Impacts of Climate Change on Water Resources and Adaptation Options

(Bhutan)

Agenda 21 (Chapter 18)

- Of the Rio declaration clearly indicated the need to understand and quantify the threat of the impact of climate change on freshwater resources and to facilitate the implementation of effective counter-measures

Bhutan's Water Resources

- In abundance and of good quality
- Climate
  - Dominated by the monsoon, heavy rainfall during July, August, September
- Rainfall
  - 500 to 6000 mm annually, decreases northward, east west trend not observed
- Major rivers
  - Flows from north to south
  - Have steep gradients
  - Large flows and sediment during monsoon
  - Rain –fed tributaries flows east-west to join these main rivers.

Source: Water Resources Management Plan-2003)

Bhutan's Water Resources

Characteristic National Feature	Value
Land Area	38,394 km^2
Population	672,000 (based on recent survey)
Long-term mean annual flow for entire country	2,325 m^3/s = 73,000 million m^3/year
Per capita mean annual flow availability	109,000 m^3
Minimum 7 days flow of 10 year return period	427 m^3/s =13,500 million m^3/year
Per capita minimum flow availability	20,000 m^3

Gross National Land Area, Runoff and Minimum Flows

Source: Water Resources Management Plan-2003)

Bhutan's Water Resources (Quality and Problems)

- Quality
  - The main rivers and some tributaries are of pristine
  - Natural water quality can be described as highly oxygenated, slightly alkaline, low conductivities and very little or no salinity
  - Localised pollution problems such as unsanitary conditions found along the banks
- Problems
  - Endowed with ample water resources with multiple use potentials
  - Problem of too much: concern for Bhutan as well as downstream areas
  - Presence of glacial lakes in many sub-basins
  - Threat of burst due to climate change impacts and also flash floods in the especially in the foothills

Source: Water Resources Management Plan-2003)

Bhutan's Water Resources (Quality and Problems)

Housing colony damaged due to flash flood in Phuentsholing - 2000

Thimphu's surface drainage – potential for impacting water quality of Thimphuchhu

Protection works against GLOF's in Punakha

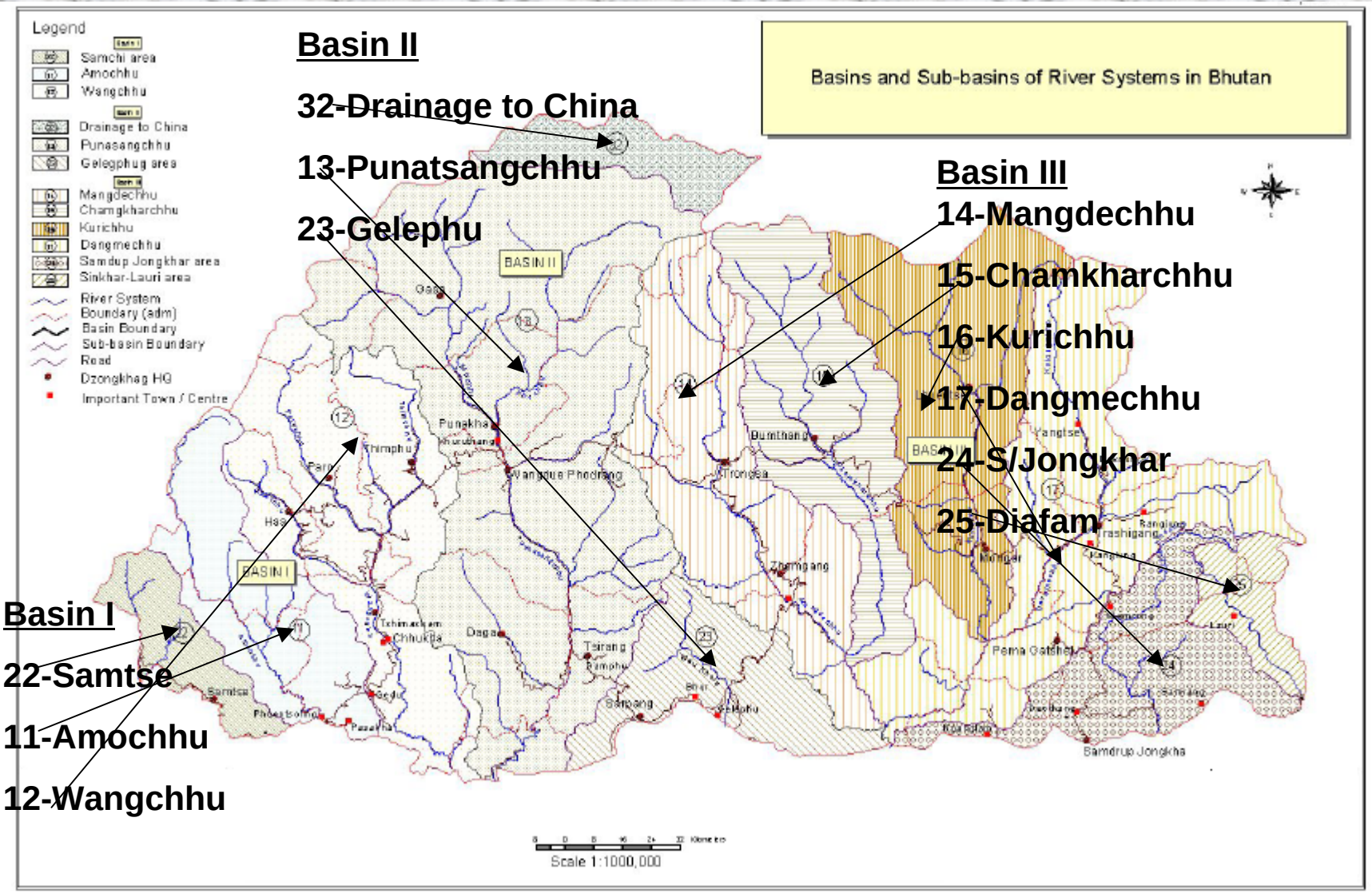
Source: Water Resources Management Plan-2003)

