Bangladesh to fill this gap.

3.7.4 Development of a Climate Change Knowledge Base

Without a continuous and reliable stream of data with broad geographic coverage, it is difficult to determine if and how climate is changing. Development of a modern knowledge base (integrated and widely shared) to support policy and development planning is therefore of great strategic importance to Bangladesh.

Bangladesh faces grave social and economic risks if it is not capable of adapting to climate change. But climate change is gradual and difficult to differentiate from the high background variability in climate conditions that Bangladesh faces normally. While this is especially true in upland areas of Bangladesh, the coastal zone offers a greater potential for monitoring to detect changes and trends, and to promote effective and timely adjustment and adaptation. This is unlikely to be possible without a sound, modern information system, improved and more cost-effective monitoring, and requisite institutional changes including more open sharing of information. The present efforts by the Bank and the Government to develop an integrated information system including GIS for the coastal zone, and the ongoing NWMP process, offer an important opportunity to move ahead on such a proposal and to make the necessary institutional changes. This study adds an important dimension to these activities by introducing a long-term strategic perspective needed for climate change adaptation.

3.7.5 Preparation of Guidelines for Planning and Design

An important recommendation in the short to medium term, is the preparation of more concrete predictions of physical changes based on a range of climate change scenarios, and the development of criteria by which proposed projects could be evaluated with respect to these climate change scenarios, just as they might be evaluated with respect to social transformation, economic impact or other project evaluation criteria. These predictions and criteria should then be translated into practical guidelines for planning and design.

Preparation of a practical guideline for including climate change scenarios in planning. As mentioned earlier, including climate change issues in planning faces methodological problems related to different time horizons and uncertainties. Planning guidelines for climate change issues would agree on best possible approaches compatible with international scientific findings and state of the art technology. The following main issues are proposed to be covered in the guidelines.

- A best possible assessment of the expected impacts. This report in Chapter 2 provides an estimate, which could be a start for building consensus on a set of impacts to be considered in planning.
- Typology of anticipatory adaptation measures, which would facilitate planners to concretely think about such measures.
- Framework for the analysis and assessment of possible adaptation measures. Such a framework would establish a methodology on how to analyze and assess a reduction in vulnerability to climate change. Traditional cost-benefit analyses are inadequate to deal with such an assessment. However, other techniques, using multi-criteria analysis seem more suitable. The problem is the prediction of climate change, not the evaluation of a project vis-a-vis climate change effects since the latter are manifested in changes in conditions that are quite typical of the considerations that must be addressed in most development projects today (flood level, drainage, water supply, salinity, etc.). Nevertheless, in the short run this would be quite controversial and difficult to do with confidence because of the predictive uncertainty, and the possible tradeoffs that might have to be made to accommodate a climate change scenario. Over time, the analytical framework for analyzing climate change scenarios in terms of their effects could strengthened (as it should be within or through WARPO since this is well within present Bangladeshi capacity), and these scenarios and criteria could become more integrated into the development thinking in Bangladesh.

Prepare a guideline to incorporate climate change in the design of infrastructure such as barrages. Design for new infrastructure should include climate change scenarios such as those presented in this report. Given that infrastructure can have a lifetime of decades or more (and that it can be cost-effective to marginally change the design of infrastructure before it is built), planners should evaluate the effect of climate change scenarios to assess whether marginal changes can reduce risks from climate change. The potential for increased flooding can be incorporated in the design and in location of roads and bridges. In addition, planners should consider whether climate change will affect the functioning infrastructure. For example, in the case of barrages, planners should examine whether climate change could result in too little flow going over the barrages, and would require alterations at a later date. Benefits of infrastructure under current climate and the costs and probabilities of altering the infrastructure under climate change should be compared. Protocols should be developed giving directions on how to incorporate climate change in the design of infrastructure.

3.7.6 Climate Change Impact Assessments (CCIA)

Part of the integrated planning approaches, discussed in Section 3.3.2, could be a more formal obligation to make a CCIA and present such an impact assessment to the CCC under the NEC. Pilot CCIAs could be made in close coordination with the development of planning guidelines (Section 3.3.5). Based on such experience, a recommendation could be made on which development activities should include a CCIA.

3.7.7 Awareness Building and Dissemination

The Third Assessment Report of IPCC (TAR, expected in the year 2001) will provide a first serious analytical look on adaptation possibilities and implications. It is likely that answers to the questions concerning who would adapt, what would they adapt to and how would they adapt etc. will be made available in the TAR. It is also expected that it will provide important guidelines for further actions, coordinating national and international activities towards achieving sustainable development, which is enshrined in the Kyoto Protocol. Once it is released, the report is expected to play a vital role in international awareness building.

It is necessary to tie up national awareness building programs with international programs. Towards this end, some important steps are now being taken in Bangladesh. Under the SEMP, environmental cells were created in 13 line ministries. They will have monthly coordinating meetings. A Sustainable Development Network Project under the sponsorship of the Ministry of Environment and Forest is also being implemented as part of SEMP. Both activities are important mechanisms for awareness raising. It might be useful to organize a short training on climate change issues for the members of the environmental cells. Feasibility for such scoping exercise is high.

To strengthen the Department of Environment, the Bangladesh Environmental Management Project (BEMP) is about to start. BEMP will also be used as a vehicle to create awareness on environmental issues. Under the purview of BEMP, a guideline on climate change impact assessment may be formulated and shared among other ministries.

Global Water Partnership has been instrumental in bringing global consensus on regional and global level water management issues to facilitate sustainable development and to resolve water-related conflicts. There is a Bangladesh chapter working on different aspects of water. Climate change adaptations, especially in water sector, could be disseminated by Bangladesh Water Partnership. This platform of the civil society could be instrumental in creating awareness. Similarly, the Climate Change Committee (CCC) could play a major role in raising awareness in the ministries concerned.

Effective understanding of the potential impacts of climate change and development of adaptations require involvement of the academic community, professionals and the public. Non-governmental research institutes such as Bangladesh Centre for Advanced Studies (BCAS), the Bangladesh Unnayan Parishad (BUP), and the Bangladesh Institute of development Studies (BIDS) can help carry out research in conjunction with the government institutes and raise awareness on climate change related issues in the country. The Association of Development Agencies in Bangladesh (ADAB) in coordination with the Coalition for Environmental NGOs (CEN) can disseminate the information at the grassroots level.

For creating general awareness, media can play the most vital role. The Federation of Environmental Journalists of Bangladesh (FEJB) should have a role, especially under the SEMP, in raising awareness about climate change related issues and adaptation possibilities in the general public. Since the number of educated people at the grassroots is still low, awareness raising by involving the printed media might not be feasible. In many cases, television is a better medium to carry the message. The Ministry of Information (MOI) should assume greater responsibility to inform people about the imminent adverse impacts and, more importantly, about the possibilities of low cost adaptations for average Bangladeshis.

C. International Positioning and Representation

3.7.8 International Activities; Addressing the Causes of Climate Change Impacts

A special type of adaptation measure focuses on the causes or sources of climate change, which are considered to be exogenous. They are not under the exclusive control of the planners and policy makers in Bangladesh, but can be and should be addressed in the international arena. Examples refer mainly to cross-boundary river flows and mitigation of green house gas emissions. Special attention should be given to the following two activities.

- *Actively participate in all international debates on climate changes.* Although Bangladesh' contribution to global greenhouse gas emission is less than 0.1%, the magnitude of the climate change impacts will be greatly influenced by the level of reduction of global emission. Therefore, Bangladesh (already member of all the most relevant conventions) should become a much more active participant in the international efforts addressing the underlying causes of the impacts of climate change. The actual level of knowledge and expertise in Bangladesh greatly facilitates such a role; the research proposed in section 3.7.3 would further enhance this. Contributions of Bangladesh should specifically stress the mitigation of greenhouse gasses where adaptation is not effective or feasible (e.g. in the ecosystems/biodiversity sector). In addition, Bangladesh should more actively promote international support to implement (costly) adaptation measures.

To strengthen its negotiating position, the government could convene a multi-ministerial task force at a suitably high level with representation from all relevant ministries, agencies and the non-government sectors. This task force could develop a strategy for Bangladesh for the international negotiations as well as for other actions to be taken within the country.

On the negotiations front, it is necessary to take a long term strategic approach to climate change negotiations which means setting up a permanent team of negotiators that regularly takes part in all the Conference of Parties (COP) meetings and in the inter-sessional meetings where much of the actual negotiations takes place (see Appendix C for more information on COP). The negotiating team should be backed up by a national team of experts that studies the issues and prepares strategies for Bangladesh to adopt and advocate in the negotiations. If deemed necessary, knowledgeable international experts can be engaged to facilitate Bangladesh in advocating its negotiating position.

In addition to the formal COP meetings, other relevant meetings such as the UNFCCC Subsidiary Bodies and the Intergovernmental Panel on Climate Change (IPCC) include detailed science of climate change and expert level debates/discussions of Clean Development Mechanism (CDM) etc. Again, Bangladesh must take a pro-active position and participate actively in these important meetings.

Several Bangladeshi experts already serve on key positions in the IPCC, including in writing the Third Assessment Report (TAR) currently under preparation. They will be able to raise the important issues for Bangladesh (such as Adaptation and Sustainable Development). However, in order to be more effective, these efforts need to be coupled with a capable negotiating team representing the government at the negotiations.

- *Incorporate climate change considerations in water sharing and other negotiations.* India and Bangladesh share 54 rivers. The river flows could be significantly affected by climate change. A treaty on sharing the Ganges waters at Farakka was signed in December 1996. This treaty also provides a commitment for settling water-sharing arrangements of all common river basins. Such negotiations should include contingencies for changes in runoff and demand due to climate change. Research indicates to an increase in the intensity and frequency of extreme natural disasters (floods and cyclones) and sea level rise. Adjustment to these conditions is beyond the reach of Bangladeshi farmers or private investors in Bangladesh. Climate change effects on flood frequency and intensity in the Ganges and Brahmaputra basins, for example, may in the long term be much more important to the dialogue with India than dry season water sharing. Importance of dam and hydroelectric power construction in India and Nepal, and greater use of Bangladeshi gas reserves in the basin, may lie more with its potential to reduce green house gas emissions rather than dry season flow augmentation.

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Appendix A
Some Basics on Climate Change

What is Greenhouse Effect?
About one percent of the earth's atmosphere is composed of green house gases, primarily water vapors, carbon dioxide (CO2), ozone, methane and nitrous oxide. Together, these gases reflect enough heat back to the earth to maintain average temperature of the atmosphere at around 60 °F. Without the greenhouse effect, the earth would be a cold uninhabitable place. For example, Mars has an average temperature of -27° F (since its thin atmosphere supports virtually no green house gas effect).

Human Influences
Human-beings influence global warming by adding to the greenhouse gases naturally present in the atmosphere.

Fossil Fuels: The supply and usage of fossil fuels account for about three-fourth's of humankind's CO2 emissions. The burning of coal, natural gas, and oil yields most of the energy used to produce electricity, heat houses, run automobiles, and power factories.

After CO2, methane is the second most important green house gas. It is produced when bacteria decomposes organic matter. About a quarter of global methane emissions from human activities comes from livestock and the decomposition of animal manure.

Deforestation: Trees remove CO2 from the air as part of their breathing process. Destruction of large forests has reduced the number of trees available to clean the air. With clearing of forests, most of the carbon in: burned or decomposed trees escape into the atmosphere.

In contrast, humans create temporary, localized cooling effects through the use of aerosols, such as smoke and sulfates from industry, which reflect sunlight away from earth.

What is Known about Climate Change

- The earth on average has warmed over .5 to 1° F over the past 100 years & CO2 abundance in the atmosphere is likely to double by 2100. With that, best estimates show about 1 to 5°C increase in temperature averaged over the globe, and a 15 to 95 cm sea level rise. The higher range of temperature would exceed the natural changes over the past 10,000 years.

- Climate is a non-linear system.

- Climate change is real, and would be slow to reverse.

- Exactly where (region), when (rate of change), and how much (magnitude) is hard to predict.

- In Bangladesh, however, with the high end estimates, sea level rise would inundate 17.5% of the country by 2100, salinity will increase. Even by 2050, both flooding and droughts will increase with 10% increase in rainfall; increased probability of extreme wet year would increase by seven fold; probability of dry years such as 1972 will increase by 4.4 times; interpolations[1] show that even with 60 cm rise in sea level, the Sundarbans will be lost with severe effects on the country's eco-system.

[1] These interpolations are approximations, and do not consider the existing/future embankments, contour of land currently within 1 m of sea level, changes in sedimentation etc.

Mitigation on a Global Level—Reaching the Developing Countries[2]
On January 18, 2000 the World Bank launched the **Prototype Carbon Fund (PCF)**—the world's first market-based mechanism to address climate change and promote the transfer of finance and climate-friendly technology to developing countries.

According to James D. Wolfensohn, president of the World Bank, "The PCF offers a tremendous opportunity to boost financial and technology flows to developing countries at a time when government-to-government transfers have fallen to historically low levels. We are determined to explore how market-based mechanisms such as the PCF—involving the considerable financial muscle of the private sector—can contribute to addressing the **twin challenges of climate change and sustainable development**."

"We are concerned about the vulnerability of poor people in poor countries to the threat of climate change. For an institution whose task is to alleviate poverty, we would be negligent if we failed to explore innovative ways of making the climate change convention work," he said.

Governments have recognized the seriousness of the threat of climate change, and during the 1990s negotiated the Framework Convention on Climate Change and the Kyoto Protocol. The protocol, which guides implementation of the convention, includes specific emissions-reduction targets for industrialized countries. It also contains provisions allowing them some flexibility so that they can meet these commitments to reduce emissions in the most cost-effective manner.

