རྒྱལ་ཡོངས་ཆུའི་གྲོས་བསྡུན་ཞལ་འཛོམས།།

National Water Symposium Technical Presentations 2017

"Towards Ensuring Water Security for Bhutan's Future"

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NATIONAL WATER SYMPOSIUM

"Towards Ensuring Water Security for Bhutan's Future"

Organized by:

National Environment Commission Secretariat
&
Ugyen Wangchuck Institute for Conservation and Environmental Research
Department of Forests and Park Services

Ariya Hotel, Thimphu
10th - 12th May, 2017

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National Water Symposium Technical Presentations 2017

"Towards Ensuring Water Security for Bhutan's Future"

Objectives of the Symposium

- Bring together water resources professionals and agencies with water resources mandates for proper coordination and efficient management
- Stock take information of the state of knowledge on water resources in Bhutan
- Identify priority areas of cooperation for water resources management and development in the 12th FYP
- Determine research areas for sustainable water resources management

Expected Outputs

- Generated information on management and development of water resources
- Identified priority areas of cooperation on water resources management and development in 12th FYP
- Identified priority research areas for water resource management
- Guide research institutions on prioritizing and streamlining research plans on water resources
- Synergies among various stakeholders identified and an action plan for integrated cross sectoral efforts for water resources in Bhutan developed.

Technical Presentations

3.0 Session I: Water Governance and Policy

Chair: Karma Dupchu, Hydrology Services Division, National Center for Hydrology and Meteorology (NCHM)

Session I: Water Governance and Policy		
1100	Water governance in Bhutan	Mr. Kunzang Rinzin, NECS
1130	Water resources and National Integrated Water Resource Management Plan (NIWRMP)	Ms. Tenzin Wangmo, NECS
1200	Local governments perspective of water resources management	Mr. Dorji Wangdi, Wangdue Dzongkhag

Water Governance in Bhutan

Kunzang Rinzin
Legal Services

- The Water Act of Bhutan 2011 and its Regulation 2014

Water resources: Property of the State

- Article 1 (12) of the Constitution of the Kingdom of Bhutan

"The rights over mineral resources, rivers, lakes and forests shall vest in the state and are the properties of the State, which shall be regulated by law."

- Section 5 (a) of the Water Act of Bhutan 2011

"Water resources are the property of the state. The rights over water resources, including beds and banks of water resources shall vest in the state."

Water Resources Management

- Integrated approach and basin management appraoch
- cross-sectoral
- National Integrated Water Resources Management Plan (IWRMP) 2016
- River Basin Management Plan

Agencies responsible in water resource management

NEC/NECS

Competent Authorities

- Ministries (MoWHS, MOAF, MoH, MOEA etc.)
- Local Governments
- CSOs and Media

Environmental Clearance for Water Abstraction

Offence to abstract water without EC

Exemptions

i. Domestic use

ii.Small Scale drinking water supply and irrigation schemes

iii.small water mills, water grinders or prayer wheels

Application for EC as per the Environmental Assessment Act (Section 34 of the Water Act)

Water Abstraction Permit

- All water abstraction requires permit

i. Abstraction not requiring EC- concerned Gewog Administration

ii. Abstration requiring EC- concerned Dzongkhag Administration

iii. Ground Water abstraction- concerned Dzongkhag Adminstration

Water use priorities

- Drinking and Sanitation
- Agriculture
- Energy
- Industry
- Tourism and recreation
- Others

Minimum environmental flow

- To support and conserve the riverine habitats and its flora and fauna
- Set minimum e-flow by NEC in collaboration with relevant CAs
- Otherwise, 30%of the lean season flow

Prevention and Control of Water Pollution

- Discharge of any effluents into water resources needs to be treated
- Comply with the standard
- Dumping of wastes into water resources is prohibited (WPMA and WPMR)

Developmental Activities along watercourse

- Need Environmental Clearance for any activities on beds and banks of watercourse and within Buffer zones
- Buffer zone: 100 feet either side of the waterbody

Thank You

Water Resources and National Integrated Water Resource Management Plan

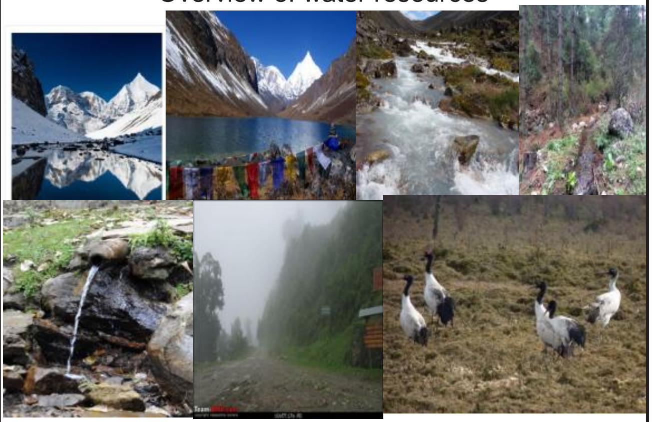
Tenzin Wangmo
Water Resource Coordination Division
National Environment Commission
May 10, 2017

Presentation outline

- Part 1 - Overview of water resources
- Part 2 – Planning and water management
- Part 3 - NIWRMP
  - ✓ Key issues and challenges
  - ✓ Water management coordination framework
- Part 4 – Priority areas

Part 1
Overview of Water Resources

Overview of water resources



Glaciers, supra-snow lakes, lakes, rivers, streams, springs, wetlands, marshes, groundwater, etc

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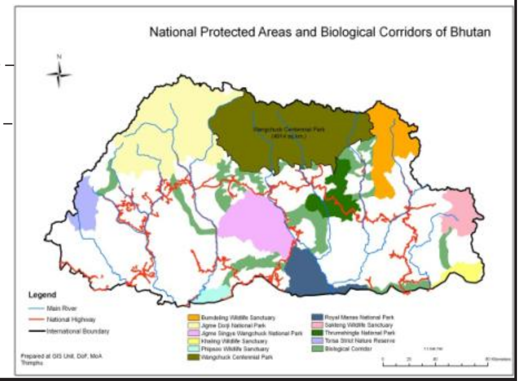
Overview of water resources

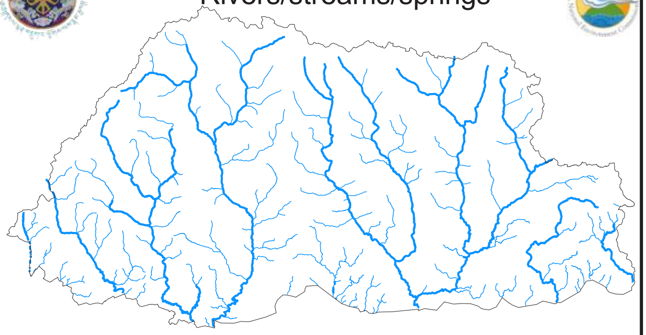
Constitutional mandate – minimum 60% under forest cover for all times to come

Forest coverage – 70.46%

Protected Areas – 51.32%

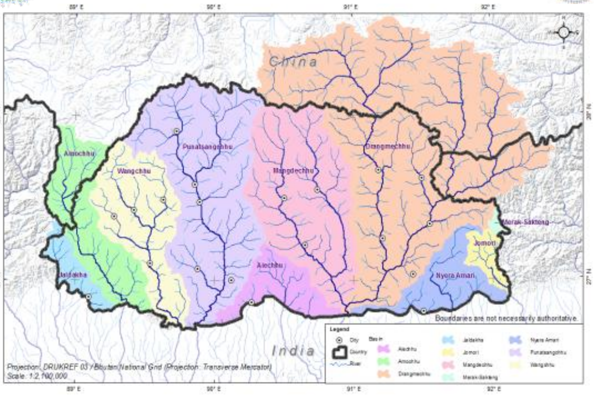


Rivers/streams/springs



River discharge – mostly fed by rainfall
- 2-12 % glacial melt
- 2 % snow melt

Hydrological basins



River basins, area & flow

River Basins	Basin Management	Area (km2)	Annual flow (MCM)
Jaldakha		942	
Amochhu	Amochhu	2310	9,375
Wangchhu	Wangchhu	4596	5,209
Punatsangchhu		9645	19,129
Aiechhu	Punatsangchhu	1937	6,989
Mangdechhu	Mangdechhu	7380	11,797
Drangmechhu		8457	13,569
Nyera Amachhu	Drangmechhu	2348	
Jomori		642	
Merak-Sakteng		137	4,506
10	**5**	**38,394**	**70,576 MCM**
	Population		746,773
	Per capita water available		94,508 m3/yr
	Flow		2,238 m3/s

Part 2
Planning and Water Management

Planning and Water Management

- National Environment Protection Act, 2007
- Environmental Assessment Act, 2000
- Waste Prevention and Management Act, 2009
- Land Act 2007
- Forest and Nature Conservation Act, 2006
- Mines and Minerals Management Act, 1995
- Electricity Act, 2001
- Water Act of Bhutan, 2011 & Water Regulation, 2014

Planning and Water Management

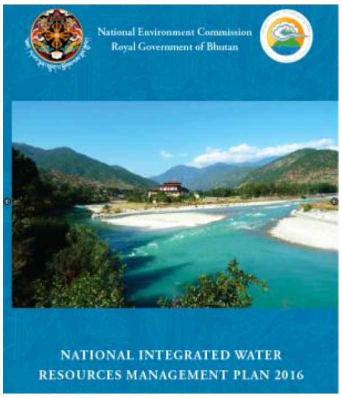
- Water Act 2011
  - NEC as the apex body for overall coordination and management of water resources
  - Planning and Management of water resource
    - National Integrated Water Resource Management Plan
    - Establishment of River Basin Committee
      - Established Wangchhu Basin Committee –pilot
    - River Basin Management Plan
      - Wangchhu Basin Management Plan

Part 3

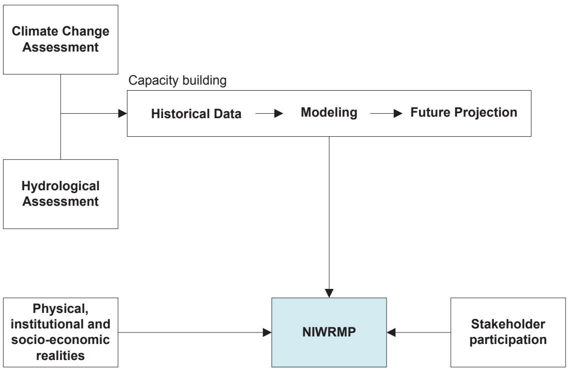
National Integrated Water Resource Management Plan (NIWRMP)

National Integrated Water Resource Manageme Plan (NIWRMP)

- Emanated from Water Act, 2011
- 11th five year plan target
- Framework for coordinated development, management, conservation and efficient use of water resources



NIWRMP- Methodology



NIWRMP 2016 contents

- ✓ Executive Summary
- ✓ Introduction and Objectives
- ✓ Context (country, hydrology, present and projected climate)
- ✓ Water-related issues
- ✓ Governance framework (policies, laws, institutions)
- ✓ Bhutan Water Security Index
- ✓ IWRM at basin level (basin delineation, RBC, RBMP)
- ✓ Priorities in the IWRM 2016 program

Key issues and challenges

1. Impacts from climate change
   - ✓ Too much and too little
   - ✓ Spatial and seasonal availability
2. Limited water storage
3. Drying up of water sources
4. Water availability versus accessibility

Key issues and challenges

Physiographic reality

Key issues and challenges

4. Water availability versus accessibility

Key issues and challenges

4. Water availability versus accessibility
   - ✓ Availability – High
   - ✓ Accessibility - Low
   - ✓ High cost of interventions
   - ✓ Dispersed low density population
   - ✓ High per capita cost

5. Water Quality
   - ✓ Solid and liquid waste
   - ✓ 15% of household in Thimphu connected to sewerage treatment plant
   - ✓ Remaining 85 % rely on individual septic tanks
   - ✓ Waste from households, automobile workshops, storm water, etc.

Key issues and challenges

7. Activities along rivers
   - ✓ diversion of rivers
   - ✓ collection of boulders/sand
   - ✓ river training works

8. Multi-sector coordination
   - ✓ Institutional linkages
   - ✓ Data and information management
   - ✓ Laboratories

Interagency Coordination Framework Water Security Index

Water Security Index.

- 5 dimensions.