Bhutan's Water Resources (Water Uses)

- The main stem rivers provide water for hydropower use, waste assimilation, tourism/recreation and ecology with exceptional use in other sectors like irrigation from Parochhu.
- Tributary rivers and streams provide sources for all other uses with emphasis on water supply and irrigation from headwater streams
- Sub-surface sources, in the form of springs and aquifers, provide water for domestic water supply and small scale irrigation.

Source: Water Resources Management Plan-2003)

Bhutan's River Basin's



Source: Water Resources Management Plan-2003)

Climate Change and Water in Bhutan

- Main driver of change on the state of the natural environment in Bhutan
  - 4th Assessment Report of IPCC warns of glaciers in the Himalayas retreating faster than any part of the world
  - Glacial lakes growing in size increasing the risk of GLOF
  - Prediction of an increase in summer flows in the rivers in the short run and a decrease in the long run
  - Under the above scenario, it would be disastrous for the hydropower economy
  - Under a warmer and more variable climate, the onset of monsoons will be more erratic which will cause disruptions in natural and agricultural cycles
  - Bhutan is already experiencing increase in frequency of intense monsoon rains causing flash floods and landslides

Source: Bhutan Environment Outlook 2008, National Environment Commission, Thimphu

Climate Change and Water in Bhutan

- Main driver of change on the state of the natural environment in Bhutan
  - Affect on water quality and diversity as increased water temperatures promote growth of algae causing problems for wastewater treatment
  - More intense rainfalls can also increase outbreaks of micro-organisms, sedimentation and pollution loads, and stress sewer systems
  - The Millenium Ecosystem Assessment (2005) predicts that species extinction due to climate change will be highest in aquatic ecosystems due to warmer waters and changes in seasonal flows

Source: Bhutan Environment Outlook 2008, National Environment Commission, Thimphu