The PCF, established in the World Bank with contributions from governments and private companies, is an ambitious first attempt to experiment with the creation of a market in emissions reductions under these "flexibility" provisions. It will invest in cleaner technologies in developing countries and transition economies, thus reducing their greenhouse gas emissions. These emissions reductions will be independently verified and certified, and then transferred to the fund's contributors in the form of emissions reduction certificates rather than cash.

"There are many opportunities to reduce emissions of greenhouse gases in developing countries," says Ken Newcombe, manager of the PCF for the World Bank. "It is the difference in cost to industrialized and developing countries of reducing greenhouse gas emissions that provides the opportunity for mutually beneficial trading relationships." During the next three years, the World Bank will invest all the fund's capital in about 20 projects. Most are expected to be linked to projects identified by the Bank as part of its regular work, but they can also originate from the private sector, other multilateral development banks, and bilateral donors. The primary focus will be on renewable energy technologies—such as wind, small-hydro, and bio-mass energy technology—that would not be profitable without revenue from emissions reductions sold to the PCF.

As the manager of the PCF, the World Bank acts as a broker in helping to negotiate a price for the emissions reductions that is reasonable for both buyers and sellers. In this process, developing countries will benefit by acquiring cleaner technology and making a profit from trade in a potentially plentiful "product"—greenhouse gas emissions reductions. Industrialized country contributors gain by paying a lower price for emissions reductions than available in the context of their own companies or countries.

2 Information under this heading has been compiled from a World Bank news release, Jan 18, 2000 and news stories from the Bank's Daily Online newspaper *Today* (April 13, 2000 and April 24, 2000)

"There are many opportunities to reduce emissions of greenhouse gases in developing countries at a cost of between \$5 and \$15 dollars a ton of carbon. This compares with a marginal abatement cost of upwards of \$50 a ton of carbon in advanced economies. It is the difference in cost to industrialized and developing countries of reducing greenhouse gas emissions that provides the opportunity for mutually beneficial trading relationships," said Ken Newcombe, manager of the PCF for the World Bank. "We will endeavor to negotiate prices for emissions reductions at about \$20 a ton of carbon (\$5 a ton of $CO2$), thus covering the regulatory and market risks to contributors while providing adequate incentives to project sponsors and their governments in developing countries."

The emission reductions from PCF projects may eventually be used against industrialized countries' commitments to reduce their greenhouse gas emissions. Under the Kyoto Protocol, by the end of 2012, they must bring the emissions down to at least 5.2 percent below their 1990 levels. Whether the emission reductions earned by the PCF will count towards these commitments depends on rules being developed by the Parties to the UN Framework Convention on Climate Change that should be defined when the Parties meet in The Hague in November 2000.

During the next three years, the World Bank will invest all the fund's capital in 20 or so projects. Most are expected to be linked to projects identified by the World Bank Group as part of its regular work, but they can also originate from the private sector, other multilateral development banks, and bilateral donors. The primary focus will be on renewable energy technologies—such as wind, small-hydro, and bio-mass energy technology—that would not be profitable without revenue from emissions reductions sold to the PCF. In some cases, the PCF will finance such projects through local carbon funds modeled on the PCF but using financing from local commercial and development banks, as well as private companies.

With this year's Earth Day focus on climate change, the World Bank announced on April 22, 2000: that the Prototype Carbon Fund (PCF) had closed its first subscription period with more money and corporate interest than anticipated.

An amount of \$135 million has now been subscribed to the PCF by 15 companies and six countries. This is well in excess of the \$100-120 million target and just \$15 million short of the \$150 million legal cap placed on the fund by the Bank's Executive Board. The cap was not expected to be reached until a second closing in a year's time. Meanwhile, another nine companies have indicated they want to participate, although they were unable to finalize arrangements for their participation before the first closing.

"The high level of corporate interest in this venture marks a major shift in how companies think about their role in contributing to new thinking about global problems such as climate change. It also points to growing competition among corporate players anxious to position themselves in what will likely become a highly competitive market," said World Bank Vice President for Environmentally and Socially Sustainable Development Ian Johnson. "We are also delighted by the strong support from six governmental participants."

In order to accommodate interest in the fund, the Bank's management has decided to ask its Executive Board to raise the \$150 million cap and bring forward the second closing to June 30, 2000. While not all nine companies are expected to join by the end of June, subscriptions in the fund are likely to go above the initial cap of \$150 million. Companies that have invested in the fund include BP Amoco; Deutsche Bank; the electric utility company Electrabel of Belgium; Gaz de France of France; the Japanese electric power companies of Chubu, Chugoku, Kyushu, Shikoku, Tohoku, and Tokyo; the Japanese trading companies of Mitsui and Mitsubishi; the

German power company RWE; and the Norwegian companies Norsk Hydro ASA and Statoil. Corporate investments in the fund are set at $5 million. Countries must contribute $10 million each. Canada, Finland, The Netherlands, Japan (through the Japan Bank for International Cooperation), Sweden, and Norway have subscribed.

As mentioned earlier, in the Prototype Carbon Fund, the primary focus is on renewable energy technologies—such as wind, small-hydro, and bio-mass energy technology—that would not be profitable without financial support from the PCF.

This Fund is just one part of the Bank's efforts to respond to the likely impact of climate change on developing countries, which are particularly vulnerable to sea-level rise, severe weather conditions, desertification, and other climate-related phenomena. The Intergovernmental Panel on Climate Change estimates that the economic costs to developing countries of climate change could reach 5 to 9 percent of their GDP.

Loans for renewable energy made by the World Bank—with its own resources and those of the Global Environment Facility, of which the Bank is an implementing agency—amount to about $2.6 billion. According to *Today*, this constitutes the largest single renewable energy portfolio of any agency in the world, and accounts for 10 percent of the Bank's lending to the energy sector over the past six years.

Appendix B
Defining Vulnerability to Climate Change and Adaptation Responses

B.1 Purpose

This appendix attempts to define the factors that contribute to vulnerability to climate change. It addresses topographical, biophysical, and socioeconomic factors that affect vulnerability. These are defined in order to identify adaptations that can be taken to reduce vulnerability in the anticipation of climate change. Although this report focuses on Bangladesh, these vulnerability factors can be applied anywhere. Addressing factors that affect vulnerability to climate change includes consideration of how affected systems or actors may respond to climate change (autonomous adaptation). The purpose is to define the limits to such adaptation so that the need for proactive adaptation (adaptation taken in advance and in anticipation of climate change) can be identified.

B.2 Sensitivity vs. vulnerability

Vulnerability to climate change is a function of the first-order biophysical change and the effectiveness of the response to that effect. Impacts of climate change are first felt in biophysical effects. Sea level rise inundates low-lying coastal areas, stronger cyclones result in increased coastal flooding, changes in crop yields, runoff changes, risks of spread of infectious diseases changes, vegetation changes, etc. The Intergovernmental Panel on Climate Change (IPCC) identifies these biophysical effects as the sensitivity of system to climate change (Watson et al., 1996).

Many impact studies examine only these biophysical effects and they are (rightly) criticized because they do not consider the potential for the affected systems to adapt to the climate change impact. Plants and animals may migrate to new locations (although topographical barriers such as oceans or human development may impede or block such migration). People can change behavior in response to a climate change impact. For example, a farmer seeing crop yields decline may switch planting dates, change varieties, add fertilizer or irrigation, or make other changes.

Such adaptations are referred to as autonomous or reactive adaptations because they are in response to an observed impact of climate change. These terms imply that affected actors can reasonably be expected to make these adaptations on their own. Presumably they have the resources, knowledge, and freedom to make the adaptations.

The term vulnerability is the net damage (or gain) to the system after autonomous adaptations are made (Watson et al., 1996). For example, if a farmer sees the climate getting hotter, switches to a more heat tolerant variety, and maintains his income, there is virtually zero net effect of climate change. The farmer has then, successfully adapted to climate change.

A system is vulnerable to climate change if autonomous adaptations cannot mitigate the damages from climate change or if the autonomous adaptations are so costly, those adapting are worse off (e.g., have less money because of the cost of adaptation). This can take several forms, including:

- ***Ineffectiveness of autonomous adaptation.*** In some cases it is not possible for autonomous adaptation to mitigate the climate change impact. Climate change could result in a flood exceeding the design specifications of already built flood control works. Lives and property will be at risk. Autonomous adaptation can reduce risks of only future floods. Modifying behavior may not completely mitigate the damages. A farmer may switch crops but yields or revenues may not be as high as before the climate change.
- ***Cost of the autonomous adaptation.*** Some autonomous adaptations may be costly and leave the actors with less income or wealth. For example, building coastal defenses may protect against

sea level rise, but may also be expensive. In developing countries, money may be diverted from other development activities to cope with climate change.

- *Negative effects of autonomous adaptation on other systems.* In some cases, an actor can mitigate the negative effects of climate change through autonomous adaptation, but this may result in negative effects on other systems. A sea wall may protect the property inland of it, but may serve as a barrier to migration of wetlands. A farmer may apply pesticides to combat new pests, but this could harm water quality.

Vulnerability to climate change is a function of whether a system is:

- *Robust.* This is the ability of a system to absorb a change in climate and continue to operate or provide services as before the change. A plant may be able to withstand higher temperatures or flood protection measures; flood works may be able to protect against a larger flood. Robustness has its limits because any system will partially or completely cease functioning at some level of climate change.
- *Resiliency.* This is the ability of a system to recover from a climate change impact. An animal may migrate to a new location or farmers can switch crops. One concern about resiliency is the extent to which climate change imposes initial damages before an adaptation is made. For example, the farmer may lose a crop because of climate change and then switch to a new variety. Even though he may have restored future income, income from that one (or more) affected crop has been reduced.

B.3 Factors that affect vulnerability

There are several general factors that determine vulnerability of a system to climate change. Such characterizations can be used in two ways to examine the need for considering climate change in a sustainable development program. The first is: to help identify vulnerabilities to climate change and where proactive adaptation needs to be considered. The second is: that identifying characteristics that contribute to vulnerability can be used to identify proactive adaptations that would change these characteristics.

The factors that affect vulnerability to climate change can be divided into three groups: climate, biophysical, and socioeconomic.

Climate Factors

The type of current climate in an area can help determine vulnerability to climate change. Arid or semi-arid areas tend to experience more variance, and droughts and floods. These areas could experience greater changes in such events. For example, arid and semi-arid areas tend to have greater changes in runoff for a given change in climate (e.g., +2°C) than humid areas. Areas already subject to extreme events may be subject to more extremities in the future. Frequency or intensity of floods, droughts, cyclones, or other extreme events could change and possibly increase because of climate change.

The nature of the change in climate also affects the sensitivity and ultimately the vulnerability of systems. A higher magnitude of climate change is likely to exceed tolerance thresholds, and a faster rate of climate change can exceed the ability of systems to autonomously adapt. For example, a plant may be able to tolerate higher temperatures or drier conditions up to a point. However, rapid climate change may result in climate zones shifting faster than plant communities can migrate.

Changes in climate variability, particularly extreme events, are important. An increase in average precipitation will most likely result in an increase in extreme precipitation events. This will increase either the frequency of rainfall events above a certain magnitude (the 100 year event is now a 50 year event) or the magnitude of certain frequency events (now the 100 year event has more precipitation). In addition, it is possible that the variance of climate events will change. In other words, extreme events could increase faster than less extreme events. Climate models have found that not only does total precipitation increase with climate change, but the increase in precipitation tends to be concentrated in the higher precipitation events (IPCC cite). Higher sea surface temperatures could increase cyclone intensity, but not necessarily frequency (Henderson-Sellers and Zhang, 1997).

Note that not all changes in variance necessarily increase the negative effects of climate change. Many studies project and even record more increase in minimum daily temperatures than maximum daily temperatures. Although this has certain adverse effects, it may be preferable to having a greater increase in minimum daily temperatures than maximum daily temperatures.

Biophysical Factors

The are numerous biophysical factors that affect the sensitivity of systems to climate change, including the following:

◆ ***Low-lying coasts.*** Deltas and low-lying coastal areas are more vulnerable to sea level rise and increased intensity or frequency of coastal storms than coasts dominated by cliffs.

◆ ***Mountainous areas.*** Mountainous areas tend to be more vulnerable to flooding from extreme precipitation events than flat areas.

◆ ***Vegetation close to heat or drought tolerance.*** The existence of natural vegetation or crops that are close to heat or drought tolerances (or have a narrow range of temperature or soil moisture they can tolerate) increases risk to climate change. Crops with low tolerance for higher temperatures will have reduced yields should frequency of hot cropping seasons increase.

Socioeconomic Factors

Socioeconomic factors tend to affect the ability of a system to absorb (robustness) or respond to climate change (resiliency). These factors include the following:

< ***Per capita income.*** Wealthier societies have more financial resources with which to respond to climate change. Adaptations such as building infrastructure are more affordable in wealthy countries. Income is also correlated with many of the factors listed below.

< ***Health of the population.*** Healthier populations will tend to be less vulnerable to such climate change effects as changes in extreme heat events, diseases, food production, or life threatening extreme events. Factors such as nutrition and access to health care are important, and per capita income is strongly correlated with these. For example, access to health care affects the sensitivity of a population to outbreaks of disease.

< ***Education.*** A well educated population can better understand changes in behavior or technology that may be necessary to cope with climate change. Higher level of education increases people's technical and scientific awareness, which can be useful in coping with climate change.

< ***Information networks.*** Having networks to disseminate information to people about climate change can reduce vulnerability and help in adaptation. Flood or cyclone warning systems enable people to take preventive measures should such extreme events be forecast. Information dissemination networks or systems such as agriculture extension services can be used to provide information on climate change risks and adaptation or disseminate adaptation technologies to particularly affected groups.