- 57 indicators

For each dimension, specify KRAs, KPIs and Strategies

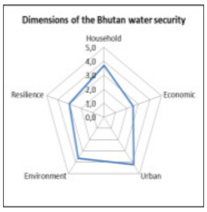
For example, on the **urban water security** dimension:

KEY RESULT AREAS	KEY PERFORMANCE INDICATORS	INTERVENTION STRATEGIES
Improved and protected urban drinking water supply	• Percentage of urban population having potable piped water supply • Percentage of urban water supply loss (un-accounted for water)	• Improve access to alternative drinking water sources (water harvesting, groundwater development) • Improve design, maintenance and management of urban water supply systems (strengthen responsible agencies)
Improved coverage and effectiveness of urban sanitation and drainage	• Percentage of urban population with improved sanitation • Percentage of urban population with (at-least weekly) waste collection and disposal service • Reduction in damage from urban flooding	• Improve condition of catchment areas and water sources (reforestation and conservation measures) • Water metering and pricing • Improve urban drainage systems • Relocate settlements from flood-prone areas • Improve solid waste collection and disposal services

How is overall water security measured?

BHUTAN WATER SECURITY INDEX (BWSI) SYSTEM

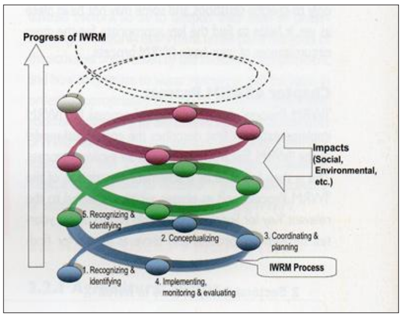
A Scoring System derived from Indicators of physical water availability &variability, and KPIs of action taken across 5 dimensions



Index	Stage
5	Model
4	Effective
3	Capable
2	Engaged
1	Hazardous

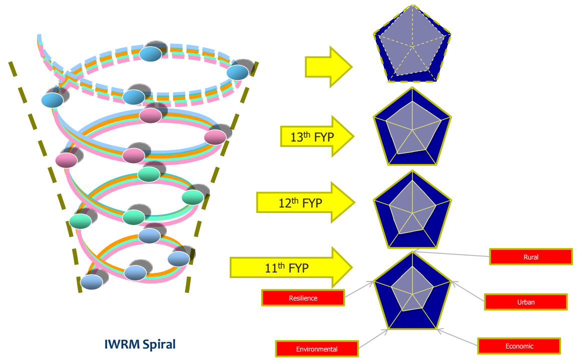
	Water Security Status	Criteria
5	Model	Sustainable financing for water security, environmental protection and management already established
4	Effective	Water security given high priority in the national agenda; appropriate public investment in water security; effective regulation and enforcement; public awareness and ongoing behavioral changes apparent
3	Capable	Increasing levels of investment and strength of regulation and enforcement; water security and environment recognized as priorities in the national development agenda; improving technical and financial capacities in addressing water-related issues
2	Engaged	Need to invest in water security recognized, including investment in capacity-building programs; ongoing institutional development and strengthening; improving policy environment in which water-related issues are addressed
1	Hazardous	Inadequate levels of investment in water-related infrastructure and poor-quality regulation and enforcement result in hazardous levels of water security

IWRM implementation through a "Spiral Learning " process



- **Iterative** (visualized as an upward spiral) and enables immediate action
- Reassess conditions to **anticipate change**
- Institutionalize an **evolving process** that continually adapts to change
- Focus initially on **governance** and institutional arrangements

How is progress tracked against the spiral IWRM learning process ?



Priority Areas

- Adoption of Water Security Index in the 12th FYP
  - NKRA 8, KPI 8.8
  - Coordinated AKRA and KPI for NKRA 8 –water
  - Need to streamline and strengthen data collection and management system.
  - Refinement under progress in Wangchhu Basin through ADB TA
- Multi-sectoral coordination
  - institutional linkages/coordination mechanism
  - Data and information management – between agencies/institutions/researchers/local government
    - Water quantity
    - Water quality
  - Laboratories

Priority Areas

- Activities along rivers
  - Sand and boulder collection
  - River training works
  - Discharge of waste and toxicity from waste into water bodies

THANK YOU

http://www.nec.gov.bt/

ས་གནས་གཞུང་གི་གནས་ཚད་ལུ་ ཆུ་དང་བྲེལ་

ལས་རིམ་ཁ་གསལ།

- ཛོང་ཁག་གི་གནས་ཚད་ལུ་ ཆུའི་ཐོན་སྐྱེད་འཛིན་སྐྱོང་གི་ལམ་ལུགས།
- ཆུ་དང་འབྲེལ་བའི་ གནོད་ལན་དང་དཀའ་ངལ།
- ཆུའི་ཐོན་སྐྱེད་འཛིན་སྐྱོང་གི་ ཐབས་ལམ་དང་གནས་སྐབས།

ཛོང་ཁག་གི་གནས་ཚད་ལུ་ ཆུའི་ཐོན་སྐྱེད་འཛིན་སྐྱོང་གི་ལམ་ལུགས།

- ཛོང་ཁག་ཚུ་ནང་ ཆུའི་ཐོན་སྐྱེད་འཛིན་སྐྱོང་གི་ལམ་ལུགས་གསལ་ཏོག་ཏོ་མེད།
- ལས་ཁུངས་ ལས་སྡེ་དང་ སྡེ་ཚན་ཚུ་གི་བར་ན་མཉམ་འབྲེལ་མེད།
  - ➢ བཟོ་རིགས་སྡེ་ཚན་གྱིས་ གྲོང་གསེབ་ཁྲུང་ཆུ་བཀྲམ་སྤེལ་གྱི་དོན་ལུ་ གཞི་རྟེན་ (infrastructure) གྱི་བཟོ་བཀོད་ ཆུ་ལང་ཤིང་དང་ ཉམས་བཙོས།
  - ➢ ཁྲིམ་སྡེ་ཡིག་ཚང་གིས་ ཁྲིམ་སྡེ་ས་ཁོངས་ནང་ཆུའི་གཞི་རྟེན་གྱི་བཟོ་བཀོད་ ཆུ་ལང་ཤིང་དང་ ཉམས་བཙོས།
  - ➢ གསོ་བའི་སྡེ་ཚན་གྱིས་ ཁྲུང་ཆུ་གི་སྤུས་ཚད་ཞིབ་དཔྱད།
  - ➢ སོ་ནམ་སྡེ་ཚན་གྱིས་ ཆུ་དགོ་པའི་ས་གོ་རྒྱ་ཚད་(Command area)དང་ ལོ་ཐོག་ལུ་ཆུའི་དགོས་མཁོ(crop water requirement)

ཆུ་དང་འབྲེལ་བའི་ གནོད་ལན་དང་དཀའ་ངལ།

- ཆུ་ཀ་ཁར་ལས་ཆུ་ ༡༠༠% སྤྱོད་འདི་ མཐའ་འཁོར་གནས་སྟངས་ཀྱི་ཆུ་ཚད་མེད།

(No Environmental Flow maintained, particularly in drinking water and irrigation water sources)

- མི་རྐྱང་ གཡུས་ཚན་ ཆེད་འདོག་ཚུ་གི་བར་ན་ ཆུ་ཀའི་བསྐོར་མ་སྒྲིགས་པ། ཆུའི་བཅའ་ཁྲིམས་ནང་ ཆུ་འདི་གཞུང་དབང་གི་རྒྱུ་ནོར་ཨིན་ཟེར་བཀོད་ཡོད་མི་འདི་ གོ་བ་ཕྱི་འགྱུར་སྦེ་ཡིན་ཡོདཔ།
- གཞིང་ཆུ་དང་ ཁྲུང་ཆུའི་ཀ་ཚུ་ བསྐམ་འགྱོ་འདི་ རང་བྱུང་ཆུ་ ༼spring༽ རོང་ཆུ་ ༼stream༽ དང་ གཙང་ཆུ་ཚུ་ལུ་ ཆུའི་དགོས་འདོད་ཡར་སེང་འགྱོ་དོ་ཡོད།

  དཔེར་ན་ དབང་འདུས་ལུ་ གྲོང་གསེབ་ཁྲུང་ཆུའི་ཀ་ཚུ་ ༦༠% རེ་ ལོ་ལྟར་བཞིན་ ཉམས་འགྱོ་དོ་ཡོདཔ།

  རྒྱུ་རྐྱེན་ བསིལ་དྲོད་གནས་སྟངས་འགྱུར་བ།

  ཆུའི་ཀ་ཁར་གོང་འཕེལ་གྱི་ལཱ་ ཤིང་བཏབ་ནི་དང་ ནོར་གསོ་སྐྱོང་ཐབས་ནི།

ཆུ་དང་འབྲེལ་བའི་ གནོད་ལན་དང་དཀའ་ངལ།

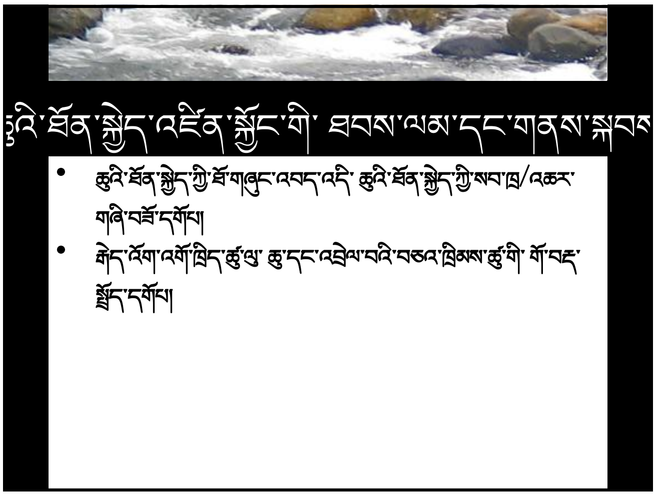
- ཆུ་དང་འབྲེལ་བའི་བར་གླིང་ (Buffer Zone)གི་བསྐོར་ ཆུའི་བཅའ་ཁྲིམས་ནང་ གསལ་ཏོག་ཏོ་མེདཔ།
- ས་འོག་གི་ཆུ་བཏོན་ནི་དོན་ལས་ ལམ་སྟོན་ཁ་གསལ་མེདཔ།
- ཆུའི་བཅའ་ཁྲིམས་ནང་ གཞན་རྒྱལ་ཁབ་(India) ཀྱིས་ ང་བཅས་རའི་རྒྱལ་ཁབ་ཀྱི་ས་ཁ་ལས་ ཆུ་བཏོན་པ་ཅིན་ ཁ་གསལ་མེདཔ།
- འཁྲུང་ཆུ་བཏོན་ནི་གི་ཐབས་ཤེས་གཞན་ ལག་ལེན་ཐབས་མ་ཚུགས།
- མི་རློབས་ཡར་སེང་ མི་སེར་གྱི་འཚོ་བའི་གནས་ཚད་ཡར་དྲག་ བཟོ་གྲྭ་ གོང་འཕེལ་གི་ལཱ་དང་ གསོ་བའི་སྲིད་ གྲོང་གསེབ་ནང་ཆུ་བཤལ་ཆབ་གསང་ ༼flush toilet༽ བཟོ་དགོཔ་ཚུ་གི་ ཆུའི་དགོས་འདོད་ ༼demand༽ ཡར་སེང་འགྱོ་ཡོདཔ།

ཆུ་དང་འབྲེལ་བའི་ གནོད་ལན་དང་དཀའ་ངལ།

- ཆེད་འདོག་འགོ་ཁྲིད་ཚུ་ ཆུའི་བཅའ་ཁྲིམས་ཀྱི་གོང་དོན་ཚུ་ ཧ་མ་གོ་བའི་དཀའ་ངལ།
- ཆུའི་བཅའ་ཁྲིམས་ ༢༠༡༢ ཅན་མའི་སྔོན་ལས་ ཆུ་དང་འབྲེལ་བའི་ཁྲིམས་ཀྱི་གྲོས་ཆོད་ཚུ་གི་ བཅའ་ཁྲིམས་ལག་ལེན་ཐབས་ནི་ལུ་གནོད་ལན།