Climate Change and Water in Bhutan

Bhutan has one of the best preserved environment

In the world and the lowest emissions of greenhouse gases

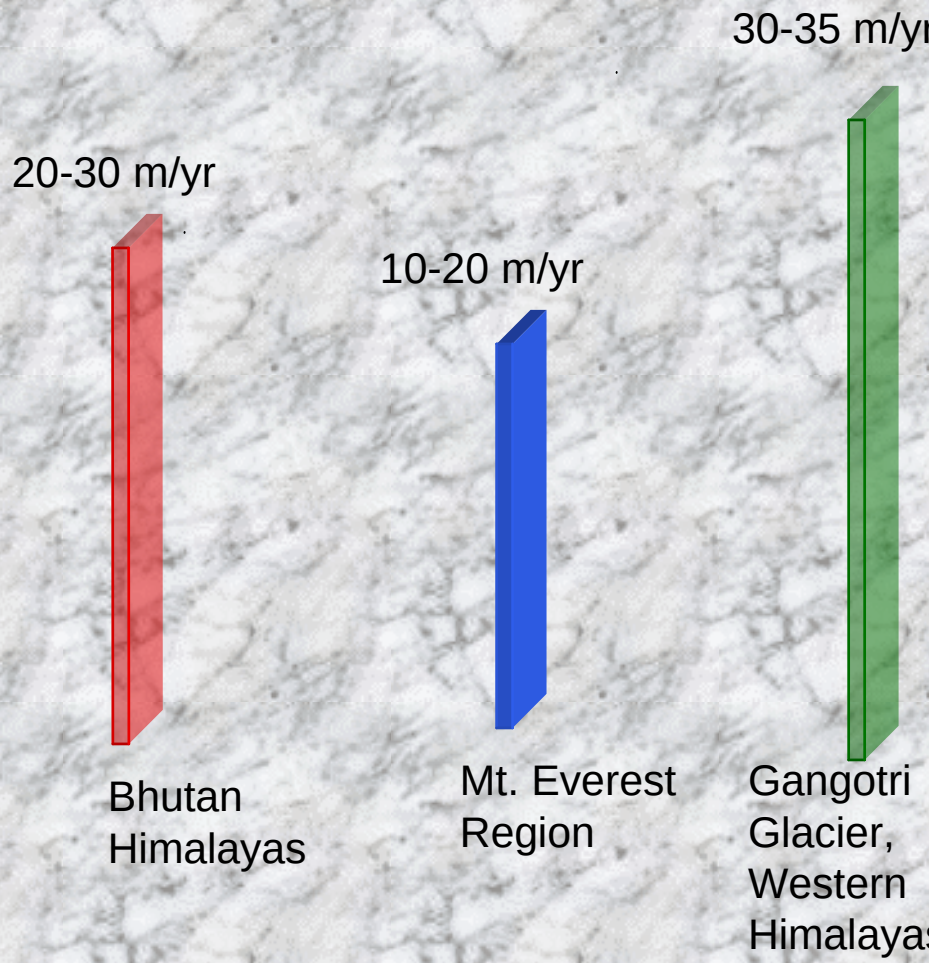
Even then, it will have to face vulnerabilities and impacts of climate change

Adapting to these changes will be necessary but expensive

Source: Bhutan Environment Outlook 2008, National Environment Commission, Thimphu

Global Warming and De-glaciation

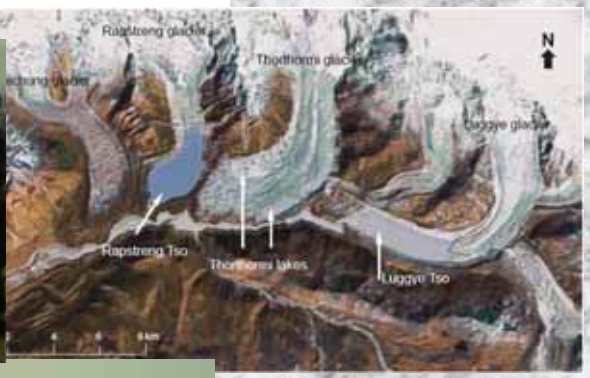
- Greenhouse gas concentrations cause global warming and climate change
- Glaciers and glacial lakes in Bhutan are directly impacted and these serve as the sources of all major rivers in Bhutan
- Bhutan has 677 glaciers and 2,674 glacial lakes, out of which about 25 are potentially dangerous



Source: Inventory of Glaciers, Glacial Lakes and Glacial Lake Outburst Floods in Bhutan, ICIMOD, and www.wikipedia.org

Source: Bhutan Environment Outlook 2008, National Environment Commission, Thimphu

Impacts



- Retreat of Glaciers
- Increases risk of Glacial Lake Outburst Floods
- Impacts water availability, hence necessary to monitor flow regimes

Impacts

- Floods
  - **Flooding frequency appears to have increased**

Impacts

- Floods

- **Sediments affect the optimal performance of hydropower plants.**
- **Study the nature of the sediment load and identification of particles causing damages important.**