< ***Research capacity.*** Climate change may necessitate the development of new varieties of crops and better systems for managing natural resources. A country's research capability or access to research networks can reduce its vulnerability to climate change.

< ***Population density.*** Population density will tend to increase risk to climate change because the potential for migration is reduced. People living in low-lying coastal areas have fewer places to go in densely populated countries than in more sparsely populated countries. Population growth is also important. High population growth rates tend to reduce per capita income and health--factors that contribute to vulnerability.

< ***Country size.*** If everything else is equal, a country with larger area will be less vulnerable to climate change than a smaller country. A larger country to likely to have a broader range of climates. Unfavorable weather in one part of the country may be compensated by good weather in another part. A larger country will tend to have more area for people to migrate to if necessary.

With the exception of country size, the factors listed above tend to be correlated with development, i.e. the level of development increases these factors, reducing vulnerability to climate change. The course that development takes can in some ways increase vulnerability to climate change. This is the case particularly if development results in the following:

- ***Institutions that discourage adaptation.*** Land tenure, subsidies, and command & control economies may be tied to particular uses of climate sensitive systems. For example, subsidies given to farmers to grow particular crops in specific locations discourage farmers from switching crops as necessary to adapt to climate change.

- ***Infrastructure with limited robustness to climate extremes or change.*** Infrastructure for managing climate sensitive resources (e.g., flood protection) with narrow tolerances for increased extreme events will result in higher vulnerability to climate change compared to infrastructure with wider tolerances.

- ***Use of resources that increase sensitivity to extreme events.*** Resources can be developed in a manner that increases sensitivity to extreme events. Areas vulnerable to coastal or riverine flooding may be developed increasing potential losses from increased sea level rise, or increased coastal storms or floods. High ratios of demand to supply of water resources increases vulnerability to drought.

Appendix C
A Brief History of Water Resources Development in Bangladesh

The effort to develop water resources in Bangladesh has a 40-year history, spanning from 1957 to 1998. During this period, under various governments in the erstwhile Pakistan and Bangladesh, water resources development shifted noticeably. These shifts have affected the natural regime of water in Bangladesh, and especially its people. Changes made to land and environment through implementation of the various policies over time have complicated management of water resources in Bangladesh. Beyond the present climate variability, future changes in climate due to global warming will complicate the management of water resources in Bangladesh. This appendix discusses the water resources development policies recommended and implemented in the last four decades.

The Krug Mission (1957)
Bangladesh endured severe floods in three consecutive years, 1954, 1955, and 1956. The then Government of Pakistan asked the United Nations to send a mission to investigate flooding problem in Bangladesh. The UN sent a technical assistance mission to Bangladesh, under the leadership of J.A. Krug.

The mission considered two serious issues in its assessment: the scarcity of information on flood hydrology, and the flatness of the country. It made several recommendations that set the background of flood control efforts in Bangladesh:

- construction of embankments, interbasin transfer of flood waters, river training, flood zoning, flood warning and forecasting, construction of a barrage on the Teesta River, and dredging for navigation and drainage of flood waters
- establishment of an autonomous water and power development authority
- cooperation and negotiation with India
- early implementation of the Ganges-Kobadak Irrigation Project and Kaptai Hydro-Power Project.

The mission mainly focused on the policy of flood control rather than broader water resources management. It did not recommend a holistic approach of water management in Bangladesh, but the mission did point out the necessity of an institution to plan, design, implement, and monitor flood control and irrigation projects in Bangladesh. It also strongly recommended the collection of a wide range of hydro-climatic data for flood control and irrigation planning.
Following the recommendation of the Krug Mission, the East Pakistan Water and Power Development Authority (EPWAPDA) was created in 1959. With the creation of the EPWAPDA, water resources planning in Bangladesh was given an institutional shape. However, the mandate of the EPWAPDA was not broad water management in Bangladesh, rather it mainly addressed activities concerned with flood control. Within a few years of its creation, the EPWAPDA installed equipment and started operating a large number stations basically for collecting rainfall data in various parts of Bangladesh.

The 1964 Water Master Plan
The year the EPWAPDA was created, it decided to prepare a master plan for flood control in Bangladesh, despite the meager amount of hydro-meteorological data and inadequate knowledge on the flood hydrology of the rivers in Bangladesh, including the Ganges, the Brahmaputra, and the Meghna.
The IECO published the Master Plan in 1964. The planning horizon was considered to be 20 to 25 years. The Master Plan focused on the development of agriculture and irrigation with the aid of implementation of flood control and drainage (FCD) and flood control, drainage, and irrigation (FCDI) projects. The main recommendations of the Master Plan were as follows:

- divide Bangladesh into four geographical regions based on hydro-meteorology

- implement 59 large FCD and FCDI projects by 1985 to meet the demand of food warranted by the increased population.
- of the total 8.75 million ha cultivable land, ensure that 4.9 million be made flood free
- expand irrigation facilities to 3.1 million ha by the end of the planning period
- install pump stations if flood control and drainage by regulator and gravity irrigation are not feasible
- use low lift pumps until the construction of barrages on the Ganges and the Brahmaputra
- consider the potential of the use of groundwater for irrigation in some areas of the country.

Unlike the Krug Mission Report, the Master Plan did not address the broader water management issues in terms of climatic extremes, environmental and institutional aspects, and people's participation. For example, the effects of drought on crop plantation, growth, and yield could be more severe than those of floods, but the Master Plan did not address drought. The environmental aspects (short and long term) were ignored. The EPWAPDA was considered to be the sole agency for water development, and the roles of other agencies like EPADC, BITWTA, BIWTC, and the Department of Fisheries were not taken into account. Just one year after the formal publication of the Master Plan, the World Bank (1966) criticized it for its many limitations. The Bank recommended that "the plan could be accepted as a framework for further analysis and planning. But before being accepted as a Master Plan for guiding future development it would require modifications" (World Bank, 1966). The Bank recommended implementation of smaller, quick yielding, and less capital intensive projects; data collection and analysis, and strengthening of institutional linkages.

The FCD Projects: The CIP, MDIP, and DND Projects

The Chandpur Irrigation Project (CIP) covers an empoldered area of 57,000 ha in the Chandpur and Luxmipur districts. The Meghna and Dakatia rivers flow on the west and north side of the CIP area. The other two sides are not bounded by rivers.

The project area was designed to provide flood protection, drainage, and irrigation to the area inside the polder. Before its implementation, the area was subjected to frequent flooding in the monsoon, when the adjacent rivers, especially the Meghna, attain high flood stages.

Since the project was commissioned in 1978, it has provided protection from frequent flooding. However, the project has created drainage problems in many of its central areas. Because of inadequate drainage canals, the main reversible pump house and the regulator are unable to drain water from heavy rainfall. Along the west side of the project, erosion of the Meghna river banks during 1988 and 1998 floods has threatened the project. The Bangladesh Water Development Board (BWDB) had to reconstruct the embankments at significant cost to save the project. In 1998, the BWDB spent significant amount of money for manufacturing concrete blocks to protect the embankment from erosion and thereby to reduce chances of breaching by the flood waves (personal communication, BWDB, 1998).

The Meghna-Dhonagoda Irrigation Project (MDIP) is one of the largest FCDI projects in Bangladesh. The MDIP is 60 km southeast of the capital city of Dhaka. The west side of the project is also bounded by the Meghna River. Due to erosion of the Meghna River, the main embankment had to be shifted inside many times. The embankment was breached severely during the 1988 flood and a large area that was supposed to be protected from floods was engulfed.

The Dhaka-Narayangonj-Demra (DND) project was constructed about 30 years ago. Initially, the purpose of the project was to provide flood protection and drainage facilities to the project area. Because of its proximity to Dhaka and Narayangonj, over the years the project area turned into a densely populated settlement. The project was implemented based on a design flood of 20-year return period (Janakantha, 1998). In 1988, the water level outside of the project was 6.36 m. However, during 1998 flood, the water level increased to 6.50 m, which created a threat to the project and over a million people in the project area.

These FCD/FCDI projects give two important lessons. First, they are still vulnerable to the natural forces and second, at times, they provide false sense of security to the stakeholders. They could not eliminate the risk of flooding completely. Most of the FCD/FCDI projects were designed for a 20-year flood. For the CIP and MDIP, the design flood level was selected based on only a small number of records because measurement of systematic discharge and water level started in early 1960. Over the years, with the occurrence of floods of higher magnitudes, the magnitude of a 20-year flood may have changed. For example, for the Baruria station on the Padma River (which carries the combined flow of the Ganges and the Brahmaputra), the recurrence interval of the 1964 flood level is just under 20 years, according to the Phase I study of the MPO, and only 9 years according to the Phase II analysis. The 20-year flood level increased from 8.72 m in the Phase I analysis to 9.02 m in the Phase II analysis (MPO, 1991). Therefore, a project designed in the past to withstand a 20-year flood (based on small samples) is unable to provide adequate flood protection now.

In 1988, the return period of peak flood discharge of the Meghna River at Bhairab Bazar was the 30-year level. As this was higher than the design flood, the MDIP was breached and the CIP was seriously threatened. Mirza (1998) showed that for a 2EC rise in the global mean temperature and 13% change in precipitation in the Ganges basin, as indicated by the UKTR GCM, a current 20-year flood for the Ganges River may be a 6-year flood.

1972 IBRD Water Sector Study

The International Bank for Reconstruction and Development (IBRD) published the IBRD Land and Water Sector Study report in 1972. The preparation of the study started before the independence of Bangladesh. Meanwhile, the EPWAPDA had started planning, designing, and implementing many of the large-scale FCD/FCDI projects recommended in the 1964 Master Plan, despite the criticism of the World Bank. The IBRD Land and Water Sector Study mainly focused on the following three issues:

- application of agricultural technology based on the availability of water and land, regional analysis of land productivity, and analysis of flood characteristics
- evaluation of project implementation policies based on past success and failure
- classification of projects based on rate of return.

The study recommended a 36 year implementation policy. The main focus of this policy was for quick yielding, less capital intensive, and more labor intensive projects. It further recommended considering land and water as integrated resources. The study placed emphasis on agricultural development rather than on flood control. The study also recommended restructuring the flood control, drainage, and irrigation program of Bangladesh. It put emphasis on employment generation in the rural areas and formulation of regional master plans.

The study indirectly recommended a policy of adaptation or adjustment with regard to floods. With regard to other climatic extremes such as drought, it put substantial emphasis on drought management in the southwest and northwest parts of Bangladesh. The study also recommended that climatic and other development activities in the large river basins in India, Nepal, and Bhutan be taken into account. These policy issues were sharp deviations from the objectives and recommendations of the 1964 Master Plan.

National Water Plans of 1987 and 1991

The terminal year of the planning horizon of the 1964 Master Plan was 1984. Therefore, in 1983, the Government of Bangladesh initiated a National Water Plan (NWP) project, with the financial assistance of the U.N. Development Programme (UNDP) and the World Bank. The purpose of the project was to prepare a comprehensive water master plan for the development of water resources of Bangladesh. To implement the project, the Government of Bangladesh created the Master Plan Organisation (MPO). Phase I and Phase II of the project were completed in 1987 and 1991, respectively. The planning horizon of the NWP was 1990-2010. Main recommendations of the NWP were as follows:

- A balanced allocation of water between various users.
- Agriculture sector receiving the highest priority with full development of groundwater.
- Drought management-- a model was developed for this purpose.
- Flood control was given the priority in the north-eastern region of the country. For this purpose, submersible embankments were proposed as a mechanism of controlling floods.
- Identified existing and potential conflicts between various water users.

The Flood Action Plan

After the disastrous floods of 1987 and 1988, a number of studies on the flood problem of Bangladesh were carried out. These studies are include: GOB (1988), UNDP (1989), USAID (1989), French Engineering Consortium (1989), and Government of Japan (1989). The Flood Policy Study of the GOB (1988) and the UNDP (1989) set 11 guiding principles for future flood management in Bangladesh. Following these studies, a Flood Control Action Plan (FAP) was undertaken, and the World Bank was asked to coordinate the study. In total, 27 studies were carried out under the FAP. Objective of the FAP was to set the foundation for a long-term program to achieve a permanent and comprehensive solution to the flood problem and to create an environment for sustained economic growth and social improvement (Chowdhury et al., 1996). The FAP introduced the concept of compartmentalization, which involved controlled flooding and controlled drainage in a protected area by means of water regulating structures along peripheral embankments and roads. The concept is still under experimentation in a pilot project in Tangail. Main findings of the FAP are as follows:

- A project should be analyzed based on multiple criteria to include costs, benefits, and social and environmental impacts in a single framework.
- The FAP regional studies should pay attention to the complete hydrological cycle and develop an integrated water management plan covering issues relevant to flood, drainage, irrigation, navigation, environment, and socio-economies.
- The FAP regional studies should be integrated with the NWP prepared by the MPO.
- The 11 guiding principles (UNDP, 1989) should be evaluated, revised, and updated to accommodate future strategies for water management plans in Bangladesh.
- The rationale of the revised guiding principles should stem from the importance of controlled flooding for rural areas, a relatively high degree of protection for urban areas, the need to integrate river training with water development projects, and the approach of integrating structural intervention with nonstructural measures.

The FAP was widely criticized with regard to environmental impacts and people's participation. In response to criticism, it investigated the alternative option of "living with floods." The institutional aspects of flood control were also discussed. However, it lacked coordination among various agencies involved with water management or water users.

The FAP studies did not address the possibility of climate change and relevant issues. The regional studies could have examined precipitation change scenarios in the hydro-dynamic model runs to assess the range of uncertainty. Only one study (FAP 1) addressed the climate change induced sea-level rise issue in the model run and the possibility of incorporation of its implications in design criteria.