ཆུའི་ཐོན་སྐྱེད་འཛིན་སྐྱོང་གི་ ཐབས་ལམ་དང་གནས་སྐབས།

- ཛོང་ཁག་ནང་ ཆུའི་ཐོན་སྐྱེད་འཛིན་སྐྱོང་གི་འགན་དབང་འདི་ ལས་སྡེ་གཅིག་ལུ་སྤྲོད་གནང་དགོཔ།
- ཆུ་སྤྱོད་ཚོགས་པ་གཞི་བཙུགས་འབད་ནི་དང་ ཧེ་མ་ལས་ཡོད་པའི་ཆུ་སྤྱོད་ཚོགས་པ་ཚུ་ སྒྲིང་སྒྲིང་པོ་ཐབས་ལུ་ རྒྱབ་སྐྱོར་འབད་དགོཔ།
- ཆུའི་ཐོན་སྐྱེད་འཛིན་སྐྱོང་གི་དོན་ལུ་ མཐའ་འཁོར་གནས་སྟངས་ཞབས་ཏོག་གི་འཐུས་ ༼PES༽ གཞི་བཙུགས་འབད་དགོཔ།
- ཆུ་བཏོན་ནི་ཐབས་ཤེས་གཞན་ཚུ་ གསར་འཚོལ་འབད་འདི་ ༼explore༽ ལག་ལེན་ཐབ་དགོཔ།
- ཆུ་སིམ་ནི་མེད་པའི་ས་ཁོངས་ ༼impermeable surfaces༽ ཚུ་ ཚད་འཛིན་འབད་འདི་ ས་འོག་གི་ཆུ་ བསྐྱར་གསོ་ ༼recharge༽ འབད་དགོཔ།


ུའི་ཐོན་སྐྱེད་འཛིན་སྐྱོང་གི་ ཐབས་ལམ་དང་གནས་སྟབས
• ཆུའི་ཐོན་སྐྱེད་ཀྱི་ཐོ་གཞུང་འབད་འདི་ ཆུའི་ཐོན་སྐྱེད་ཀྱི་སབ་ཁྲ/འཆར་གཞི་བཟོ་དགོཔ།
• ཆེད་འོག་འགོ་ཁྲིད་ཚུ་ལུ་ ཆུ་དང་འབྲེལ་བའི་བཅའ་ཁྲིམས་ཚུ་གི་ གོ་བརྡ་སྤྲོད་དགོཔ།

བཀའ་འདྲིན་ཆེ།

Session 2: Water and Ecology

Chair: Mr. Ugyen Lhendup, Bhutan Trust Fund for Environmental Conservation

Session 2 : Water and Ecology		
1400	Watershed management & wetland conservation in Bhutan	Ms. Sonam Choden, WMD, DoFPS
1430	Freshwater macroinvertebrates biodiversity in Bhutan	Mr. Jigme Wangchuk, UWICER, DoFPS
1500	Brief account on freshwater biodiversity of Bhutan	Mr. Ugyen Dorji, CNR, Royal University of Bhutan
1520	Fishery resources of Bhutan: threats and opportunities.	Mr. Gopal Prasad Khanal, NRCR&LF
1540	**Tea Break**	
1600	Study on minimum environmental flow for hydropower projects of Bhutan	Mr. Tenzin Khorlo, NECS
1630	**Q&A Session**	
	End of Day 1	

Watershed Management and Wetlands Conservation in Bhutan

National Water Symposium

Ariya Hotel, Thimphu

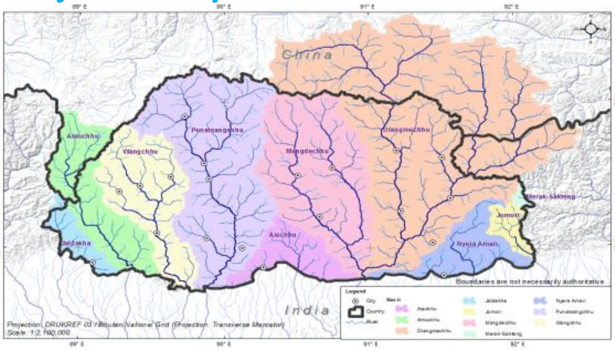
10th – 12th May, 2017

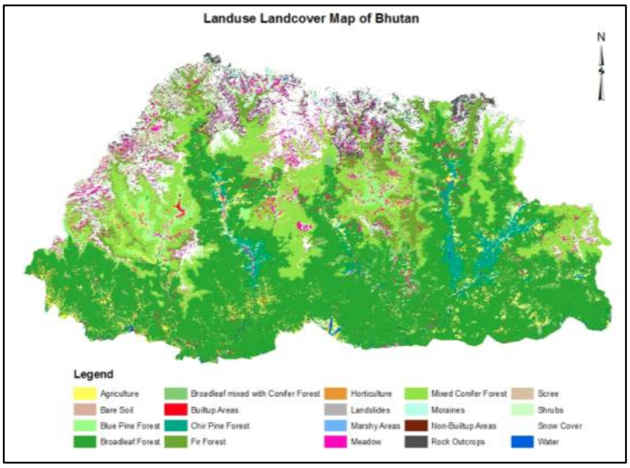
sonamchoden@moaf.gov.bt

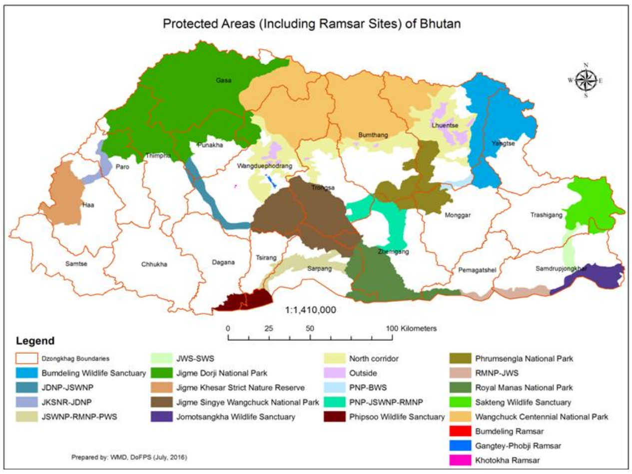
Outline

- Water Resources in Bhutan
- Policy Overview
- National Agencies Involved
- Establishment of Watershed Management Division
- WMD & its Mandates
- Watershed Management Processes
- Wetlands Conservation in Bhutan
- How far have we reached?
- Challenges in the 11th FYP
- Opportunities for 12th FYP

Major River Systems in Bhutan







Policy Overview

1. Vision Statement of 2020 (1999)
2. Bhutan Water Vision 2025
3. Bhutan Water Policy (2003/2008)
4. National Forest Policy (2011)
5. Water Act (2011)
6. Water Regulation (2014)
7. Forest and Nature Conservation Act (1995)
8. Forest and Nature Conservation Rules (2006)& (2017)
9. Land Act (1979) & (2007)
10. Mines and Minerals Act (1995)
11. Electricity Act (2001)
12. Waste Prevention and Management Act (2009)
13. Environmental Assessment Act (2000)
14. National Environmental Protection Act (2007)

National Agencies Involved

- Water Resources Coordination Division - National Environment Commission
- Watershed Management Division - Department of Forests and Park Services, Ministry of Agriculture and Forests
- Department of Hydro Metrological Services - Ministry of Economic Affairs
- Department of Agriculture - Ministry of Agriculture and Forests
- Ministry of Health - Public Health Engineering Division & Public Health Laboratory
- Water and Sanitation Division - Ministry of Works and Human Settlement
- RSPN - Bhutan Water Partnership

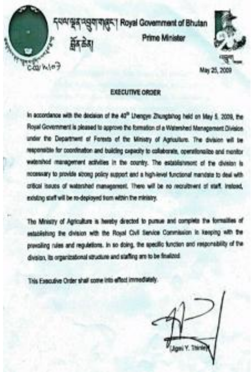
What is watershed management?

Watershed management refers to the management of watersheds **taking into account all aspects that are likely to influence the quality and quantity of water flowing from the watershed**. This is what "holistic" means.

A watershed management plan is **not** a rural development plan.

Why was WMD created?

- Initially a section under Social Forestry Division for 8 years (2002-2009)
- Wang River Basin Management Framework: **<u>Recommended a lead agency for watershed management</u>** (3/2009)
- Established in May 2009 because (Cabinet order No. C-02/In/07)



Royal Government of Bhutan
Prime Minister

C-02/In/07

May 25, 2009

EXECUTIVE ORDER

In accordance with the decision of the 40th Lhengye Zhungtshog held on May 5, 2009, the Royal Government is pleased to approve the formation of a Watershed Management Division under the Department of Forests of the Ministry of Agriculture. The division will be responsible for coordination and building capacity to collaborate, operationalize and monitor watershed management activities in the country. The establishment of the division is necessary to provide strong policy support and a high-level functional mandate to deal with critical issues of watershed management. There will be no recruitment of staff. Instead, existing staff will be re-deployed from within the ministry.

The Ministry of Agriculture is hereby directed to pursue and complete the formalities of establishing the division with the Royal Civil Service Commission in keeping with the prevailing rules and regulations. In so doing, the specific function and responsibility of the division, its organizational structure and staffing are to be finalized.

This Executive Order shall come into effect immediately.

(Jigmi Y. Thinley)

Mandate of WMD for watershed management planning

1. Assess the conditions of watersheds and wetlands across the country; classify watersheds to identify those that are **degraded/critical**.
2. Prepare watershed and wetlands management plans for degraded/critical watersheds to remove/mitigate degrading influences.

Also:

3. Prepare management plans for watersheds that, for social/economic reasons, require management interventions to ensure provision of specific watershed goods and services

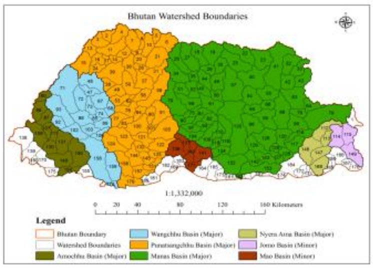
Mandates of WMD as per Road Map for Watershed management in Bhutan 2011

- Coordination and building capacity to collaborate, operationalize and monitor watershed management activities
- Provide strong policy support and high-level functional mandate to deal with the critical issues of watershed management
- Pursue innovative sustyainable financial mechanisms for watershed management, including options for payment of ecosystem services (PES), and develop appropriate modalities

Rationale for the Management Plan

Rapid classification of watersheds –

- Classification Guideline, 2010
- Watershed Classification Guidelines, 2016

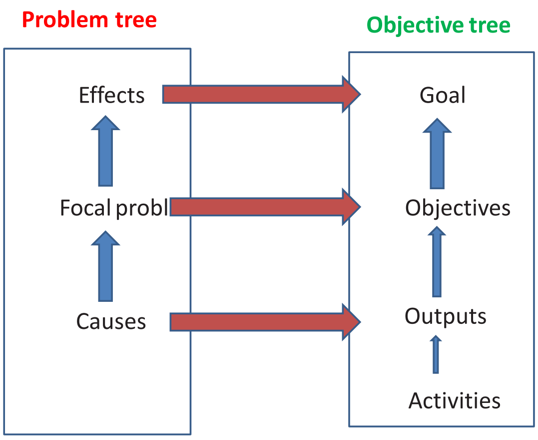


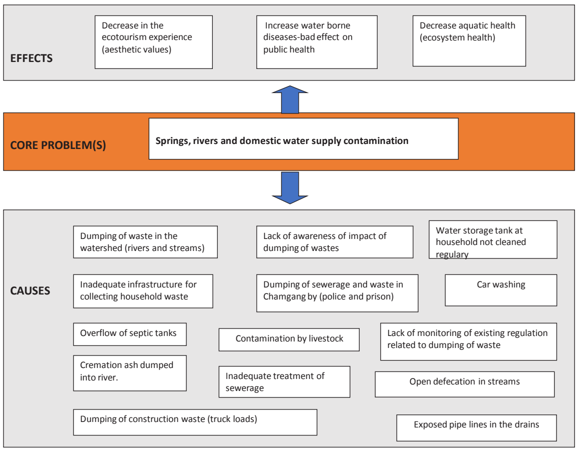
Purpose of the Management Plan

- Identify the degrading influences
- Reduce or mitigate the degrading influences through the proposed activities

Nine steps to complete a LFA

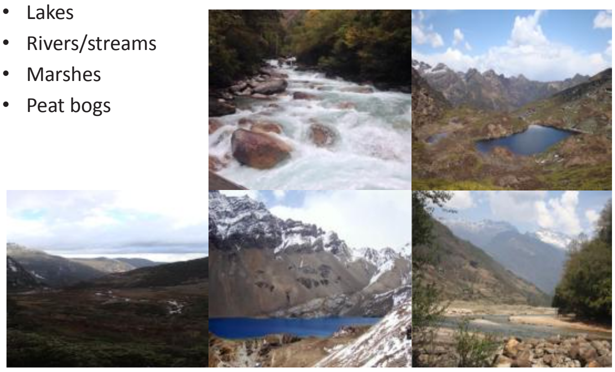
1. Analysis of the Context
2. Stakeholder Analysis
3. Problem Analysis
4. Objectives Analysis
5. Plan of Activities
6. Resource Planning
7. Indicators/Measurements of Objectives
8. Risk Analysis and Risk Management
9. Analysis of the Assumptions





Wetlands Classification

- Lakes
- Rivers/streams
- Marshes
- Peat bogs



The Wetland Story of Bhutan

- Wetlands Program (2010)
- Ministerial Notification (04.14.2011)
- Rapid Wetlands Assessments
- Procedural Guidelines for Determination and Protection of Jurisdictional Wetlands (12.01.2012)
- 161st contracting party to RAMSAR (09.07.2012)
- Water Regulations mandates WMD to prepare wetlands management plans (2014)
- Wetlands conservation incorporated in the Forest and Nature Conservation Rules (2016)

Where have we reached so far?