Kurichhu Hydropower Plant

Dam of 1020 MW Tala Dam under Construction

GLOF and its Threats

- **Glacial Lakes-** All major rivers in Bhutan originate from glaciers and glacial lakes of the higher Himalayas
- **GLOFs**- GLOFs occurred in 1957, 1960, 1968 and 1994 with varying intensity and damage to life and property in the lower valleys
- 1994 GLOF – The most devastating GLOF in living memory and occurred on 7th OCTOBER 1994.
- **POTENTIAL DANGERS-**A recent study warns that Raphstreng and Thorthormi glaciers and lakes could become dangerous by about 2010 unless mitigation measures are taken. A GLOF of these two lakes would release over 53 million cubic meters of water and would have unimaginable consequences downstream

Source: Bhutan National Adaptation Programme of Action

Flash Floods, Landslides and their impacts

Flash Floods and Landslides-Records maintained by the Hydro-met Services Division show that from 27th July to 3rd August 2000, the southern regions of Bhutan received maximum rainfall unprecedented in the recorded history of meteorology in Bhutan. The highway to Thimphu, the capital was closed for a month

Hydropower Plants at Risk – In 2003, a landslide dam created a lake on a tributary of a river which has a hydropower plant. While there was no damage, it was a reminder of how vulnerable the country's hydropower facilities are.

Eastern Floods (July-August) – In 2004, while western Bhutan had lesser rainfall, eastern Bhutan experienced heavy rainfall which resulted in major flooding and damages

Source: Bhutan National Adaptation Programme of Action

Vulnerability to Climate Change- Water Resources

- Temporal and spatial variation in flow, mainly affecting electricity generation due to disruption of average flows for optimum hydropower generation
- Increased sedimentation of rivers, reservoirs and distribution network affecting irrigation schemes productivity/agricultural crop yields
- Reduced ability of catchment arease to retain water/increased runoffs with enhanced soil erosion

Source: Bhutan National Adaptation Programme of Action

Proposed Water Sector Adaptation Activities

- Raising of community awareness on sustainable use of water resources
- Improve land use planning in degraded catchment areas to promote afforestation, improve watershed management
- Extend, improve and maintain water supply infrastructure
- Provision of technological and financial support to harness hydropower potential
- Conduct research for other renewable energy alternative
- Optimization in design of installed capacity of existing as well as future power plants
- Improve efficiency in irrigation
- Assess GLOF threat in hydropower projects

Source: Bhutan National Adaptation Programme of Action

Adaptation Options-Based on Climate Hazards

- **GLOF (due to temperature rise)**
  - Installation of early warning systems with associated awareness raising
  - Artificial lowering of glacier lake levels
  - Implementation of hazard zonation plans
  - Assessment of GLOF threats for hydropower projects

Source: Bhutan National Adaptation Programme of Action

Adaptation Options-Based on Climate Hazards

- **Landslides (due to weather pattern change-high rain intensity)**
  - Soil conservation and land management
  - Adoption of environment friendly road construction techniques
  - Development of a national database on landslide prone areas to assess the risk of landlides
  - River bank protection
  - Small stream catchment protection
  - Slope stabilization of areas with major landslide and flash flood problems

Source: Bhutan National Adaptation Programme of Action

Adaptation Options-Based on Climate Hazards

- **Flash floods (due to GLOF or weather pattern change-high rain intensity)**
  - Watershed management integrated with land management/soil conservation
  - Weather and climate forecasting
  - Promotion of community based forest management and afforestation projects to conserve, land, water and wood production

Source: Bhutan National Adaptation Programme of Action

Adaptation Options-Based on Climate Hazards

- **Drought (due to temperature rise and/or weather change pattern-longer intervals between rains)**
  - Optimize installed power plant capacities
  - Carry out low flow/water shortage studies impacting power generation, drinking and irrigation water supplies
  - Promote research and development on water use efficiency, resistant crop varieties and water harvesting

Source: Bhutan National Adaptation Programme of Action

HOW CAN GEOSS CONTRIBUTE TO THE MANAGEMENT OF WATER RESOURCES IMPACTED BY CLIMATE CHANGE ?

- Improve earth observations by integrating data from various sources so that a holistic picture of impact emerges and then develop adaptation mechanisms for each impact
- Development of reliable climate models to reliably predict future impact scenarios
- Capacity building on adaptation mechanisms
- Promote coordination between different entities with regard to management of water resources under this new threat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