Appendix D
The Framework Convention on Climate Change, the Kyoto Protocol, and the Role of Adaptation

The Global Convention on Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in May 1992, and was made available for signature at the UN Conference on Environment and Development in June 1992. The Convention entered into force on 21 March 1994, 90 days after receipt of the 50th ratification. It currently has been ratified by 176 countries (IISD, 1998).

The goal of the convention is to achieve "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (UNFCC, 1992).

The convention calls on the developed countries to take the lead in combating climate change and its adverse effects. All parties to the convention agreed to develop national inventories of greenhouse gas emissions and submit national communications containing the inventories and reports on mitigation and adaptation activities. Developed countries further committed to the "aim" of keeping their greenhouse gas emissions below the1990 levels by 2000.

Mitigation and Adaptation: The Two-Pronged Approach

While the main focus of the convention is on reducing greenhouse gas emissions (mitigation), the convention also recognizes the role of adaptation. All parties are called on to "cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture, and for the protection and rehabilitation of areas . . . affected by drought and desertification, as well as floods" [Article 4, Section 1 (e)]. The convention also states, "The developed country Parties and other developed Parties . . . shall also assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting the costs of those adverse effects" (Article 4, Section 4).
At the first meeting of the Conference of the Parties (COP) to the UNFCCC, the delegates endorsed a framework with three stages for adaptation planning (Decision 10/3). Stage I is planning, Stage II is preparation, and Stage III is initiation of adaptation measures. The COP agreed to fund Stage I activities provided they are undertaken as part of the development of national communications for developing countries.

The Third Conference of the Parties (COP-3) to the UNFCCC was held 1-11 December 1997 in Kyoto, Japan. In the Kyoto Protocol, Annex I Parties (developed countries and countries with economies in transition) to the UNFCCC agreed to commitments with a view to reducing their overall emissions of six greenhouse gases (GHGs) by at least 5% below 1990 levels between 2008 and 2012. The Protocol also establishes emissions trading, joint implementation between developed countries, and a clean development mechanism (CDM) to encourage joint emissions reduction projects between developed and developing countries. As of 13 November 1998, 60 countries have signed the Kyoto Protocol.

Increased Interest in Adaptation Strategies

The Kyoto Protocol reaffirms and extends the UNFCCC's commitment to address adaptation. The Protocol calls on all parties to "cooperate in scientific and technical research . . . to reduce uncertainties related to the climate system, the adverse impacts of climate change . . ." [Article 10, Section (d)].

The CDM is mainly concerned with international cooperation in the reduction of greenhouse gas emissions, the so-called "certified Project activities," but Article 12 also provides in Clause 8: "the Conference of the Parties serving as the meeting of the Parties to this Protocol shall ensure that a share of the proceeds from certified project activities is used to . . . assist developing country Parties that are particularly vulnerable to the adverse effects of climate change to meet the costs of adaptation."

Bangladesh is a signatory of the UNFCCC, and the Bank is playing a lead role in helping to fulfill terms of the UNFCCC. The Bank may also play a leading role in helping to implement the Kyoto Protocol. The Global Environment Facility is the financial mechanism on an interim basis for the UNFCCC.

The Fourth Conference of Parties (COP) was held in Buenos Aires, Argentina, 2-13 November 1998. The conference focused mainly on strengthening the mechanisms for implementing the Kyoto Protocol, in particular, the CDM.

COP Five was held in Bonn, Germany in November, 1999. The Bangladesh delegation was headed by the Minister for Environment and Forest Resources. In her speech, the Minister emphasized Bangladesh's vulnerability, and its limitation of resources and means to meet the adverse impacts of climate change.

Appendix E
Development Activities and Climate Change Adaptation

E.1 Introduction

Various projects, programs and activities are now being implemented in Bangladesh with the goal of sustainable development of the country. A number of activities are also in the process of being initiated. Unfortunately, most of these activities do not consider climate change impacts or adaptation to such impacts. There are two principal reasons to evaluate development activities in this country in the light of climate change:

i. success of development activities may be affected by the impacts of climate change,

ii. these projects may offer clear opportunities for reducing Bangladesh' vulnerability to climate change

This appendix provides a short description of sixteen identified development activities, and describes whether or not these activities take the impact of climate change into account, and whether there are possibilities for adaptation. These projects/activities are major initiatives in one or more of the key sectors that are most affected by climate change: coastal resources, water resources, agriculture, human health and biodiversity.

It should be noted that a '*climate change impacts assessment*' is beyond the scope of this study. Therefore, analysis of these various projects is general, and the appendix does not provide a comprehensive evaluation of each individual project. In addition, the study did not consider all the projects now being implemented and/or formulated in the country, nor does it claim to provide a complete list of projects that are potentially affected by climate change.[1] The focus has been mainly on projects in the climate change affected sectors that are likely to be affected by climate change, and that could contribute to reducing Bangladesh' vulnerability to climate change. Due to its obvious relevance in relation to climate change, the National Water Management Plan (Section E.3) has been examined in greater detail.

E.1 Project descriptions

The main projects that were identified are listed in table E.1. This table also gives a tentative indication of project susceptibility to climate change, and the possibilities for adaptation.

The table only identifies in what area climate change is likely to affect the project and whether or not there is a potential for adaptation. Chapters 2 and 3 present more information on specific climate related impacts in each sector with relevant examples for adaptation.

The following questions were considered in the formulation of table E.1.

1. What natural resources and socio-economic sectors does the project target? (indicated by ■)
2. Does the project target any of the key impacts? (if any, indicated ■).

[1] For example, UNDP sponsored ongoing Sustainable Environment Management Program (SEMP) was not reviewed by the consultants (GOB &UNDP, and other counterparts may wish to comment -note from IDA)

3. What are the possibilities for adaptation to climate change within the project? The possibilities depend on (i) the target sector, (ii) the proposed activities in a project and (iii) the key impacts of climate change. Considerations to make the assessment are illustrated in Figure E-1.

After assessing the possibilities for adaptation to the key impacts of climate change within a certain project, the project can either be (i) very promising to reduce vulnerability to climate change (■), (ii) offering opportunities to reduce vulnerability (■), or (iii) not particularly suitable to include activities that reduce Bangladesh' vulnerability to climate change (■).

E.1.1 *Small-scale Water Resources Development Sector Project (SSWRDSP)*

Name of the project:	***Small-scale Water Resources Development Sector Project (SSWRDSP)***
Implementing Agency:	Local Government Engineering Department (LGED)
Project Duration:	August 1995- June 2002
Development Partner:	Asian Development Bank (ADB)

The objective of the project is to facilitate a sustainable increase in agricultural production and incomes for smallholder farms in about 400 locations in western Bangladesh. The project is aimed at removing constraints imposed by inadequate flood protection, waterlogging, and limited irrigation.

It is envisaged that the objectives will be achieved by:

(i) assisting beneficiaries to organize themselves to participate in the selection, design, implementation, and subsequent O&M of water control systems;

(ii) implementing small-scale flood control, drainage improvement, water conservation, and command area development schemes to improve water resource management with environmental monitoring and with appropriate agricultural extension and aquaculture development; and

(iii) supporting project management in small-scale water resources development at the national, district and thana levels.

Although the issue of climate change has not been addressed in the project activities, intended improvements of flood control and drainage systems in combination with the command area development activities would facilitate, to some extent, towards minimization of the adverse impacts of climate change concerning drainage, freshwater availability and flood management. In general, the project offers possibilities to reduce vulnerability to climate change.

E.1.2 *Command-Area Development Project (CADP)*

Name of the project:	***Command-area Development Project (CADP)***
Implementing Agency:	(i) Bangladesh Water Development Board (BWDB), lead agency (ii) Department of Agriculture Extension (DAE) (iii) Department of Fisheries (DOF)
Project Duration:	October 1995- December 2000
Development Partner:	Asian Development Bank (ADB)

The objective of the project is a sustainable increase in agricultural production by realizing the full potential of irrigated area within two existing irrigation systems at Pabna and Meghna-Dhonagoda. The project aims at developing the command areas under the two irrigation systems, prevent environmental pollution from the misuse of pesticides in agricultural production by introducing integrated pest management, and mitigate the adverse environmental impact of flood protection works on fisheries by means of small-scale fisheries development.

The project did not address the issue of climate change and its adverse impacts on agriculture in embanked areas. Since the Meghna-Dhonagoda irrigation system is located in an area that would certainly experience sea level rise-induced higher backwater effects, the success of the project may be decreased by the impacts of climate change. Flood-stage at higher-than-expected levels might pose greater risk of breaching of embankment, leading to catastrophic consequences in that area. The project activities do not include any specific measure to reduce vulnerability of climate change in the project areas.

E.1.3 *Khulna-Jessore Drainage Rehabilitation Project (KDRP)*

Name of the project:	***Khulna-Jessore Drainage Rehabilitation Project (KDRP)***
Implementing Agency:	(i) Bangladesh Water Development Board (BWDB) (ii) Department of Agriculture Extension (DAE) (iii) Department of Fisheries (DOF)
Project Duration:	November 1995- June 1999 (continued)
Development Partner:	Asian Development Bank (ADB)

The principal objective of the project is poverty reduction through increased agricultural production and creation of on-farm employment in the project area. It is envisaged that the objective will be achieved by:

(i) mobilizing beneficiary participation in design, implementation and subsequent O&M of the project facilities;

(ii) rehabilitating the existing drainage infrastructure to reduce congestion and protect the project area from tidal and seasonal flooding;

(iii) providing support for the expansion of agricultural extension services that will be necessary; and

(iv) improving management of fisheries in polder areas.

The EIA/SIA study which was executed between mid 1997 and mid 1998, identified and studied tidal basins as an alternative solution to major regulators proposed by the project. Tidal basins would solve the drainage problem of the region by generating tidal flows in the main river system, which will prevent them from siltation. In addition, sediments will be brought in the beel areas as requested by the local people. Supported by the public opinion, the decision has been taken to implement a tidal basin in the upstream part of one of the main river systems. A stepwise, learning by doing approach will be followed, based on an extensive monitoring, which should build up experience with the performance and management of these tidal basins. Water Management Groups and Associations play an important role in the implementation.

The rehabilitation works executed under the project could be affected by the adverse impacts of climate change. Coastal tidal influence, drainage, freshwater availability in the winter and morphological changes induced by backwater effect will threaten the long-term success of the project. On the other hand, the efforts of rehabilitation in itself can reduce vulnerability to climate change. Although climate change has not been explicitly mentioned in the project document, this provides an example how activities entailed in a project may provide adaptation to climate change, whereas the success of project itself is likely to be impacted by climate change.

E.1.4 *Sundarbans Biodiversity Conservation Project (SBCP)*

Name of the project:	***Sundarbans Biodiversity Conservation Project (SBCP)***
Implementing Agency:	Department of Forest (DF)
Project Duration:	November 1998 - June 2006
Development Partner:	Asian Development Bank (ADB) and Global Environment Facility (GEF)

The overall objective of the SBCP is to develop a sustainable management and biodiversity conservation system for all resources of the Sundarbans Reserve Forest (SRF). In achieving the objective, the project will target: (i) improved institutional capacity to manage the SRF; (ii) adoption of biodiversity conservation and sustainable resource management measures; (iii) reduction in the poverty level of people in the fringe areas through expanded economic opportunities, improved social infrastructure etc.; (iv) promotion of ecotourism and enhancement of environmental awareness; and (v) reduction of industrial pollution.

The project did not consider climate change induced exogenous changes. The Sundarbans is very likely to be impacted by climate change and its impacts. The most dramatic effect is expected on the forest vegetation due to a combination of both increased sedimentation and low-flow induced saline intrusion. Significant changes in vegetation cover would be detrimental for the animal biodiversity. Extraction of timber and wood for pulp production would further endanger the existence of the forest. Although the activities envisaged under the project are designed to improve the quality of the forest, the additional threats associated with climate change might negate such improvements.

Assurance of sustained flows in the Gorai-Madhumoti systems during the lean season might help achieving the objectives of the project. This project's susceptibility to the altered water regime under climate change scenarios needs to be considered.

E.1.5 *Coastal Greenbelt Project (CGP)*

Name of the project:	***Coastal Greenbelt Project (CGP)***
Implementing Agency:	Forest Department (FD) of the Ministry of Environment and Forest
Project Duration:	June1995 – June 2002
Development Partner:	Asian Development Bank (ADB)

The objective of the CGP project is to protect and improve the coastal environment by augmenting tree cover in the coastal region and to help reduce poverty of the local population by generating supplementary income opportunities through the use of state owned land. A major activity under the project is to raise plantations along the embankments, roadsides and railsides, in homesteads and foreshore areas. It is envisaged that the plantations would be maintained by the local people, through a participatory approach, and that they will directly benefit from the project activities. In addition to generating income for the beneficiaries, the tree plantation would provide support against cyclone storm surges, a frequent visitor of the coastal areas of Bangladesh.

Although the project did not consider the possible implications of climate change and sea level rise, it does consider the fact that severe cyclones could possibly threaten the newly planted saplings in the foreshore. On the other hand, it is expected that the 'greenbelt' would reduce the threats from cyclone storm surges in future. Since climate change induced effects would be pronounced only after a few decades, it may be expected that by that time, the new plantation (if planted accordingly) would be firmly established in the foreshores, and effectively reduce the intensity of the storm surges. A remaining threat is the impact of a foreseen reduced fresh water availability on the 'greenbelt'.

It should be noted that, in addition to the local level (possible) adaptation benefits, the project would incur global benefits by helping sequestration of CO_2 from the atmosphere (mitigation). Such a project provides a good example of anticipatory adaptation, even if this was not an explicit objective of the project.