- Roadmap for WM
- Guidelines for Classification of Watersheds
- Rapid Assessment & Classification of Wangchhu and Punatsangchhu River Basins
- Management plans for watersheds within major river basins are being developed (Chamkharchhu, Mangdechhu, Kurichhu, Punatsangchhu and Wangchhu
- Management plans for wetlands have been developed
- Designation of Ramsar sites and development of their management plans
- Enhanced Watershed and Wetlands Regulations

- Awareness programs
- Capacity building on watersheds assessment & use of watershed classification guidelines
- Assessments of water sources drying up
- Providing technical support for national donor agencies and field offices
- Scaling up of REDD+
- Scaling up of PES schemes
- Develop framework for 1% royalty from the hydropower sector

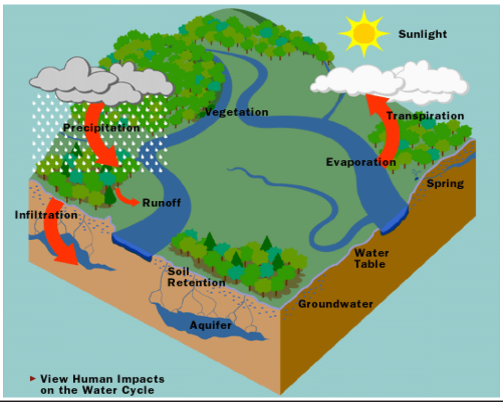
Challenges to Watershed Management

1. **Climate change** and its impact on water
   - Problem of plenty
   - Problem of Scanty
2. **Multiple Agencies** - enhanced complexities
   - Weak coordination
   - Common resource conundrum - rights & responsibility mismatch
3. **Weak Science -** mountain hydrology
   - Uninformed decision making process
   - Insufficient hydro metrological stations
4. **Limited enabling authority** for implementing integrated watershed management plans

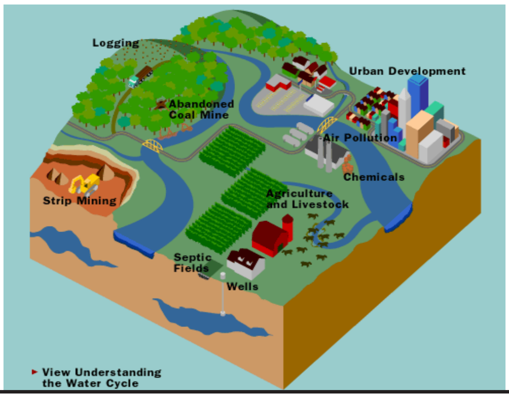
Challenges to wetlands Conservation

- Knowledge gap on wetlands and their functions
- Wetland benefits are misunderstood
- Very minimal or scarce database
- Development and gradual change in values

Water Cycle: Ideal Situation



Water cycle: Disturbed Situation



Thimphu City in 70 years

Deteriorating Mid Altitude Lakes

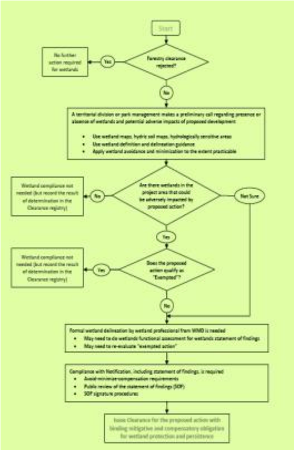
What would we like to see improved in the Water Sector in the 12th FYP?

1. Enhanced coordination and cooperation - removal of agency stereotyping
2. Strengthen the valuation of water and its ecosystems - economic and spiritual
3. Explore the Cumulative effects (climate change - food security - energy nexus)
4. Implement the polices – approaching development activities through a watershed perspective
5. Integration of right approaches to wetlands conservation by all sectors

Opportunities for WMD in the 12th FYP

- Implementation of watershed management plans and wetland management plans
- Improving the knowledge on wetland science – understanding wetland functions
- Improved Advocacy on wetlands and their benefits – Institutional advocacy programs
- Strengthening and implementing regulations by up-scaling Forestry Clearance without compromising its quality - Carrying out wetlands inventory and mapping to serve as a tool for field managers
- Enhanced collaborations for implementation with field offices

- Enabling the Implementation of watershed and wetlands management plans –
  Integrating watershed management and wetlands conservation in grass root watershed planning and management - empowering local governments - by harnessing the decentralized process



KADINGCHELA

Freshwater Macroinvertebrate Biodiversity in Bhutan

Record from the past studies and current scenario

- 10th May 2017
- Jigme Wangchuk
- Center for Water, Climate Science and Environment Policy
- Ugyen Wangchuck Institute for Conservation and Environmental Research
- Lamai Gompa: Bumthang

Structure of Presentation

- Background
- Importance of freshwater macroinvertebrates
- Past record of freshwater macroinvertebrate in Bhutan
- Current scenario
- Gaps
- Needs

Background

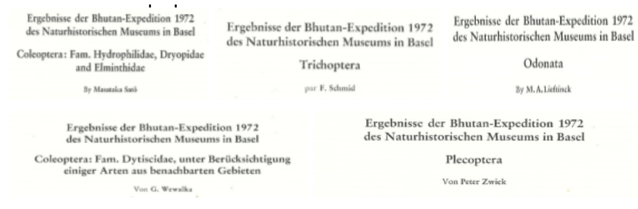
- World
- There are over 45000 species of insects, known to inhabit diverse freshwater ecosystems (Balaram, 2005).
- Odonata over 5680 species
- Mollusca over 5000 species
- Decapoda over 1863 species
- Region (Eastern Himalaya)
- Mollusca 186 species (112 gastropods and 74 bivalves)
- Odonates 367species
- Decapoda 57 species

Importance of freshwater macroinvertebrate

- Indicator for health of environment and water quality
- Decomposition of organic matter
- Nutrition recycling
- Water purification
- Food source for trophic levels

Past record on freshwater macroinvertebrates

- Freshwater macroinvertebrates was first studied during Expedition to Bhutan by Naturalist from Basal, 1972
- Western and Central Bhutan assessed during the expedition
- Taxa on Coleoptera, Odonata, Trichoptera and Plecoptera



Ergebnisse der Bhutan-Expedition 1972
des Naturhistorischen Museums in Basel
Coleoptera: Fam. Hydrophilidae, Dryopidae and Elminthidae
By Masataka Satô

Ergebnisse der Bhutan-Expedition 1972
des Naturhistorischen Museums in Basel
Trichoptera
par F. Schmid

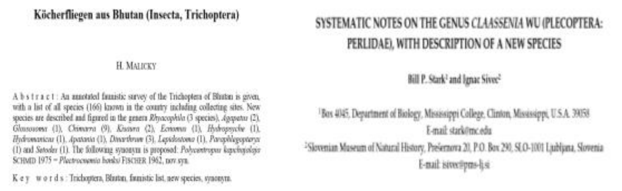
Ergebnisse der Bhutan-Expedition 1972
des Naturhistorischen Museums in Basel
Odonata
By M. A. Lieftinck

Ergebnisse der Bhutan-Expedition 1972
des Naturhistorischen Museums in Basel
Coleoptera: Fam. Dytiscidae, unter Berücksichtigung einiger Arten aus benachbarten Gebieten
Von G. Wewalka

Ergebnisse der Bhutan-Expedition 1972
des Naturhistorischen Museums in Basel
Plecoptera
Von Peter Zwick

Past record on macroinvertebrates

- HKH (Hindu Kush-Himalaya) Assess Project 2005-2008 surveyed 34 sites in Bhutan (Covering central and western Bhutan)
- 199 taxa were used for HKHbios score
- -2 taxa (order) 142 taxa (family) 6 taxa (Subfamily) 49 taxa (Genera),) 2 taxa (tribes)



Köcherfliegen aus Bhutan (Insecta, Trichoptera)

H. MALICKY

Abstract: An annotated faunistic survey of the Trichoptera of Bhutan is given, with a list of all species (166) known in the country including collecting sites. New species are described and figured in the genera *Rhyacophila* (3 species), *Agapetus* (2), *Glossosoma* (1), *Chimarra* (9), *Kisaura* (2), *Ecnomus* (1), *Hydropsyche* (1), *Hydromanicus* (1), *Apatania* (1), *Dinarthrum* (3), *Lepidostoma* (1), *Paraphlegopteryx* (1) and *Setodes* (1). The following synonym is proposed: *Polycentropus kapchojalaja* SCHMID 1975 = *Plectrocnemia hoenei* FISCHER 1962, nov syn.

Key words: Trichoptera, Bhutan, faunistic list, new species, synonym.

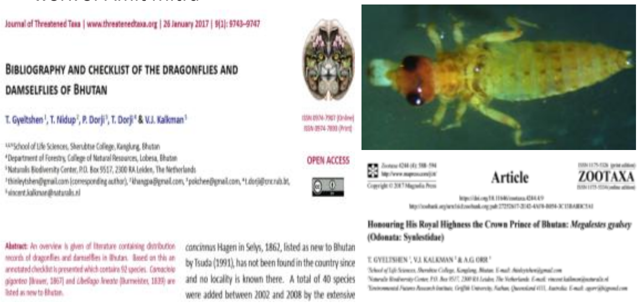
SYSTEMATIC NOTES ON THE GENUS *CLAASSENIA* WU (PLECOPTERA: PERLIDAE), WITH DESCRIPTION OF A NEW SPECIES

Bill P. Stark[1] and Ignac Sivec[2]

[1]Box 4045, Department of Biology, Mississippi College, Clinton, Mississippi, U.S.A. 39058
E-mail: stark@mc.edu
[2]Slovenian Museum of Natural History, Prešernova 20, P.O. Box 290, SLO-1001 Ljubljana, Slovenia
E-mail: isivec@pms-lj.si

Past studies on macroinvertebrates-Odonata

- The taxa odonata are the most studied taxa compared to other taxa
- Records of odonates in the country are mostly contributed by the work of Amit Mitra

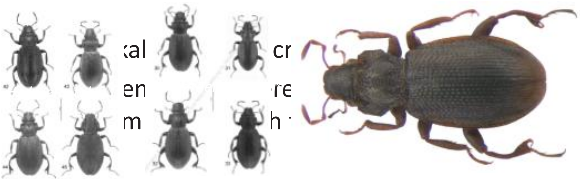


Past records on macroinvertebrates-Diptera

- Taxa simuliidae (18 species) chironomidae (6 species) and drsophilidae (4 species) between 1981 to 2008

Past studies on macroinvertebrates-Coleoptera

- Wewalka, 1975, first recorded the freshwater coleoptera in Bhutan
- -Described three new species from Bhutan
- Sato and Smetana,1977 described five new species from Bhutan



Past studies on macroinvertebrates-other TAXA

- Trombidiforemes
- - Pešić and Smit, 2007 recorded five species and two
- were new to science
- Decapoda
- -Amongst nine species recorded*, Gecarcinucas*
- *(Liotelphusa) wuermlii* was described new to science
- (Pretzmann, 1975)

- Hemiptera
- -Three species were described new to science in 2007 from
- ten records (Zettel and Duc, 2007)