E.1.6 *Forestry Sector Project (FSP)*

Name of the project:	***Forestry Sector Project (FSP)***
Implementing Agency:	Department of Forest (DF)
Project Duration:	January 1997 - December 2003
Development Partner:	Asian Development Bank (ADB)

The objectives of the project are: (i) to enhance conservation of forests in selected protected areas; (ii) to increase overall wood production; and (iii) to institute sustainable management of forest resources. It envisaged plantation of about 40,000 ha of *Sal* forest, over 36,000 ha of conservation areas, and 40,000 ha of hill forests etc. Although afforestation in the tea estates in Sylhet Forest Division is included as a sub-program, the risk of climate change induced increased temperature on tea plants is not considered.

However, the project, if implemented properly, will facilitate carbon sequestration and thereby, would contribute in offsetting some CO_2 from the atmosphere.

E.1.7. *Agriculture Research Management Project (ARMP)*

Name of the project:	***Agriculture Research Management Project (ARMP)***
Implementing Agency:	Bangladesh Agriculture Research Council (BARC)
Project Duration:	July 1996 – December 2001
Development Partner:	World Bank (WB)

The objective of the project is to increase the efficiency of the national agriculture research system through: (i) improving research organization and management; (ii) supporting priority research programs in promising areas; (iii) strengthening client orientation; and (iv) improving research resource allocation. The project aims at supporting priority research programs through the formulation of a Master Plan of research for the Agriculture Research Institutes (ARIs) with provisions for contracting research proposals from the private research communities; development, testing and adapting of new technologies at the farm level, and improving linkages between research and extension by various modes.

Although the issue of climate change and adaptation is not explicitly written in the project agenda, it has room to accommodate research on identifying possible and techno-economically feasible adaptations and their testing at farm levels. A long-term climate change adaptation cell may be established at BARC to foster research in this direction. The NARS institutes should be given the responsibility to develop and test new drought and saline tolerant (C3 and C4) crops and consider demonstration at field levels. Such activities may still be initiated under the aegis of the ARMP.

E.1.8 *Proposed Coastal Zone Development Program (CZDP)*[2]

Name of the project:	***Proposed*** *Coastal Zone Development Program*
Implementing Agency:	(i) Bangladesh Water Development Board (BWDB) (ii) Local Government Engineering Department (LGED) (iii) Forest Department (FD) (iv) Water Management Associations (WMAs) and NGOs (v)
Project Duration:	
Development Partner:	World Bank (WB), The Netherlands

The Government over the past 30 years has invested nearly US $800 million in various development activities in the coastal zone. Major among these investments has been the construction of a system of embankments and polders, known as the coastal embankment system (CES), that provide protection from cyclone storm surges and saltwater intrusion, to establish conditions conducive to agriculture. This has been successful in transforming the region in the monsoon season into a significant rice producing area. IDA has supported this development in recent years through the Priority Works Project, which was a direct response to the 1991 cyclone and the follow-up Coastal Embankments Rehabilitation Project (CERP) implemented in 1996. However, sustainability of both the embankment system and the natural ecosystem, and further economic growth are constrained by the extreme physical risk associated with the coastal area, lack of infrastructure, and repeated and frequent storm & cyclone damage that degrade the CES.

In response to this situation, the government has been thinking more recently about how to develop and manage the coastal zone in a more sustainable fashion. A *National Water Policy* was approved in 1998. In 1999, GOB prepared a well conceived *Policy Note on Integrated Coastal Zone Management* (ICZM) that outlines the issues and concepts for a new strategic approach for the coastal zone, based on the premise that the natural resources of the coastal areas are so different from their terrestrial counterparts that different forms of management are required. The note also emphasized the multiple and unique vulnerabilities of the area, the use pressure exerted on ecosystems and resources, the land use conflicts, and the overall unsustainable uses in the coastal area. All these issues require a more broad-based, multi-sector and long-term development management approach. The Note also stresses that national goals will need to be adapted in consultation with stakeholders to meet the specific needs of people in the coastal area.

The proposed CZDP has evolved from the subsuming of the proposed Integrated Coastal Zone Management Project (planned as a FY 04 project) and the former CERP II which was held up recently at the Project Concept Document stage because of concerns over CES sustainability issues, lack of progress with BWDB institutional reforms and the need for a longer term strategy for development of the coastal zone. The proposed program would address all these concerns by adopting a longer term approach with earlier activities concentrated on i) well informed investment planning, ii) development of appropriate strategies underpinned by extensive community consultation, and iii) appropriate institutional reform. Substantial investments would come later and be conditional on substantive advances in these three areas, which would be identified from the outset and constitute trigger points to allow progression from one phase of the program to the next. The underlying concept would be that GOB access to increasing levels of funding would be directly related to the adoption and successful implementation of increasingly significant institutional reforms/strengthening and community-based investment planning and implementation.

[2] Information under this heading has been derived from a CZDP Concept Note, May 2000

Since the program is expected to continue beyond 7 years, within the next three years, CZDP could implement some specific components such as i) complete preparation of the Integrated Coastal Zone Management Plan involving wide-ranging community consultations; ii) explore and develop financial and administrative arrangements for a proposed disaster repair and rehabilitation fund for emergency and urgent works, etc. The overall development outcome of the evolving CZDP would be i) substantial and sustainable reduction in the risk of loss of life, and damage to property and economic assets; (ii) restored and sustainable natural ecosystem functions and services; and (iii) Equitable improvements in farm and non-farm employment and income.

Although the additional risks associated with climate change and sea level rise to cyclone storm surges are not yet thoroughly elaborated, it is a good candidate where the issues may be addressed and adaptation measures may either be strengthened or built in. Such a project would in the long run, facilitate adaptation processes in the coastal zone. Since the project is yet to be finalized, a climate change impact assessment could be attempted that could strengthen the project and increase its usefulness in achieving the overall objectives of the project, even in a warmer world. Acknowledging the impacts of climate change in an early stage of the work, will significantly contribute to ensuring the long-term success of the various activities that will constitute the CZDP.

E.1.9 *Forest Resource Management Project (FRMP)*

Name of the project:	***Forest Resource Management Project (FRMP)***
Implementing Agency:	(i) Forest Department (FD) (ii) Institute of Forestry and Environmental Sciences (IFES) (iii) Bangladesh Forest Research Institute (BFRI)
Project Duration:	1992 – December 2000
Development Partner:	World Bank (WB)

The projects primary objectives are to: (i) establish and maintain a forest management system fully responsive to the economic, environmental and social goals of Bangladesh; (ii) improve the productivity of government-owned forests in order to meet the country's wood and energy needs; and (iii) protect the country's environment. It was envisaged that the primary objectives would be accomplished by:

i) improving the resource information base and the information system;

ii) integrating environment and socio-economic factors and criteria into resource management of forests and dependent resources;

iii) carrying out a pilot scheme for people's participation in forest development;

iv) expanding the country's forest resources and forest productivity through plantations and improved forest management;

v) formulating management plans for nature conservation areas;

vi) streamlining organizational structure of the Forest department (FD); and

vii) supporting professional and technical education and training, and mangrove research.

The project considered a number of important elements that could address climate change adaptation, although it was not intended for climate change per se. The important elements include (a) formulation of integrated forest management plans, (b) preparation of conservation management plans, and (c) design programs for mangrove research. Formulated plans could be re-evaluated to accommodate some of the adaptations and could also be linked up with other projects including the Sundarbans biodiversity development project, the coastal greenbelt project and the integrated coastal zone management plan. A number of mangrove studies could be initiated to examine the viability of mangrove development in the low-lying foreshores that are likely to be inundated, possible problems concerning succession of forest species under severe low flow conditions, etc. The project has an important ongoing mangrove plantation component.

It should be noted that the project has a plantation component, which will contribute to the sequestration of carbon from the global GHG pool, thereby contributing to the process of adapting through mitigation. This benefit, may not have much effect on a local level, but does have the potential to contribute to the global mitigation efforts. This fact needs to be emphasized in international negotiations to the country's advantage.

E.1.10 *Fourth Fisheries Project (FFP)*

Name of the project:	***Fourth Fisheries Project (FFP)***
Implementing Agency:	(i) Department of Fisheries (DOF) (ii) Bangladesh Water Development Board (BWDB) (iii) Local Government Engineering Department (LGED)
Project Duration:	Five years, August 1999 – December 2004
Development Partner:	World Bank (WB) Global Environmental Facility (GEF) Department for International Development (DFID)

The general objective for developing the project was to support sustainable growth and equitable distribution of the benefits generated from increased fish and shrimp productions for domestic consumption and exports. It is envisaged that the objectives would be achieved through the following interventions:

(i) improvement of inland open-water fisheries management through the development of sustainable, community-based institutions;

(ii) establishment of sustainable and equitable institutional arrangements for managing shrimp polders and works to facilitate the development of environmentally friendly smallholder shrimp production;

(iii) improvement of sustainability of shrimp fry collection;

(iv) development and application of an appropriate extension strategy for freshwater aquaculture;

(v) studies of key issues in aquatic resource development and management; and

(vi) strengthening the capacity of DOF to manage and support the fisheries sector, plan for its development and long-term sustainability and implement national fisheries policy.

The issue of climate change with connotations to fisheries resources both in the floodplains and in the coastal zones are not directly addressed in the project. Interventions realizing sustainable management could facilitate the fisheries sector as a whole. Identification of fisheries related problems under a warmer world and seeking solutions for each of the problems could strengthen the project activities and reduce the sectors' vulnerability to climate change in the future. This may also be linked with the components on studying key issues in aquatic resources development and management.

The project may be impacted by climate change, especially during the dry season when low flow coupled with increased demand of surface water could threaten the fish habitats. Wetland areas will be particularly vulnerable due to climate change induced effects. Low water volumes in standing water bodies including privately operated ponds could increase concentration of agricultural residual pollutants, thereby damaging the quality of the habitat for the fries and the juveniles. Implementing the periodic excavation of aquaculture ponds/tanks could be beneficial in increasing the depth of water even under climate change conditions.

There are possibilities for adaptation under the program, that will directly influence the sustainability of the fisheries sector and other environmental activities. Similar activities could, however, be designed under the Sustainable Environment Management Programme (SEMP). In that sense the projects could be complimentary to each other and would benefit from increased coordination.

E.1.11 *The Gorai River Restoration Project*

Name of the project:	***Gorai River Restoration Project (GRRP)***
Implementing Agency:	Bangladesh Water Development Board (BWDB)
Project Duration:	Mid 1998 – end 2000
Development Partner:	World Bank (WB)

The GRRP investigates, to detailed design stages, river training works and a program of maintenance dredging to augment the flows of the Gorai River and also prepares contract documents so that the works can be implemented. The project will update and supplement wherever necessary the results of previous studies covering technical, social, environmental and economic assessments of the proposed project and use the lessons learned from the dredging carried out under the priority works program. The priority works comprise the dredging of a 30 km long reach of the Gorai River from the off-take to be executed on a pilot basis.

The project has the following major components: priority works; hydro-morphologic surveys and model investigations; environmental and social impact assessment and monitoring and drafting an environmental management plan; and development & evaluation of options and design of preferred option.

The study has been ranked as a category A project as per World bank classification, implying the execution of a full scale EIA/SIA. This component of the project explicitly considers different scenarios for climate changes.

The project clearly ranks in the category of anticipatory adaptation and offers ample opportunities to include considerations of climate change. Such considerations could, however, occupy a more central place in the final decisions and design, whereas they presently are accounted for only in the EIA/SIA study.

E.1.12 *The Third Inland Water Transport Project*

Name of the project:	***Third Inland Water Transport Project***
Implementing Agency:	Bangladesh Inland Water Transport Authority (BIWTA) Bangladesh Inland Water Transport Corporation (BIWTC)
Project Duration:	1991-1999
Development Partner:	World Bank (WB)

The project grew out of a realization that: inland water transport was critical to the country especially during floods, safety standards were poor, and the infrastructure was rapidly deteriorating as a result of past neglect. The project aims to improve inland water transport operations and the effectiveness of sector agencies through:

(iii) improving waterway safety and environmental controls;

(iv) increasing inland passenger transport capacity;

(v) improving capital asset utilization

(vi) reducing inland water freight transport costs

(vii) improving country boat operations

(viii)improving the finances of BIWTA and BIWTC; and

The issue of climate change has not been addressed in the project activities, but intended improvements in dredging of waterways would facilitate, to some extent, in minimizing the adverse impacts of climate change concerning drainage. Although dredging is an expensive solution to drainage, efficient dredging to improve inland water transport will increase Government revenue and in the long run prove to be more cost effective.

The project may be impacted by climate change, especially during the dry season where low flow coupled with sedimentation could threaten the navigability of certain rivers and increase the risk of accidents.

E.1.13 *The River Bank Protection Project*

Name of the project:	***River Bank Protection Project (RBPP)***
Implementing Agency:	Bangladesh Water Development Board (BWDB)
Project Duration:	1996-2001
Development Partner:	World Bank (WB)

The principle objective of this project is to prevent the erosion of riparian land at two locations on the west bank of the Brahmaputra by the construction and maintenance of improved river-bank protection works which would: (a) protect Sirajganj town's built-up and semi-urban areas from major damage and cumulative destruction; and (b) prevent the merger of the Brahmaputra and Bangali Rivers in the vicinity of Sariakandi, and consequential increased regional flooding. A further objective is to assist GOB in developing permanent institutions for improved water sector planning, preserving the institutional capacity built under FAP and making multi-disciplinary planning part of Bangladesh's normal water sector planning processes.

The main issues addressed in this project are Bangladesh's vulnerability to floods, and bank erosion along major rivers. Changes in precipitation, river flows and sediment transport, due to multi-dimensional impacts of climate change, may increase this vulnerability. Incorporating climate change related adaptations will increase the benefits of this project over a longer period. This project can also be used in preparing a program to address climate change issues in extending river bank protection to other critical areas along Bangladesh's river system.

E.1.14 *The Water Sector Improvement Project*

Name of the project:	***Water Sector Improvement Project (WISP)***
Implementing Agency:	Bangladesh Water Development Board (BWDB) Local Government Engineering Department (LGED) Water Management Associations (WMAs)
Project Duration:	
Development Partner:	World Bank (WB)

The objective of this project is to improve the performance of the water management systems in Bangladesh and ensure their sustainability through improved operation and maintenance, appropriate institutional reforms (specifically the redefinition of the role of the government), and required physical improvement of small-scale and medium-scale water sector infrastructures.

The project would assist GOB in implementation of its National Water Policy. This objective would contribute to sector-related goals of increasing agricultural production and floodplain fisheries, improving local navigation, mitigating adverse environmental effects of past investments, and ensuring environmental protection. As indicated in the Aide-Memoire, WSIP would be the forerunner for the various water sector pipeline projects; and would create the institutional framework for developing and implementing these projects.

The project offers an excellent opportunity to address and integrate climate change related issues in resource management development planning. WISP supports integrated planning, which is identified as one of the key adaptations to reduce Bangladesh' vulnerability to climate change, particularly fresh water resources. The key project components, community participation on different levels and strengthening of local management organizations are essential parts of integrated planning for functional resources management.

E.1.15 *The National Water Management Plan Project (NWMP).*

Name of the project:	***National Water Management Plan Project (NWMP)***
Implementing Agency:	Water Resources Planning Organization (WARPO)
Project Duration:	Three years, March 1998 – March 2001
Development Partner:	World Bank (WB)

The NWMP has set a number of objectives to achieve through maximum utilization and management of water resources of the country:

- ◊ alleviate poverty;
- ◊ improve environmental protection and pollution control;
- ◊ improve water-related infrastructure and services both to support economic growth and to improve the well-being of the population;
- ◊ increase equity in access to water and water-related services and facilities ;

- ◊ be better prepared for disaster;
- ◊ contribute to the achievement and maintenance of food-grain self-sufficiency;
- ◊ maximize economic efficiency; and
- ◊ feed Bangladesh at least cost, subject to social and environmental constraints.

Among the above objectives, four are crucially important and likely to be affected by possible changes in climate at the end of the medium-term planning horizon (5-15 years) of the NWMP and beyond. These four objectives (e.g. *poverty alleviation, environmental protection and pollution control, natural disaster preparation, and self-sufficiency in food*) are further discussed below.

The NWMP has set *poverty alleviation* as its main priority through the development of water resources. This appears to be a change in the objectives of water development from previous plans (see Appendix I), which basically concentrated on agricultural development. Despite economic reforms and various strategies formulated and implemented in the past, poverty alleviation in Bangladesh is highly constrained by natural disasters caused by climatic fluctuations and extremes. A drought or a medium to extreme flood leaves a trail of economic hardship, especially for the bottom 48% people of the society in Bangladesh. Women and the children suffer the most. The success of NWMP in alleviating poverty will, by and large, depend on the management of floods and droughts and on how benefits of water resources development will be distributed among the various income groups. This will be a difficult task, especially in a future warmer world.

Environmental protection and pollution control has lately received attention in the planning process in Bangladesh. Deterioration of the environment is largely linked to poverty and resource scarcity, as well as inadequate training and implementation mechanisms. Climatic extremes are a threat to the environment and health of Bangladesh. This fact is equally applicable for a drought or flood. During the 1994-1995 drought in the northern districts, an outbreak of diarrhea and dysentery resulted from the use of unsafe drinking water (Sajjan, 1998). The exact number of deaths from these diseases was not known. The long lasting 1998 floods affected the quality of drinking water in the capital city of Dhaka, as well as of Sirajgonj, Pabna, Gaibandha, Kurigram, Chapai Nawabgonj, Bogra, Rangpur, Noagaon, Natore, and Rajshahi. More than 300,000 tube-wells were out of order because of the flood. In the capital city, 14 pumps of the Dhaka WASA were closed down. Flood also disrupted the drainage of water and urban sewage in Dhaka, and the flood water in the river remained high for more than two months. The pumping stations did not work because electrical substations were under water. Overflows of storm water and urban sewage affected many residential areas. In many areas, polluted flood waters were mixed up with the piped supply water. Polluted drinking water caused outbreaks of diarrhea, jaundice, fever, and dysentery in Dhaka and other areas of the country (Ittefaq, 21 September 1998).

The NWMP focuses on better preparations for *dealing with natural disasters*. Water related natural disasters includes flood and drought. Most of the previous plans in Bangladesh recommended structural measures for flood hazard mitigation. However, the experience during the1988 and 1998 floods, led to questions regarding the effectiveness of the flood control and drainage projects in protecting people from flood hazards. Moreover, these nonstructural measures cannot reduce damages to infrastructures and agriculture.

In the past two decades, Bangladesh has had some success in disaster management in terms of relief operation, evacuation, and post-disaster recovery. Unfortunately, drought management has received little attention. The effects of drought often receive less attention because they happen over a longer period of time and the visible effects of damage are comparatively slower. In the future, climate change is likely to make management of droughts more complex and more expensive.

While attaining *self-sufficiency in food* was the first priority in the previous water plans, it is the seventh priority in the NWMP. On average, the food deficit in Bangladesh is about a million tons which escalates during a year of natural disaster. The deficit is also related to the timing and duration of natural disasters. For example, crop damages by the 1988 flood was lower than that of the 1998 flood. Mainly the *Aman* production in 1988 suffered a setback. In terms of duration, area inundated, and depth of flood, the 1998 flood superseded the effects of the 1988 flood. As a result, crop damages estimated by the Ministry of Agriculture was roughly 3.4 million tons (Ittefaq, 21 September 1998). The food deficit may reach nearly 5 million tons (HOLIDAY, 1998). Similarly, on average, a drought can cause damage to more than half a million tons of crop agriculture.

Both floods and droughts are, therefore, obstacles to attaining self-sufficiency in food in Bangladesh. Natural disaster related additional food deficit compels the government to import food, either by borrowing from international financial institutions or diverting resources from the annual development program. In a warmer climate, the increased risk of flooding of higher magnitude and longer duration or more intense drought of longer duration will most likely pose a threat to the attainment of self-sufficiency in food.

Climate change issues for the NWMP relate to resource assessment and estimating water demands (such as irrigation, fisheries, navigation, domestic and industrial water demands). In addition there are several planning issues including the formulation of climate change scenarios and criteria for assessing the changes in vulnerability for climate change. These issues are addressed in more detail in the next section.

Adaptation options for the National Water Management Plan (NWMP)

The latest document by the NWMP Project (implementation agency), released in May 1999, provides a general guideline on how the Plan is about to be completed. It has identified a number of Topic Papers that will deal with water management issues in Bangladesh. Since climate change will have the most profound effects on water related issues, it is important to consider how climate change impacts could be dealt with in defining a water management plan.

In general it was felt that, although climate change is to be mentioned in topic paper 7, the NWMP could integrate climate change related issues in development planning on a much larger scale. What is of concern is that the NWMP does not mention drainage congestion as a major concern, or one deserving a special policy statement. This issue is of crucial importance because of the already encountered problems with drainage in the country, and especially due to the multi-sector causes of this problem. An amendment of the NWMP in this regard would serve to: focus attention of everyone undertaking public or private works that may affect the drainage system and its performance on these issues, enable the Government to develop and apply some criteria and standards that mitigate loss of capacity or damage, and put in place a review system to ensure that all projects in all sectors pay attention to these criteria and standards.

Based on the topic papers, this section discusses where and how climate change could be integrated into the NWMP in order to reduce the climate change vulnerability of Bangladesh.

In addition, table E.2 summarizes a number of possible concrete adaptations that could be included in the NWMP to help Bangladesh become less vulnerable to the effects of climate change.

Topic Paper 1: Defining the issues.

It is mentioned that the topic paper will re-examine the most recent Water and Flood Management Strategy of Bangladesh. If Climate Change is identified as an issue, its implications on flood management strategy could be analyzed under this topic.

The People's Participation and Consultation Programme could be a vehicle for building awareness of climate change issues and adaptations. People could be informed about what is known about regional climate change, and they in turn can provide information on local climatic fluctuations and extremes, and on their traditional means of coping with a changing environment. The NWMP could begin collecting traditional knowledge on adapting to climatic fluctuations and extremes during the public consultation phase.

Topic Paper 2: Economic setting.

Since climate change could adversely affect the national economy with the most harmful effect on the poor, it would be worthwhile to take a note of how such adverse effects could be minimized and how NWMP could effectively reduce vulnerability of the poor and disadvantaged.

Fisheries and aquaculture should be given due attention under this topic. This is especially important in view of future conflicts between fisheries and the agricultural sector (compounded by the pressure on fresh water availability)

The feasibility of water-pricing and other measures to encourage more efficient water-use could be studied under this topic.

Topic Paper 3: Social and gender issues.

Land-loss and loss of food grain, due to increased morphological activity, is one of the key risks from climate change, and may contribute to social conflicts and should therefore be included in the analysis.

Considering the social structure of the country, women are obviously most vulnerable to the effects of climate change, and gender issue discussions should incorporate that fact.

Topic Paper 4: Environmental Setting.

While identifying major environmental issues in relation to water management, the impacts of climate change on the environmental setting of the country should be covered. More specifically, the impact of salt intrusion and increased soil salinity needs to be included in this topic paper. Analysis of environmental issues, including the impacts of climate change, would generate ideas concerning management of water resources under a warmer world.

Topic Paper 6: Legacies and lessons

Full advantage should be taken not only from former studies and projects but also from traditional knowledge. The NWMP could pay attention to the adaptations that people are already practicing in the river basins to maximize the availability of the scarce water resource.

Attention should also be paid to the problems that the previous projects have faced. As an example: many old Flood Control and Drainage/Flood Control Drainage and Irrigation (FCD/FCDI) projects suffer from drainage problems. At the Chandpur Irrigation Project in the Meghna basin, inadequate drainage is a chronic problem (Mirza, 1991). The drainage problems of this project were also evident during the 1998 flood. Drainage is also a serious problem in the coastal polder projects in the Jessore-Khulna districts.

With regards to the climate change issues, the NWMP could address the issues of checking overtopping of flood waters, increasing internal and external drainage, and better irrigation water management for possible droughts in the monsoon and dry season. Rainfall in monsoon is expected to increase in a warming climate.

Topic Paper 7: Land and water resources.

Aiming at a summary of land and water resources availability and demand, topic paper 7 will cover climate change as indicated in the following quotation:

'The extent to which climate change and sea level rise over the planning period are likely to affect land and water resources and demands is an issue to be evaluated on the basis of the latest findings of the international studies on climate change'.

However, the question is: whether an evaluation of the impact should be confined to the planning period only. Currently, the irrigation and fisheries sectors compete for water. No explicit guidelines have yet been determined for estimating water demand for the fisheries sector. For fresh water aquaculture fisheries, there would be an increased risk of inundation due to climate change. During the 1998 floods, many farmers lost their complete fish crops because of inundation. While there is an argument that floods help redistribute fish from closed water to open water, farmers' financial losses are considerable in the process.

It is also important to move away from the idea of "seasons" under a rigid timeframe. The timing and intensity of seasonal rainfall is expected to be impacted by climate change. Again, a shift in rainfall patterns is likely to have a significant impact on the availability of water resources and other season dependant activities such as agriculture. This issue needs to be taken into account in assessing water resources.

The NWMP stated that it is important to consider the effects of development in the upstream riparian countries on the future flows of transboundary rivers. These flows are expected to be significantly impacted by climate change.

Future climate change could change the overall hydrological pattern of the cross-border rivers in two ways. First, increased monsoon rainfall might increase the dry season supply of water; most of the dry season discharge of these rivers is generated as a baseflow from the rainfall that recharges the groundwater aquifers. Decreases in the monsoon rainfall could have the opposite effect. Second, an increased rate of snowmelt could also increase the dry season flow of the Ganges, the Brahmaputra, and the Teesta. Since the signal of climate change may be evident as early as 2020, these issues could be considered in the NWMP.

The study underlying this report, identifies possible changes in annual precipitation in the Ganges, Brahmaputra, and Meghna basins by 2020 in the range of -6 to +14%. This indicates a range of uncertainty with regard to the supply of baseflow to the dry season river flow in the cross-border rivers. Scenarios for the basins can be generated from a number of GCMs, and a sensitivity analysis can be carried out to assess the effect of changes in rainfall on increases or decreases in groundwater recharge and its contribution to the baseflow of main and regional rivers. This type of analysis would help the NWMP planners estimate uncertainty, that has to be taken into account.

The NWMP can analyze the possible effects of a rise in sea level using the modeling capability of the SWMC. This analysis will be particularly important for the medium planning horizon and beyond.

Topic Paper 8: Water and basic human needs.

In identifying the options to meet water-dependent human needs, the basic issues concerning food security, cyclone, flood preparedness and droughts could be re-examined in relation to impacts of climate change and sea level rise.

The implications of climate change to future urban and rural water supply could be manifold. First, in the summer, increased urban temperatures would enhance the demand for water for drinking and bathing. Second, increased temperatures may increase the demand for industrial cooling water as well as cooling water for transports. These augmented demands may aggravate the current conflict between domestic and industrial water supplies in the urban areas. Third, in rural areas, ponds are used for bathing by people and for livestock. Increases in temperature may increase the rate of evaporation; therefore, the standing water bodies may dry up even more quickly than now. Further, the shortage of water in the standing water bodies will generate pressure on hand tube wells, depleting further the groundwater table. This will be aggravated by salt water intrusion in the coastal zone. If the monsoon droughts increase, the domestic water supply in rural areas will suffer, and the current conflict with irrigation water supply will further worsen.