- Megaloptera
- -Only *Neochauliodes indicus* was recorded

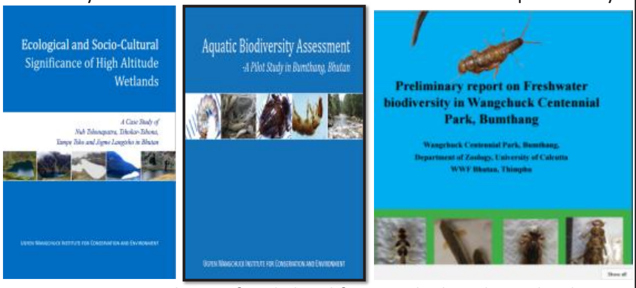
- Gastropoda
- -11 species are recorded , due for publication

species Recorded and NEW species described in Bhutan-Published Papers

Order	Family	Species	New to science	Remarks
Plecoptera	5	34	20	6 species identified at genera level
Trichoptera	24	173	33	16 species identified at genera level
Odonata	16	101	5	4 species identified at genera level
Diptera	3	28	18	5 species identified at genera level
Coleoptera	8	37	11	4 species identified at genera level
Decapoda	3	9	1	
Hemiptera	3	12	3	2 species identified at genera level
Megaloptera	1	1		
Gastropoda	6	11		1 species identified at genera level
Trombidiformes	1	5	2	
Total	**70**	**411**	**93**	

Reports

Recently 2012 onwards few Bhutanese researcher took up the study



Taxa were reported up to family level from High altitude wetland, Bumthang District and Wangchuck Centennial National Park

Journals, Thesis

UTILITY OF AN EXISTING BIOTIC SCORE METHOD IN ASSESSING THE STREAM HEALTH IN BHUTAN

A THESIS SUBMITTED

IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Kinzang Dorji

Science and Engineering Faculty

School of Earth, Environmental and Biological Sciences

Queensland University of Technology

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ISSN 1982-3932

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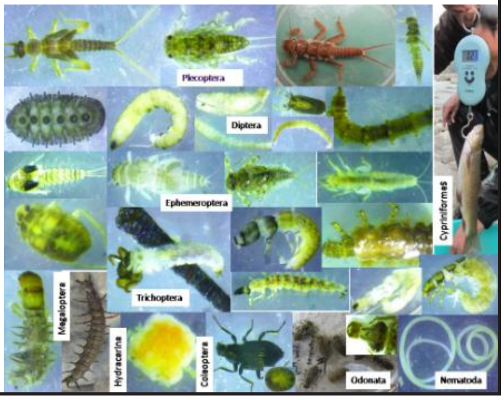
URBAN GROWTH AND WATER QUALITY IN THIMPHU, BHUTAN

Nandu Giri and O. P. Singh

Different Taxa Recorded in Bhutan from REPORTs and Unpublished Papers

- Order -21
- Family- 109

- ☑ Aeshnidae
- ☑ Amnicolidae
- ☑ Aphelocheiridae
- ☑ Arctopsychidae
- ☑ Astacidae
- ☑ Athericidae
- ☑ Atyidae
- ☑ Baetidae
- ☑ Belostomatidae
- ☑ Blephariceridae
- ☑ Brachycentridae
- ☑ Caenidae
- ☑ Calamoceratidae
- ☑ Calopterygidae
- ☑ Capniidae



GAPS

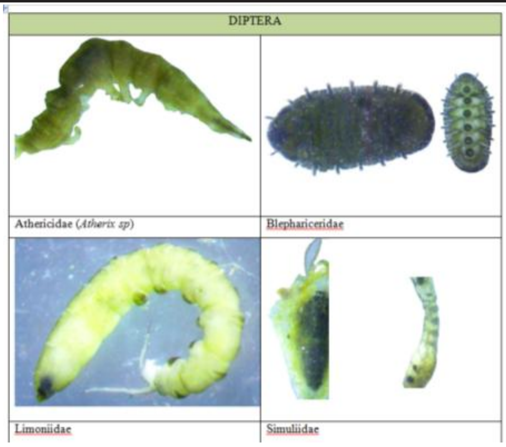
- Limited study, covered partially in central and western Bhutan
- Lack of expertise at National level
- Key for identification not available, HKH-Assess keys incomplete
- Less interested personnel in this field as it involved taking lots of voucher-Buddhist belief

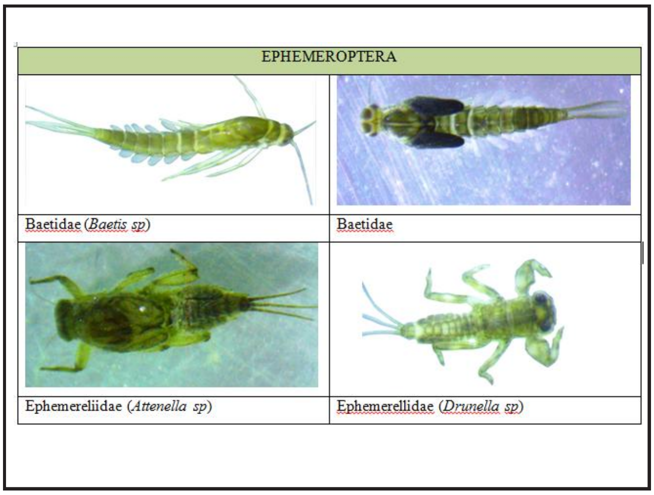
Needs

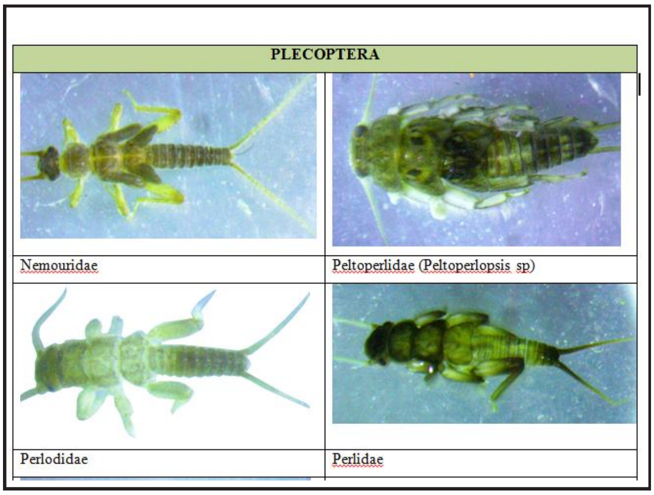
- Identify the national voucher specimen repository in the country for the purpose of education and future references
- Pooling of voucher specimen, identification, authentication from experts, DNA analysis to validate the species
- Need to encourage the national to specialize on particular taxa group

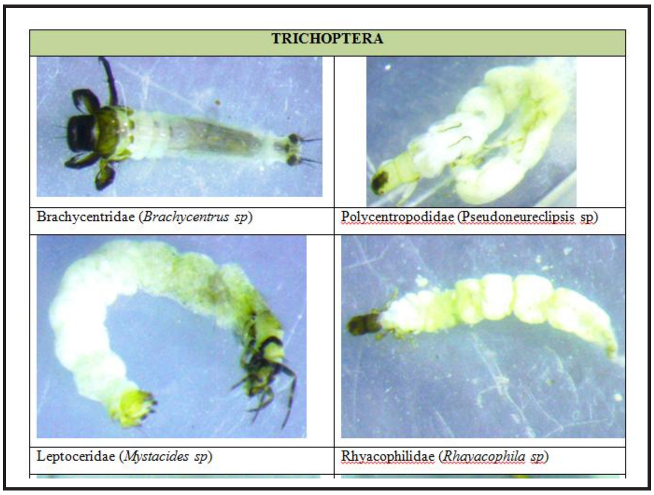
Needs

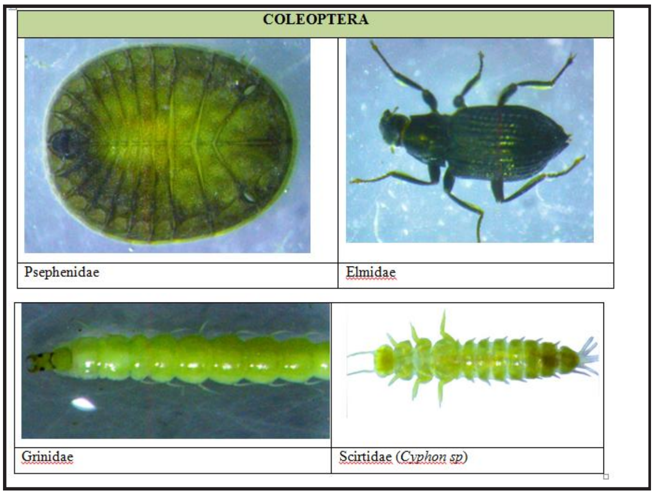
- Nation wide Systematic Aquatic-biodiversity Surveys and Research
- National Specimen repository
- Protocols- Uniformity
- Special funding : For research as well as publishing
- Awareness-Research needs vs Religious Sentiments
- Capacity building

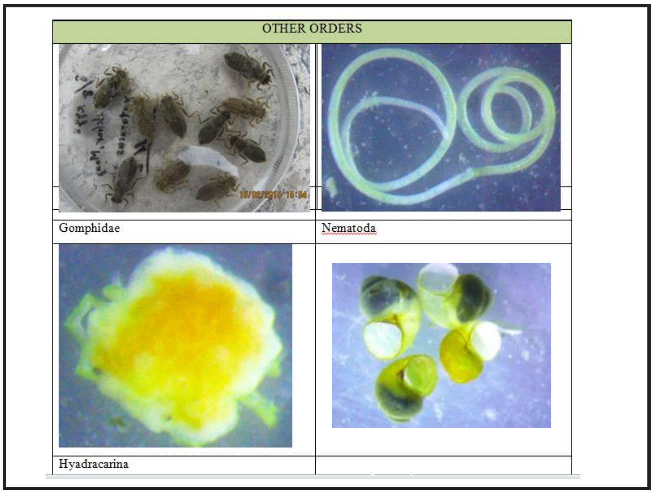


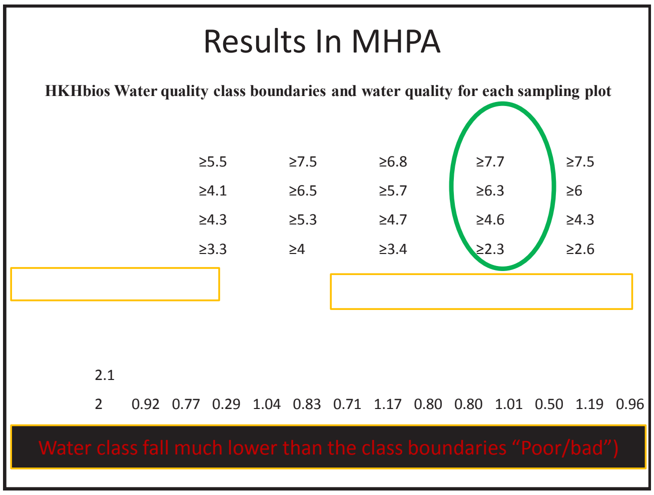

EPHEMEROPTERA
Baetidae (Baetis sp)
Baetidae
Ephemereliidae (Attenella sp)
Ephemerellidae (Drunella sp)


PLECOPTERA
Nemouridae
Peltoperlidae (Peltoperlopsis sp)
Perlodidae
Perlidae


TRICHOPTERA
Brachycentridae (Brachycentrus sp)
Polycentropodidae (Pseudoneureclipsis sp)
Leptoceridae (Mystacides sp)
Rhyacophilidae (Rhayacophila sp)


COLEOPTERA
Psephenidae
Elmidae
Grinidae
Scirtidae (Cyphon sp)


OTHER ORDERS
Gomphidae
Nematoda
Hyadracarina


Results In MHPA
HKHbios Water quality class boundaries and water quality for each sampling plot
≥5.5 ≥7.5 ≥6.8 ≥7.7 ≥7.5
≥4.1 ≥6.5 ≥5.7 ≥6.3 ≥6
≥4.3 ≥5.3 ≥4.7 ≥4.6 ≥4.3
≥3.3 ≥4 ≥3.4 ≥2.3 ≥2.6
2.1
2 0.92 0.77 0.29 1.04 0.83 0.71 1.17 0.80 0.80 1.01 0.50 1.19 0.96
Water class fall much lower than the class boundaries "Poor/bad")

THANKS

National Water Symposium

Ariya Hotel, Thimphu (10-12th May 2017)

Overview

- Introduction
- Major groups of freshwater biodiversity
  - Fish
  - Freshwater decapods
  - Macroinvertebrates
  - Aquatic plants
  - Freshwater molluscs
- Trends, gaps and way forward
- Conclusion

Introduction

Freshwater Biodiversity

Life forms — Ecosystem

<<Interaction>>

@Ugyen Dorji

Major groups of freshwater biodiversity

Fishes of Bhutan

@ugyendorji

- First specimen-Griffith ,1838
- Three species-Beavan ,1877
- Five species-Day 1889
- Fish introduction-1930
- 41 species-Petr, 1999
- 49 species-Lei ,2008
- 11 species from Bumdeling-Batarrai and Thinley, 2005
- 52 species-Gurung *et al*, 2012

109 species of fishes comprising of 64 genera and 24 families from Bhutan- Gurung and Thoni, 2015 is the highest number of records of fishes from Bhutan.
Many of the specimens are under the process of identification. The number is expected to increase.