The NWMP could look into the problems likely to be encountered by the domestic and industrial sectors in the future in a warming climate. In addition, flood induced prolonged periods of standing water , will increase the risk of water borne diseases.

Topic Paper 9: Regulatory and economic instruments.

As mentioned in chapter 4, there are a number of regulatory and economic instruments that can be considered as institutional adaptations to the effects of climate change. The NWMP could highlight those regulatory and policy instruments as facilitators of adaptation to climate change.

Topic Paper 11: Managing the environment.

As a logical consequence of topic paper 4, the management issues could elaborate how to deal with some specific environmental management aspects concerning floods and drainage, cyclones, freshwater availability (dry season water shortage) and morphological changes. For example, low flow condition combined with higher evaporation in winter will necessitate increased irrigation. If the farmers depend on increased number of STWs then the rate of groundwater abstraction from the shallow water tables will be much higher.

Topic Papers 12 and 13: Managing the seasonal problems.

The current seasonality and associated problems will only be greater under climate change.

The recent flooding in Bangladesh has given new impetus to flood control and mitigation. This could be reflected in the NWMP, especially with regard to climate change. First, changes in precipitation should receive high priority because they fall within the medium- and long-term planning horizons. The climate changes scenarios described in this study could be used, with emphasis on scenarios of extreme precipitation events. Second, with climate change leading to an increased hydrologic cycle, future floods could be even more intense (Trenberth, 1998). Third, change in a mean flood indicates likely changes in the land categories of various inundation classes. It could alter current cropping patterns in the country. Any change in F_0 land category means that a net area under *Aman* cropping would be lost. This will particularly be important for Bangladesh, where the *Aman* crop contributes to about half of the annual rice production. Fourth, increased vulnerability of rural and urban infrastructures should be investigated. Fifth, the drainage problem, especially in the Chandpur confluence, could be investigated by taking into account the effects of the rise in sea level.

Moreover, sea level rise will increase salinity intrusion, and thus will affect NWMP planning in the coastal areas as well as further inland. In a broad sense, the effects of sea level rise have significant implications for the NWMP; it could significantly affect future GOB investment allocations in the water resource sector.

Topic Paper 15: Major investments

Climate change may have considerable implications for transboundary river flows and development of the Ganges Dependant Area. First, Bangladesh and India will have to formulate a framework to share any additional flows in the dry season in the Ganges River at Farakka and at any sharing point for the Brahmaputra (to be decided in the future). Second, increased flood flows may have implications for the design parameters of possible barrages, such as the length of waterways, pond levels, crest levels, pavement, length and thickness of upstream and downstream aprons, divide walls, sediment excluders, and head regulators. Design parameters for the irrigation canals and regulators, siphons, aqueducts, etc. will also need to be changed. Third, the still rapidly expanding infrastructure network and embankments have an adverse effect on drainage that has to be accounted for as well.

In its ToR, the NWMP has decided to consider global warming for the Ganges Development Area (GDA), but it does not explicitly describe whether climate change issues will be addressed for design of barrages.

Topic papers 16 and 17: Strategy alternatives and Planning and process

Planning and strategy formulation has been identified an important vehicle to anticipate climate change and its impacts. This could be reflected in the proposed measures and strategies, but in addition, proper planning procedures are needed to address these issue correctly. Two such procedures are important in this context.

- The formulation of *climate change scenarios.* On a central planning level, the planning framework should identify and formulate different development scenarios which account for exogenous changes that might affect the performance of the water management strategies. Examples of these changes include: demographic and economic growth, the world market price of rice etc. Part of such scenarios should be a clear specification climatic changes as, e.g., summarized in Chapter 2 (on precipitation, river flows and sea level rises).
- *Assessment criteria* are needed to properly account for the effectiveness of measures and strategies in terms of reduction of vulnerability of climate change. This should be done as part of a multi-criteria approach. Adaptation measures can not be assessed on a mere cost-benefit criteria. In addition to effectiveness, assessments should consider their feasibility and contribution to sustainable development.

Figure E.1: Considerations in evaluating possibilities for adaptation within projects

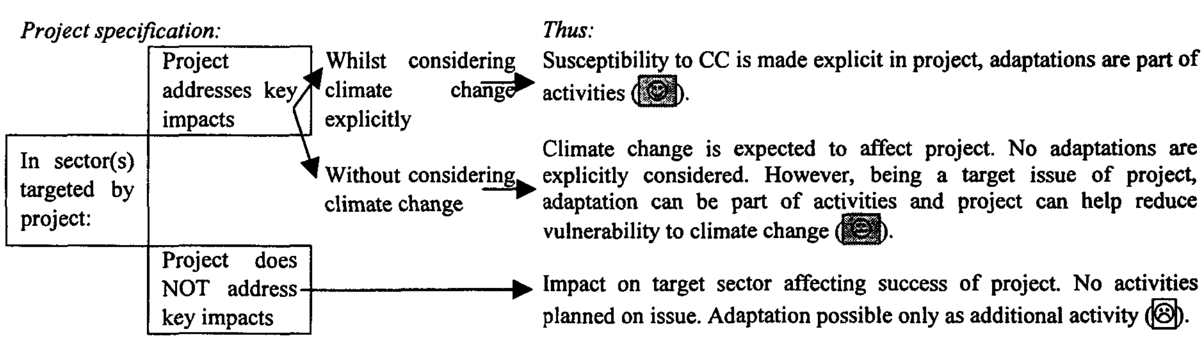

Table E.1: Overview major projects and their relation to climate change vulnerable issues

	Coastal resources	*Drainage congestion*	*Fresh water availability*	*Morphologic dynamics*	**Fresh water resources**	*Drainage congestion*	*Fresh water availability*	*Morphologic dynamics*	**Agriculture**	**Public health**	**Ecosystems/biodiversity**
Small Scale Water Resources Development Sector Project (SSWRDSP)	■	▒	▒	☹	■	▒	▒	☹	■		
Command-area Development Project (CADP)	■	☹	☹	☹	■	☹		☹	■		
Khulna-Jessore Drainage Rehabilitation Project (KDRP)	■	▒	☹	▒					■		
Sundarbans Biodiversity Project (SBCP)	■	☹	☹	☹							■
Coastal Greenbelt Project (CGP)	■		☹	▒							
Forestry Sector Project (FSP)					■		☹	☹			■
Agricultural Research Management Project (ARMP)									■		
Proposed Coastal Zone Development Program (CZDP)	■	▒	▒	▒	■				■	■	■
Forestry Resources Management Project (FRMP)			☹				☹				■
Fourth Fisheries Project (FFP)		☹	☹				▒				■
1Gorai River Restoration Project	■	▒	▒		■	▒	▒	▒			
Third Inland Water Transport Project					■	▒		☹			
River Bank Protection Project (RBPP)					■			▒			
Water Sector Improvement Project (WISP)					■	▒	☹	▒	■		
Sustainable Environmental Management Program **	■				■					■	■
Third Water Supply and Sanitation Project**					■					■	
National Water Management Plan (NWMP)	■	▒	▒	▒	■	▒	▒	▒		■	

Key:		*Characteristics of project:*	☹ 😐 ☺	*Impact of climate change, in target sector of project. Depending on proposed activities in project, incorporation of adaptations can be relatively easy or difficult. This is indicated as follows:*
	■	Target sector in project	☹	Impact on target sector affecting success of project. No activities planned on issue. Adaptation possible only as additional activity
	▒	Target issue in project; activities are planned	▒	Impact on target issue. No adaptations considered. However, as a target issue of project, adaptation can be part of activities, and project can help reduce vulnerability to climate change
			▒	Vulnerability to CC made explicit, adaptations is part of activities
			■	The project is vulnerable to climate change, however the proposed activities allow for adaptation. Opportunities to reduce vulnerability exist
			■	Proposed activities make project very promising to reduce vulnerability to climate change

**Note from SASRD, World Bank: consultants did not submit review of these two activities.

Table E.2: Overview of possible adaptation in anticipation of climate change

Sector	Adaptation response
Resource Assessment	Study traditional water conservation methods in Bangladesh
Irrigation Water	Introduce rice strains with shorter maturation periods Increase irrigation efficiency: ◆ Line irrigation canals to reduce conveyance losses ◆ Implement night-time irrigation programs where possible Privatize water supply and delivery systems Give local communities authority to decide on how to share the limited common resource. Develop and implement pricing systems
Fisheries	Increase elevation of fish pond banks to prevent flood losses Relocate fish farming operations to areas with lower flooding risks
Navigation	Maintain currently required depth of water in navigation channels Maintain adequate channel depths through dredging
Domestic and Industrial Water Use	Increase efficiency of water use: ◆ Encourage water-conserving domestic practices ◆ Introduce efficient water cooling systems to industry Privatize water supply and delivery systems Develop and implement on-peak and off-peak pricing systems
Design of Barrages	Account for revised climate change (flood and drought) scenarios in design
Flood Control	Account for revised climate change (flood) scenarios in design Improve flood-related forecasting, preparation, and response
Cyclone Management	Account for multi-purpose cyclone-shelters for people, livestock and assets. Improve cyclone-related forecasting, preparation, and response

Appendix F
Flood Changes in Bangladesh, for 2020

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Changes in Temperature and Precipitation

Changes in temperature and precipitation over the Ganges-Brahmaputra-Meghna river basins and Bangladesh for 2020 were extracted from SCENGEN for seven general circulation models (GCMs) (Table 1). These temperature and precipitation changes are consistent with the range of climate change projections discussed in this chapter. The results are for a climate sensitivity of 4.5°C. There is minimal difference in 2020 between different greenhouse gas (GHG) emission scenarios. The first three GCMs were used for scenarios provided by T. Wigley (personal communication, T. Wigley, National Center for Atmospheric Research, May 1998), and the last four were used to determine flood changes in BDCLIM (Kenny et al, 1998).

Table 1
Changes in Temperature and Precipitation for the GBM Basins, 2020

	Ganges (W) 27.5N, 82.5E		Ganges (E) 27.5N, 87.5E		Brahmaputra 27.5N, 92.5E		Meghna 22.5N, 92.5E		West Region 22.5N, 87.5E		East Region 22.5N, 92.5E	
GCM	**ΔT**	**ΔP**	**ΔT**	**ΔP**	**ΔT**	**ΔP**	**ΔT**	**ΔP**	**ΔT**	**ΔP**	**ΔT**	**ΔP**
HADCM2	1.5	-9.6	1.4	-5.5	1.3	0.5	1.4	2.5	1.6	-3.6	1.4	2.5
OSU	1.1	3.5	1.1	3.6	1.1	3.6	0.9	11.2	0.9	11.4	0.8	11.2
CSIRO9M2	0.9	-0.4	0.9	2.1	0.9	3.5	0.7	3.8	0.7	5.3	0.7	3.8
CSIRO9	0.9	4.0	0.9	0.8	0.8	-0.2	0.6	2.1	0.7	3.6	0.6	2.1
UKTR	1.6	5.5	1.6	6.7	1.6	5.5	1.2	5.3	1.3	10.4	1.2	5.3
GFDL	0.9	0.7	0.8	5.0	0.8	5.6	0.7	5.2	0.7	5.4	0.7	5.2
LLNL	1.5	0.4	1.5	0.3	1.4	0.8	0.9	3.6	0.9	5.4	0.9	3.6

Changes in Peak Discharge

Changes in peak discharge were calculated for 2020 and 2050. Results for 2020 are provided in Table 2. The greatest changes occur with the GFDL and UKTR GCMs, and relatively smaller changes are found with the CSIRO9 and LLNL GCMs (the last two show decreased discharge from the Brahmaputra river basin). Results are provided for climate sensitivities of 1.5, 2.5, and 4.5°C, and correspond with the precipitation changes in Table 1. Changes in peak discharge are relatively higher between 2050 and 2020, than between 2020 and 1990 (Table 3).

Table 2
Peak Discharge (m^3/s) for the Mean and 20-Year Floods for the Ganges, Brahmaputra, and Meghna Rivers

	Mean			20-year		
	Ganges	**Brahmaputra**	**Meghna**	**Ganges**	**Brahmaputra**	**Meghna**
1990						
	51,050	67,200	14,080	66,354	89,025	19,016
2020						
CSIRO9						
1.5	51,994	66,871	14,232	67,298	88,696	19,168
2.5	52,399	66,730	14,297	67,703	88,555	19,233
4.5	52,972	66,531	14,389	68,276	88,355	19,326
UKTR						
1.5	52,398	67,385	14,469	67,702	89,210	19,405
2.5	52,976	67,465	14,636	68,280	89,289	19,572
4.5	53,795	67,577	14,873	69,099	89,401	19,809
GFDL						
1.5	51,665	67,240	14,467	66,969	89,065	19,403
2.5	51,929	67,257	14,633	67,233	89,082	19,569
4.5	52,303	67,282	14,867	67,607	89,106	19,803
LLNL						
1.5	51,321	66,946	14,343	66,625	88,812	19,279
2.5	51,437	66,837	14,455	66,741	88,721	19,392
4.5	51,602	66,683	14,615	66,906	88,592	19,551

Table 3
Range of Change in Peak Discharge (m^3/s) for Both Mean and 20-Year Flood Events, 2020 and 2050

River	1990 to 2020	2020 TO 2050
Ganges	+271 to +2,745	+252 to +3708
Brahmaputra	-669 to +377	-904 to +509
Meghna	+152 to +793	+141 to +1,071

Changes in Flooded Area and Land Inundation Classes

There are two important outputs from the flood calculation in BDCLIM, the change in total flooded area and the change in land inundation classes. The latter are defined by the depth of flooding (see Table 4) and are a primary determinant of land use in Bangladesh. Changes in total flooded area, and area of each of the land inundation classes were calculated for both the mean and the 20-year flood. Results are provided for the mean flood only (Table 5). The 1990 20-year mean values are incorporated in Table 5 for comparison.