Major groups of freshwater biodiversity

Fishes of Bhutan

Family	Genus	Species	Family	Genus	Species
Anguillidae	1	1	Sisoridae	6	14
Cyprinidae	26	43	Eristhistidae	1	1
Psilorhychidae	1	2	Clariidae	1	2
Balitoridae	1	1	Heteropneustidae	1	1
Botiidae	1	2	Chacidae	1	1
Cobitidae	2	3	Salmonidae	2	2
Nemacheilidae	5	10	Belonidae	1	1
Bagridae	2	6	Mastacembelidae	2	2
Olyridae	1	1	Nandidae/Badidae	2	3
Siluridae	1	2	Cichlidae	1	1
Schilbeida	1	1	Channidae	1	5
Amblycipitidae	1	3	Tetraodontidae	1	1

(Gurung and Thoni, 2015)

Challenges

Impacts of Dams

Fish migration

@ugyendorji

Fish ladder and e-flow

Illegal fishing

Major groups of freshwater biodiversity

Macroinvertebrates

@ugyendorji

Highly *sensitive* to pollutions and contaminations.

key indicator aquatic ecosystems

Mitra, 2000; Mitra ,2006; Malicky *et al.,* 2008; Wangyal *et al.* 2011; Giri and Singh, 2012; Wangchuk and Eby, 2013;Dorji, 2014…

Approximately, macroinvertebrates belonging to 21 orders and 109 families.

Major groups of freshwater biodiversity

Order	Family	Order	Family
Order	Family	Order	Family
Order	**Family**	**Order**	**Family**
Annelida	Hirudinea		Chlorocyphidae
Lepidoptera	Crambidae/Pyralidae	Chlorolestidae	Cordulegasteridae
	Pyralidae		Planaridae
Anura	Ranidae		Gammaridae
Trombidiformes	Hydrachnellae	Planaria	
Gastropoda	Physidae	Amphipoda	
	Polymitarcyidae		Libellulidae
Tricladida	Dugesiidae		Coenogrionidae
	Planariidae		

Major groups of freshwater biodiversity

Freshwater Decapods

Courtesy: Ugyen Lhendup

Metabolize and control the flow of energy

Economic importance in fisheries: Food and ornament

Worldwide: 14,756 species distributed in 2,725 genera

Dorji and Gurung, 2014; Nagphel and Gurung ,2015; Lhundup, 2017; Samdrup, 2017.

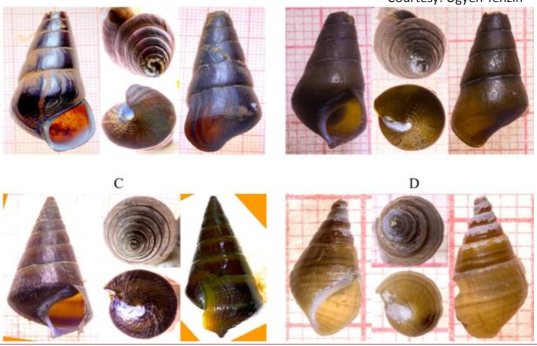
Shrimps *viz., Macrobrachium assamense* and *Caridina* sp.
Crabs: *Himalayapotamon atkinsonianum, Himalayapotamon emphysetum, Himalayapotamon* sp. *,Potamiscus sikkimensis,* and *Meydelliathelphsa edentula* .

Major groups of freshwater biodiversity

Freshwater snails

Courtesy: Ugyen Tenzin

A B



C D

A-C. *Brotia costula* (A: black, B: brown & C: rings along whorls) D. *Melanoides tuberculata*

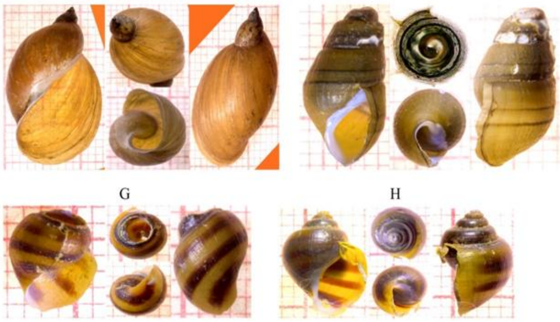
(Tenzin and Dorji, 2017)

Major groups of freshwater biodiversity

Freshwater snails

Courtesy: Ugyen Tenzin

E F



G H

E. *Lymnaea acuminate,* F. *Tarebia lineate,* G-I. *Paludomus conica*

(Tenzin and Dorji, 2017)

Major groups of freshwater biodiversity

Aquatic flora

Less literatures

About 43 species belonging to 28 families recorded

Mostly , stable- Least Concern.
Nine species -Not Evaluated
One species -Data Deficient.

Sources of food and habitat for insects, fish and other aquatic or semi-aquatic organisms

Human: food, religious offerings and decorations, medicine, bio-fertilizers, cleaning sewerage water, and enhancing local economy.

Major groups of freshwater biodiversity

Aquatic flora

Family	Genus	Species	Family	Genus	Species
Acoraceae	1	1	Lentibulariaceae	1	2
Alismataceae	1	2	Limnocharitaceae	1	1
Aponogetonaceae	1	1	Lythraceae	1	2
Brassicaceae	1	1	Menyanthaceae	1	1
Elatinaceae	1	1	Nymphaeaceae	2	2
Eriocaulaceae	1	2	Podostemaceae	1	1
Haloragaceae	1	1	Polygonaceae	1	1
Hippuridaceae	1	1	Pontederiaceae	2	2
Hydrocharitaceae	3	3	Potamogetonaceae	1	3
Juncaginaceae	1	2	Schrophulariaceae	2	2
Lemnaceae	1	2	Typhaceae	2	2

(Dorji and Gurung, 2017)

Way forward

Fish Passages vs E-flow

Hatchery

The baseline data on the freshwater meso and meiofauna of Bhutan is unavailable till date.

Need of development of biotic index, especially for lentic water bodies.

Need of comprehensive assessment of diversity and distribution

Awareness and public outreach program

NATIONAL WATER SYMPOSIUM

Fishery Resources of Bhutan, Threats and Oppurtunities

Gopal Prasad Khanal

National Research Centre for Riverine and Lake Fisheries (NRC&LF), Haa.
Department of Livestock (DoL).
Ministry of Agriculture and Forests (MoAF).

10th May, 2017.
THIMPHU: BHUTAN

76

OUTLINE

- Introduction
- Fisheries Resources of Bhutan
- Fisheries Institution In Bhutan
- Inventory on Fisheries Resources of Bhutan
- Fishery Diversity of Neighbouring Countries and Region
- Conservation Status of Fishes in Bhutan
- Threats to Fishery Resources
  - Hydropower Dams
  - Road Construction and Mining
  - Extraction of Sand and Aggregates
  - Exotic and Invasive Alien Species (IAS) of Fish
  - Illegal Fishing

77

OUTLINE

- Fisheries Conservation Programs by MoAF (DoL):
  - Fish Fauna Assessment
  - Golden Mahseer Telemetry Study
  - Establishment of Fish Monitoring Station
  - Ex-situ Breeding Of Golden Mahseer
  - Other Conservation Activities
- NRCR&LF, HAA (WAY FORWARD; 12th FYP)

78

A) INTRODUCTION

- Bhutan is endowed with rich water resources.
- Most important natural resources of the country.
- Bhutan ranks 6th in terms of per capita internal freshwater resources @ 0.102 million cubic meters.
- The inland water bodies mainly comprises of rivers, streams, springs, lakes and marshlands.
- Rivers (5 major and 5 minor river system; 7200 km).
- Lakes (> 3000 m elevation; 1722 lakes; 49.97 sq.km).
- Marshlands (> 3000 m elevation 63 marshlands; 0.497 sq.km).
  - Adequate assessment of lakes and marshlands in other parts of country is yet to be done.

4

- Supports many forms of aquatic lives.
- The aquatic biodiversity of the country has not been properly assessed.
- Lately, several researchers and institutions made efforts to study the aquatic biodiversity.
- Bhutan's aquatic biodiversity is highly vulnerable to various anthropogenic activities.
  - Prompt need to FUTTHER STRENGTHEN the study on BHUTAN's FRESHWATER BIODIVERSITY for proper management in future.

5

B) FISHERIES RESOURCES OF BHUTAN

- **Based on purpose and source of exploitation:**
  - Culture Fisheries
  - Capture Fisheries
- **Based on natural range of distribution:**
  - Indigenous Fishes
  - Exotic Fishes
    - Approved species for food fish culture and ornamental rearing.
    - Intentionally introduced fish species.

C) FISHERIES INSTITUTION IN BHUTAN

- Ministry of Agriculture and Forests (MoAF).
  - Department of Livestock (DoL).
    - National Research Centre for Riverine and Lake Fisheries (NRCR&LF) , Haa.
    - National Research Centre for Aquaculture (NRCA), Gelegphu.

6

D) INVENTORY ON FISHERY RESOURCES OF BHUTAN

Though, Bhutan lacks complete information on diversity of its fishery resources, **considerable progress** has been made to list down the icthyofauna diversity during the recent years.

19th CENTURY
- John McClelland (1839).
- Sir Francis Day (1889).

→

20th CENTURY
- G. P. Dubey (1978).
- T. Petr (1999).

→

21st CENTURY
- Engagement of Bhutanese researchers/institutions.
- Discovery of additional species including endemic one.

7

McClelland (1839): TWO (2) SPECIES; Indian Cyprinidae.

→ Day (1889): FIVE (5) SPECIES; Fauna of British India.

→ Dubay (1978): FOURTY TWO (42) SPECIES; FAO mission to Bhutan; (BROWN TROUT).

→ Petr (1999): FOURTY NINE (49) SPECIES; (7 warmwater species)

→ Bhattarai and Thinley (2005): 11 additional species from Bumdeling Wildlife Sanctuary.

→ SIXTY (60) SPECIES; (53 Indigenous and 8 Exotic)

→ Dema (2007): SIXTY (61) SPECIES; (Tshoka Tsho)

→ Gurung *et al.* (2013); NINETY ONE (91) SPECIES.

→ Thoni and Gurung (2015) ; NINETY TWO (92) SPECIES (Khaling Torrent Catfish)

8

Gurung and Thoni (2015) ; HUNDRED NINE (109) SPECIES (Fishes of Bhutan: A Preliminary Checklist).

↓

NRCR&LF (DoL/MoAF): 104 SPECIES (Species Composition and Distribution of Fishes in Western Bhutan) BTFEC FUNDED STUDY

↓

INDEGENIOUS:	**93 SPECIES**
EXOTIC:	**11 SPECIES**
TOTAL:	**104 SPECIES**

9

FISHERY DIVERSITY OF NEIGHBOURING COUNTRIES AND REGIONS

SL. NO.	COUNTRY/REGION	NO. OF FRESHWATER FISH SPECIES
1	EASTERN HIMALAYA	520
2	ASSAM	311
3	ARUNACHAL PRADESH	271
4	MEGHALAYA	231
5	MANIPUR	325
6	MIZORAM	202
7	NAGALAND	210
8	SIKKIM	194
9	TRIPURA	199
10	NE INDIA INCLUDING SIKKIM.	422
11	NEPAL	230
12	BANGLADESH	265
13	BHUTAN	109

10

E) CONSERVATION STATUS OF FISHES IN BHUTAN

- Golden mahseer, a globally endangered fish is totally protected in Bhutan.
- It is enlisted in **Schedule-I** of totally protected animals and birds through **Forest and Nature Conservation Act of Bhutan** (1995) and **Forest and Nature Conservation Rules of Bhutan** (2016).