Table 4
Flood Inundation Classes, and Crop Suitability, in Bangladesh*

Land Type of Inundation Class	Range of Inundation Depth	Crop Suitability
Medium Highland — I (F0)	0 cm and 30 cm	Land suited to HYV T. aman in wet season, wheat and HYV boro in rabi season
Medium Highland — II (F1)	30 cm to 90 cm	LAND SUITED TO LOCAL VARIETIES OF AUS AND T. AMAN IN WET SEASON; WHEAT AND HYV BORO IN RABI SEASON
Medium Lowland (F2)	90 cm to 180 cm	Land suited to *B. aman* in wet season and wheat and HYV boro in rabi season
Lowland and Bottomland (F3 and F4)	Greater than 180 cm	Land suited to *B. aman* in wet season and HYV boro in rabi season. LV boro in bottomland (F4)

* Derived from Brammer et al. (1996).

Table 5
Changes in Area of Flood Inundation Classes and Total Flooded Area

	Area (km²)				
	F0	**F1**	**F2**	**F3**	**Total**
1990					
Mean	6,170.40	16,042.20	20,568.60	24,327.60	67,108.80
20-year	3,598.80	12,012.60	27,130.80	48,069.00	90,811.20
2020 — INCREASE IN AREA RELATIVE TO 1990 MEAN					
CSIRO9					
1.5	8,477.40	727.20	844.80	1,159.80	11,209.20
2.5	8,636.40	1,350.60	1,249.20	1,740.60	12,976.80
4.5	7,323.60	2,562.60	1,777.20	2,581.20	14,244.60
LLNL					
1.5	8,831.40	748.80	894.00	1,164.00	11,638.20
2.5	8,977.20	1,404.60	1,312.20	1,736.40	13,430.40
4.5	7,486.20	2,738.40	1,877.40	2,571.00	14,673.00
GFDL					
1.5	10,530.00	762.60	1,056.60	1,461.60	13,810.80
2.5	10,411.20	1,572.00	1,507.20	2,175.00	15,665.40
4.5	8,251.80	3,283.80	2,149.80	3,229.80	16,915.20
UKTR					
1.5	10,907.40	727.20	1,084.20	1,555.20	14,274.00
2.5	10,660.80	1,584.00	1,555.20	2,304.60	16,104.60
4.5	8,391.00	3,371.40	2,207.40	3,423.60	17,393.40

By 2020, most of the scenarios indicate that the total area flooded approaches the amount of area flooded under the current 20-year flood event. However, there are differences in the depth of flooding (and thus the flood inundation classes). Most of the 2020 increases in flooded area are in the shallowly flooded land (F0). The higher rainfall GCMs (GFDL and UKTR) coupled with a climate sensitivity of 4.5°C show a proportionately higher increase in the more deeply flooded land. However, the area of deeply flooded land under these two high scenarios is still much smaller than the area of deeply flooded land for the current 20-year flood event.

Low Probability, High Risk Flood Events

The climate change projections suggest the possibility of precipitation changes as low as -7% and as high as +15% by 2020. The geographic spread of such changes needs to be considered. An examination of results from 11 different GCMs over the GBM basins showed precipitation decreases for only one of the three major river basins (Brahmaputra), for two GCMs only (CSIRO9 and CCCEQ). Of the scenarios provided by T. Wigley for 2020, only the HADCM2 result shows a decrease (Table 1). This decrease is in the Ganges basin and is coupled with small increases in the Brahmaputra and Meghna basins. The OSU (SCENGEN result, Table 1) scenario shows relatively higher precipitation increases over Bangladesh for 2020 than those used to generate the flood changes. However, these higher increases over Bangladesh are coupled with precipitation increases over the Ganges and Brahmaputra basins (the two largest river systems) that are comparable in magnitude to those used to generate the previous set of results (see Table 1).

Given these qualifications, some judgment is provided as to possible consequences of more extreme precipitation changes than examined earlier. The following two cases are considered:

Case 1 — A Uniform Decrease (-7%) in Precipitation

The BDCLIM system, at present, is based on scenarios that show precipitation increases, so it is not possible to run the model for this situation. However, it is possible to make some judgments through examination of results for precipitation increases.

The UKTR GCM results show uniform precipitation increases over the three basins of +6% for 2020 for a climate sensitivity of 4.5oC (Table 1). This scenario gives a 26% increase in flooded area. A precipitation decrease of similar magnitude could have two possible outcomes:

- a decrease in total flooded area of a least 26%, with no changes in distribution of flood classes
- a nonlinear decrease in flooded area and a redistribution of the land inundation classes, with a tendency toward a greater proportion of more shallowly flooded land.

The latter seems to be a more likely outcome.

Case 2 — A High (+15%) Uniform Precipitation Increase

A sensitivity analysis was conducted using BDCLIM, which involved scaling the UKTR scenario (which shows uniform precipitation changes in the GBM basins) to approximate a 15% increase in precipitation. Results show minimal change in the area flooded under the 20-year flood event compared to 1990 (Table 6). Most significantly, however, they show that such a precipitation increase would result in the mean flood to be very close to the current 20-year flood event, in terms of both total flooded area and area of land inundation classes. Such a scenario could have severe impacts on Bangladesh.

Table 6

Results from UKTR with 2.5°C Global Warming (surrogate for 15% increase in prec.)

	Area (km^2)				
	F0	**F1**	**F2**	**F3**	**Total**
1990 mean	6,170.4	16,042.2	20,568.6	24,327.6	67,108.8
Mean flood	4,963.2	15,925.2	27,055.8	35,471.4	83,415.6
20 Year	3,635.4	11,988	27,031.2	48,295.2	90,949.8

Appendix G
VARIOUS REVIEW WORKSHOPS

Sectoral Review Workshop
at the BRAC Centre

May 25 2000 at 9:30 a.m.

List of Participants

Sl.No.	Name	Organization
1.	Ainun Nishat	Country Rep., IUCN
2.	Tauhidul Anwar Khan	D.G., WARPO
3.	Julian Francis	IFRCS
4.	Monzu Morshed	CARE
5.	Saeedur Rahman	BWDB
6.	Jalaluddin Md. Abdul Hye	SWMC
7.	Bushra Nishat	Resource Analysis
8.	Ahsan Uddin Ahmed	BUP
9.	Kamal Kishore	ADPC, Thailand
10.	Md. Shamsul Islam	DG, MDMR
11.	Dr. Kamal Ranjan Talukdar	DGHS
12.	Nurun Nahar	MOEF
13.	Dr. Atiq Rahman	BCAS
14.	Mozaharul Alam	BCAS
15.	M. Anwar Iqbal	BARC
16.	Rashid Faruqee	WB
17.	Sarwat Chowdhury	WB

Review Workshop at the Hotel Sheraton

May 8, 2000 at 9:30 a.m.

List of Participants

Sl.No.	Name	Organization
1.	Fred. Temple	WB
2.	Rashid Faruqee	WB
3.	Farouk Chowdhury	WB
4.	Imtiazuddin Ahmad	WB
5.	S.A.M. Rafiquzzaman	WB
6.	Sarwat Chowdhury	WB
7.	Syed Marghub Murshed	Secretary, MOEF
8.	Azad Ruhul Amin	Secretary, MDMR
9.	Monowar Hossain	BUET
10.	Prof. Sayed A. Hye	Jahangirnagar Univ
11.	Bushra Nishat	Resource Analysis
12.	Anwar Ali	SPARRSO
13.	M. Reazuddin	DOE
14.	Paul Martin	WB
15.	Ahsan Uddin Ahmed	BUP
16.	Rob Koudstaal	Resource Analysis
17.	Mozaharul Alam	BCAS
18.	Mahfuz Anam	The Daily Star

Review Workshop
on
Bangladesh: Climate Change and Sustainable Development
Date: December 30, 1999
Venue: BIAM Auditorium
63 New Eskaton, Dhaka

Program

10:00-10:05	Opening Address by Workshop Chair *World Bank's Interest on Climate Change Issues* (Rashid Faruqee, South Asia Rural Development Unit, SASRD, World Bank)

Presentations:

10:05-10:15	*Introduction to the Study & How it Relates to the Overall Sustainable Development of Bangladesh* (Sarwat Chowdhury, SASRD World Bank)
10:15-10:30	*Climate Change Scenarios, Impacts & Vulnerability in Bangladesh: What the Study Found* (Ahsan Uddin Ahmad, Consultant from Bangladesh Unnayan Parishad)
10:30-10:45	*Adaptation in Bangladesh –Plan of Action* (Atiq Rahman, Consultant from Bangladesh Centre for Advanced Studies)
10:45-11:00	Break

Discussions:

Session I

11:00-11:35	*Climate Change Impacts and Adaptation Priorities* Discussant- Q. K. Ahmad, Bangladesh Unnayan Parishad

Session II

11:35-12:10	*Policy Options for Bangladesh in Climate Change Adaptation* Discussant- Reazuddin, Director, Department of Environment
12:10-12:15	Summing Up of the Review Workshop (Rashid Faruqee, World Bank)

BANGLADESH: CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Review Workshop at the BIAM Auditorium

December 30, 1999 at 10:00 a.m.

List of Participants

Sl.No.	Name	Organization
1.	S.M. Mahbubur Rahman	SWMC
2.	Syed Haaider Ali	
3.	Hans Van der Menuel	WARPO
4.	Md. Ataul Huq	2nd CERP
5.	M.A. Matin	2nd CERP
6.	Prof. M.S. Shah	Khulna University
7.	Rezaul Karim Khan	ADB
8.	Dr. Nilufa Islam (PSO)	WARPO
9.	Dr. Parvin Sultana	UNDP
10.	Nasiruddin Md. Humayun	DOF
11.	Imtiaz Ahmed	FFP (DOF)
12.	Sylvia Islam	CIDA/CHC
13.	Dr. D.A. Quader	SPARRSO
14.	Dr. Anwar Ali	SPARRSO
15.	Dr. Abdus Sattar Syed	
16.	G.M. Salehuddin	DAE
17.	A.R. Khan	DG, DAE
18.	M. Reazuddin	Director, DOE
19.	Kazi Golam Mustafa	LGED
20.	Atiq Rahman	BCAS
21.	Q.K. Ahmad	BUP
22.	Ahsan Uddin Ahmed	BUP
23.	M. Anwar Iqbal	BARC
24.	Imtiazuddin Ahmad	WB
25.	A.S.M. Bashirul Huq	WB
26.	Tajul Islam	WB
27.	M. Monowar Hossain	BUET
28.	Rashid Faruqee	WB
29.	Sarwat Chowdhury	WB
30.	S.A.M. Rafiquzzaman	WB

WORKING GROUP DISCUSSIONS

BANGLADESH: CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Date: 28 June 1999

Venue: LGED Auditorium (Level 4), LGED Bhaban, Agargaon, Dhaka.

PROGRAM

09:15	Registration

Opening Session

09:30-09:45	Opening Address World Bank's Interest on Climate Change Issues in Bangladesh Robert Epworth, SASRD, World Bank
09:45-10:10	*Climate Change and Bangladesh: Impacts, Adaptation and Vulnerability* Ahsan Uddin Ahmed, Bangladesh Unnayan Parishad
10:10-10:45	Open discussion
10:45-11:00	Tea break

Closing Session

11:00-11:25	*Introducing Adaptation to Climate Change* Rob Koudstaal, Resource Analysis
11:25-12:25	Break-out Group Discussions on Adaptation Possibilities
12:25-12:55	Report from the Groups
12:55-01:15	Responses to Group Discussions
01:15-01:30	Summing up Saleemul Huq, Bangladesh Centre for Advanced Studies
01:30	Prayer and Lunch

List of participants at the June discussions

Dr. Anwar Ali Chairman SPARRSO	Prof. Monower Hossain Water Resources Engineering Department BUET
Mr. Ahmedul Hasan Technical Advisor EGIS II	Dr. Ijaz Hossain Department of Chemical Engineering BUET
Mr. Mizan Khan Project Management Unit (SEMP) Ministry of Environment and Forest	Mr. John Ratsey Consultant National Water Management Plan
Mr. Moshiur Rahman Executive Engineer LGED	Mr. Mozaharul Alam Fellow BCAS
Ms. Sara Hannan Assistant Engineer LGED	Mr. Quazi Tofazzal Hossain Department of Agriculture Extension
Md. Shahidul Haque Executive Engineer LGED	Mr. Saad M. Siddique SWMC
Mr. Anwar Hossain Deputy Forester Department of Forest	Prof. Sayed A. Hye Department of Economy Jahangirnagar University
Mr. Robert Epworth World Bank	Mr. Anwar Iqbal CSO BARC
Ms. Sarwat Chowdhury World Bank	Dr. M. Asaduzzaman Research Director BIDS
Mr. Rashid Faruqee World Bank	Ms. Shamima Sultana BUP
Mr. Imtiazuddin Ahmad World Bank	Mr. Ahmed Salahuddin BUP
Dr. Saleemul Huq Executive Director BCAS	Dr. Atiq Rahman Director BCAS
Dr. Ahsan Uddin Ahmed Head (Environment & Development) BUP	Mr. Rob Koudstaal Project Leader Resource Analysis
Ms. Saskia E. Werners Resource Analysis	Mr. Zafar Ahamed Sohel Associate Resource Analysis