The conservation status of fishes in Bhutan is yet to be evaluated at **"NATIONAL LEVEL"** and hence most of the information's pertaining to conservation status are being adopted from **"IUCN Red List of Threatened Species".**

11

F) THREATS TO FISHERY RESOURCES BHUTAN

(I) HYDROPOWER DAMS

- **The biological consequence:** Obstruction of fish migration within feeding, spawning and refugee habitats.
  - ✓ Dam water favours environment for establishment of other non-native species.
- **The physical consequences** include the accumulation of sediments and alteration of natural flow of water in dewatered reaches of river.
  - ✓ The cleaning of sediments through rapid flushing of water from dams will not **only bring changes downstream** but will also devastate downstream flora and fauna.
- The **chemical consequences** are mainly brought by transformation of free flowing river (lotic) to stagnant (lentic) body., thereby changing the chemical composition.
  - ✓ Changes in chemical composition due to transformation of aquatic habitat, inter-basin transfer and stratification of water may **not be suitable** for **the aquatic species available within the area** and thereby favours the establishment of other non-native species.

12

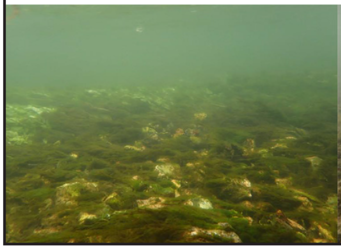
(II) ROAD CONSTRUCTION AND MINING

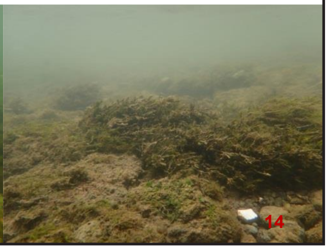
- The **soil and debris** from road construction and mining **mostly land** up in rivers and streams thereby increasing **suspended solid** and **sediment loads**.
- The turbidity from the **suspended solids** will have direct impact on fish either by:
  (1) killing them (2) slowing growth (3) reducing resistance to disease and (4) by altering the natural movement and migration.

13

ROAD CONSTRUCTION AND MINING

- The **sediments** from debris will prevent successful development of fish eggs and larvae.
- It will also reduce the food availability within the aquatic ecosystem.
- The impact from road construction will be more during monsoon due higher amount of debris transported by surface runoff.





14

(III) EXTRACTION OF SAND AND AGGREGATES

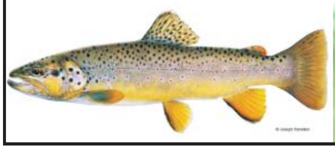
- Important abiotic component in aquatic ecosystem providing habitat for many benthic organisms.
- It provides spawning, feeding and hiding grounds.
- The ecological consequences of extraction are:
  - ✓ Habitat degradation,
  - ✓ Bank instability (erosion),
  - ✓ Short-term turbidity and so on.

When the quantity of extraction exceeds replenishment limits due to increase in population and developmental activities it will be a major problem to river system.

15

(IV) EXOTIC AND INVASIVE ALIEN SPECIES (IAS) OF FISH

- Brown trout is first exotic fish species to be introduced to Bhutan during 1930.
- To promote fish farming eight species of fish has been introduced so far since 1980's.
- By considering:
  - Shifting focus of fish production sector on aquaculture sources;
  - Adverse ecological impacts associated with irresponsible aquaculture practices &;
  - Importance of aquaculture sector in achieving food, nutrition and economic security;
- It is high time to adopt "**Responsible Fish Farming Guidelines"** so to reap the benefits without compromising the environment.



91

EXOTIC AND INVASIVE ALIEN SPECIES (IAS) OF FISH

- 9 varieties of ornamental fishes are approved for import in Bhutan.
- Illegal introduction of other ornamental fishes is likely.
- **Policy guideline for introduction of exotic fishes.**
- **Guidelines on ecologically sound ornamental fish keeping practice with appropriate disposal method.**

92

EXOTIC AND INVASIVE ALIEN SPECIES (IAS) OF FISH

- Invasive alien species of fish like **African sharptooth catfish** in Bhutan is presumed to be introduced through *Tsethar.*
- **Mozambique tilapia** is also reported from Crocodile Rehabilitation Centre, Phuentshogling.
- In freshwater habitats, **invasive alien species** are considered to be **the second leading cause of species extinction** along with **habitat destruction.**

- The invasive alien species are known **change the local ecosystem and its functions.**
- They may also have potential to **hybridize with closely related indigenous fish species** there by leading to decline and even extinction of native fish species.

93

EXOTIC AND INVASIVE ALIEN SPECIES (IAS) OF FISH

- The import of live animals for the purpose of *Tsethar* is banned through adoption of **Livestock Rules and Regulations of Bhutan (2008).**
  - Awareness on existing laws and consequences (ecological, economic and public health) from such act including recommending an alternative to **"*Tsethar* of Exotic Species"** is required.

His Holiness the 17th **Karmapa, Ogyen Trinley Dorje** has commented that the meaning is broad and that people can use intelligence to **expand the practise in other ways**; indicating that **planting one tree may be more beneficial then carrying out *Tsethar* for many beings.**

94

(V) ILLEGAL FISHING

- Illegal fishing is predominant across most parts of country.
- Only concerned with their catch and neglect the species, size and stages of development of their catch.
- Impact on fisheries diversity in long run.
- DoL in collaboration with DoFPS have legalized capture fishery program to utilize the fisheries resources with sustainable and scientific management practices.
- Develop sense of ownership to the resource among the community.
- The NRCA, Gelegphu is in process of engaging the riverside communities in fish farming.

95

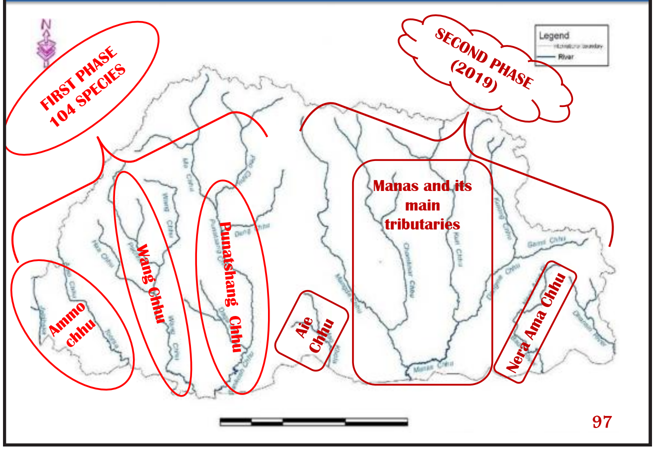
G) FISHERIES CONSERVATION PROGRAMS BY MoAF (DoL)

(I) FISH FAUNA ASSESSMENT

- The "Fish Fauna Assessment of Bhutan" is a **"BTFEC Funded Project"** and is executed by **NRCRL&LF, Haa** in collaboration with **DoFPS.**
- Aims to study the species composition and distribution of fishes in Bhutan's major river system **for development of well researched data base** which can later be used for **formulating good fisheries management and mitigation plans.**
- The study is being conducted for period of six years in two phases.
  - The **first phase** of project completed the study of species composition and distribution of fishes in **western Bhutan's three major river basins** (Amochhu, Punatshangchhu and Wangchhu).
- **Second phase** of the project has been initiated and will cover the **main rivers and tributaries of Manas, Nyera Ama Chu and Aie Chhu** and is scheduled to be completed by 2019.

96

FISH FAUNA ASSESSMENT (BTFEC FUNDING)



97

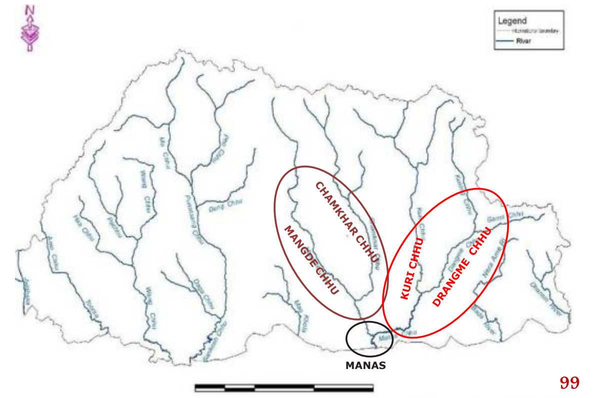
(II) GOLDEN MAHSEER TELEMETRY STUDY

- This study is mainly focused **to strengthen the conservation measures for golden mahseer in Bhutan**, which is being subjected to **population decline** from **increasing pressure of habitat loss** associated with various developmental activities.
- The study is a part of **"Mahseer Conservation and Development Project"** which is being implemented by **MoAF (DoL)** in collaboration with **WWF-Bhutan** and **Fisheries Conservation Foundation (FCF), USA** for period of **five years** (2015-2019).
  - The **Manas river** basin covering **Mangdechhu, Chamkharchhu, Drangmechhu, Kurichhu and Sherichhu** are chosen as the **study site.**

98

STUDY SITES

To **establish scientific baseline data** of **mahseer population** and **migration pattern:**



99

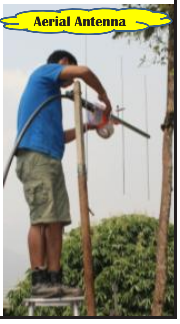
RESEARCH QUESTIONS TO BE ADDRESSED BY TEMEMETRY STUDY:

- When and where do mahseer go to spawn, and what is the length of that migration?
- When and where do mahseer live during the rest of the year?
- How do mahseer navigate high water during the monsoon season?
- Do mahseer move into India, where they are potentially harvested?
- What are the critical habitats for each of the mahseer's life history stages?

100

COMPONENTS OF RADIOTELEMETRY EQUIPMENTS

- **Radio transmitter** is a radio tag, programmed to emit coded radio signals at regular *frequency*. These transmitters are surgically implanted into the body cavity of each fish with the antenna trailing on the outside of the body.
- An **aerial antenna** picks signals from transmitter (implanted in fish) and the **receiver** records and saves those signals (Secure Digital Cards) at every receiver station.
  - The SD cards are replaced every three months for downloading the data.

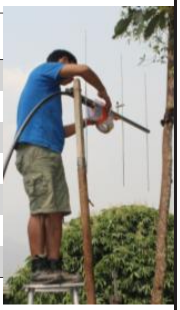


101

METHODS IN RADIO TELEMETRY

(a) CONSTRUCTION OF RECEIVER STATION

River/Tributary	Receivers
Mangdechhu	5
Drangmechhu	5
Chamkharchhu	2
Lower Manas	2
Kurichhu	1
Sherichhu	1
TOTAL	16



102

(b) CAPTURE OF FISH AND IMPLANTATION OF TRANSMITTER

103

Stitching of incision.

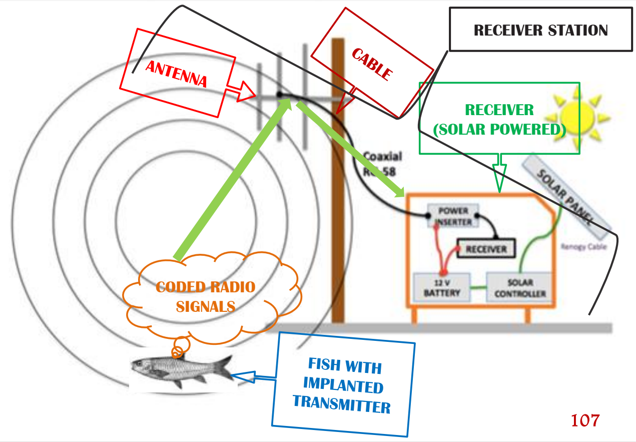
104

(c) RECOVERY AND RELEASE OF FISH

Manually tracked using hand held receiver to assure that they are moving, and hence, survived surgery.

105

(d) HOW TELEMETRY WORKS?



107

CURRENT STATUS

- ❑ 100 fishes have been surgically implanted with radio transmitter (70 golden and 30 chocolate mahseers).

Findings:

- ❑ Both Golden and Chocolate Mahseers migrate long distances often migrating 25+ km in 1-2 days
- ❑ Not all Mahseers migrate to India in winter.

WAY FORWARD

Knowing that the fish are seen congregating at the mouths of tributaries, the next step is to set up receiver stations in these tributaries to capture spawning data.

108

(IV) CONSTRUCTION OF FISH MONITORING STATION

- In order to **study and mitigate the impact to fisheries resources** by any major **developmental undertakings**, the NRCR&LF, Haa

is currently engaged in setting up of fish monitoring station with aim to:

  - Study and mitigate the impact on fisheries resource and aquatic ecosystem,
  - Understand the biology of fishes;
  - Develop and standardize the captive breeding technology for affected species.

Two such facilities have been planned and will be funded by Punatsangchhu Hydropower Project Authority (PHPA-I & II) and Tangsibji Hydro Energy Limited (THyE).

109

(V) EX-SITU BREEDING OF GOLDEN MAHSEER

- The **NRCA, Gelegphu** is engaged in **ex-situ breeding** of golden mahseer **since 2012.**
- **Developed standard breeding techniques.**
- The centre with funding from **Mangdechhu Hydroelectric Project Authority (MHPA)** is also:
  - Engaged **in ex-situ breeding of golden mahseers collected from Mangdechhu river basin** through project titled **"Conservation of Endangered Golden Mahseer."**
  - With same project **Conservation Centre for golden mahseer and other native species** has been set up at NRCA facility.
- Around **3000** hatchery bred golden mahseer fingerlings has been released by NRCA to **further strengthen the golden mahseer population** in Mangdechhu.

110

EX-SITU BREEDING OF GOLDEN MAHSEER (NRCA)

111

(VI) OTHER CONSERVATION ACTIVITIES

Containment of African sharptooth catfish in sewerage tank of Phuentshogling *Thromde*:

Bhutan Agriculture and Food Regulatory Authority (BAFRA); NRCA and Phuentshogling *Thromde*

Breeding of sub-tropical native fish of Bhutan:

NRCA (DoL), Gelegphu.

112

NRCR&LF, HAA (WAY FORWARD; 12th FYP)

- Monitor the **capture fishery program.**
- Study the extent of **brown trout establishment at Haachhu** through **recreational fishery data.**
- Initiate **baseline fisheries ecological studies** in lakes.
- Initiate **baseline fisheries ecological studies** in rivers.
- Study the **efficiency of fish ways** at Kurichhu Hydropower Plant and Dagachhu Hydropower Plant through application of **Advanced Passive Integrated Transponder (PIT) tag application.**
- **Establish Fisheries Ecological Lab at NRCR&LF.**
- Develop breeding technologies for native fishes.
- Continue baseline **fish fauna assessment of eastern** Bhutan.
- Continue **radio telemetry of golden mahseer.**

113

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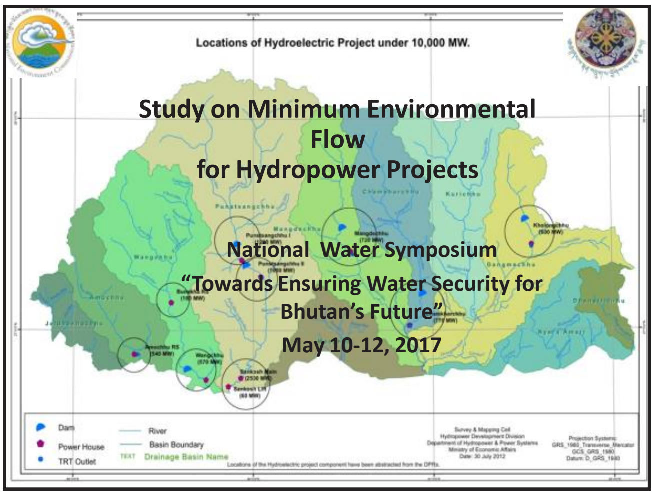
116

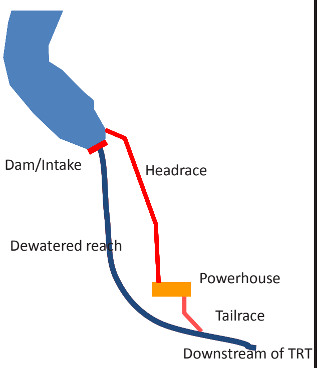


Structure

5/16/2017 Environment Service Division, National Environment Commission Secretariat 118

Background

- Legislative requirement – Establishing Minimum Environmental flow standard (NEPA 2007 & WAB 2011);
- Preliminary study;



5/16/2017 Environment Service Division, National Environment Commission Secretariat 119

Cont.

- Development of Hydropower;
  - ✓ Overall potential: 30,000MW
  - ✓ Shortlists 76 projects
  - ✓ Existing and pipeline projects

Hydropower	Capacity (MW)	Nos.
Commissioned	1606	5
Under construction	3658	5
Pipeline	1520	3
Total	**6784**	**13**

- Build national capacity for future assessments, monitoring and analysis; and
- Ensure minimal environmental impact from development activities.

5/16/2017 Environment Service Division, National Environment Commission Secretariat 120

Project brief

- Project Title: Study on Minimum Environmental Flow for Hydropower Projects in Bhutan;
- Project Duration: October 1, 2014 till December 31, 2017; and
- Funded by: Austrian Development Agency

Cont.

Objective:

- The overall objective of the project is to minimize or avoid negative impact on environment from hydropower development by establishing rivers/project specific minimum environmental flow.

Cont.

Outcomes:

- Develop guideline for assessment and determination and monitoring of compliance for environmental flow;
- Minimum environmental flow established for at least 1 river, 1 hydropower project under construction, 1 hydropower project under operation and 1 hydropower project planned for development; and
- Capacity of regulatory authority and partner agencies built.

Progress

- **4 sites selected**
  - ✓ 1 wild river;
  - ✓ 1 hydropower project under construction;
  - ✓ 1 hydropower project under operation; and
  - ✓ 1 hydropower project planned for development.
- **Data collections**
  - ✓ November 25 - December 19, 2016 ;
  - ✓ February 12 - 19, 2017 and March 20-25, 2017 and March 4 - April 4, 2017; and
  - ✓ Data configuration and compilation completed and modeling exercise under progress.

Challenges

- ??????
- Implementation;
- ✓ Modified river system; and
- ✓ Lack of ecological data.

Conclusion

- ✓ Developed Minimum E- Flow standard;
- ✓ Developed Guideline; and
- ✓ Integration of E-Flow with EA process.

5.0 Session 3: Climate, Cryosphere, Water and Disaster

Chair: Karma C Neydrup, NECS

Day 2: 11th May 2017		
Session 3 : Climate, Cryosphere, Water and Disaster		
0900	Weather and climate observation and information	Mr. Tayba Buddha Tamang, NCHM
0920	Cryosphere monitoring and information in Bhutan	Mr. Phuntsho Tshering, NCHM
0940	Hydrological observations and flood early warning systems in Bhutan	Mr. Karma Drupchu, NCHM
1000	Application of environmental isotopes as a tracer in hydrological studies	Mr. Tshewang Dendup, Sherubtse College
10.20	Climate change and adaptation in Bhutan	Ms. Sonam Lhaden Khandu, NECS
10.40	Overview of climate and water resource studies at UWICER	Mr. Dawa Yoezer, UWICER

National Water Symposium

"Towards Ensuring Water Security for Bhutan's Future"

Weather and Climate Observation and Information

Tayba Buddha Tamang
Deputy Chief
Weather and Climate Services Division
National Centre for Hydrology and Meteorology
tbtamang@nchm.gov.bt

Outline of Presentation

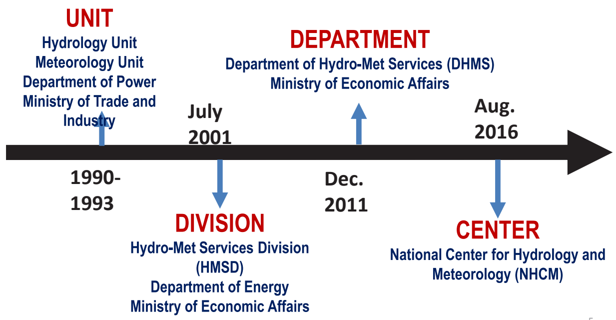
- Background on NCHM
- Meteorological observational network
  - Manual Weather Station
  - Automatic Weather Station
- Weather Information Services
  - Weather Forecast
- Climate Information Services
  - Historical climate data
  - Seasonal prediction
  - Climate projection
- Education and Awareness

3

BACKGROUND ON NCHM

4

Chronology of Organisational Development of Hydro-Met Services in Bhutan



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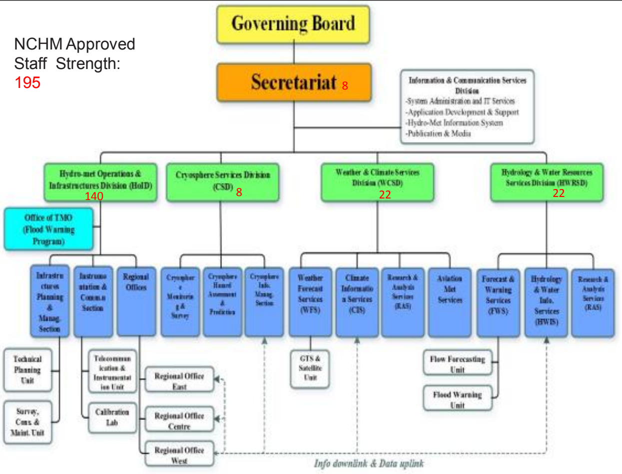


METEOROLOGICAL OBSERVATIONAL NETWORK

7

MANUAL WEATHER STATION

- **Agro-met (Class A) – 20 nos**

Daily measured parameter
- Rainfall
- Temperature/Humidity
- Wind
- Sunshine duration
- Soil Temperature
- Evaporation

- **Climatology (Class C) – 64 nos**

Daily measured parameter
- Rainfall
- Temperature/Humidity

- **AUTOMATIC WEATHER STATION (AWS) – 80 Nos**

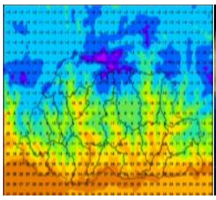
9

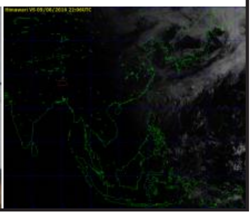
WEATHER INFORMATION SERVICES

10

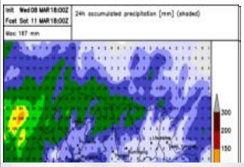
Weather forecast – 3 days

- WRF Model
  - WRF – 72 hours forecast runs
  - Runs every 6 hours 00,06, 12, 18 UTC
  - Initial conditions - GFS models NCEP, NOAA
  - Runs for 72 hours (3 days)
  - Nested domain 15 km and 3 km resolution
  - Vertical=45 levels
- Satellite images – Himawari 8
- Global Telecommunication System





Weather Forecasting



Moderate to heavy precipitation was predicted on 11 March

Snowfall on March 11 Thimphu

Monitoring and Dissemination

- Weather monitored 24/7
- Disseminated:

CLIMATE INFORMATION SERVICES

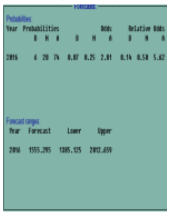
14

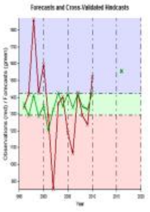
Present status of climate services

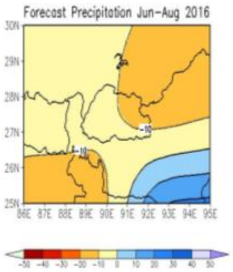
Provision of historical climate data

Seasonal Climate Information

- Monsoon Season (Jun – Sept)
- Winter Season (Dec - Feb) – on trail







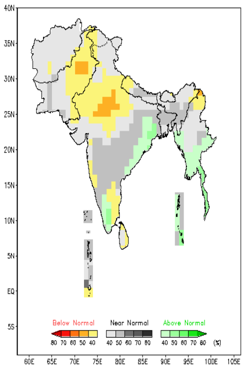
Preparation and Dissemination of Seasonal Climate Information

- Regional Level: South Asian Climate Outlook Forum (SASCOF)
  - 10th SASCOF hosted in Bhutan, 24-26 April 2017

Consensus rainfall probability forecast SASCOF 10

- Normal rainfall is most likely during the 2017 southwest monsoon season (June – September) over much of South Asia.
- More specifically:
  - Below-normal rainfall is most likely over broad areas of north-western, central and south-eastern parts of South Asia.
  - Above-normal rainfall is most likely over broad areas of eastern and the south-western parts of the region.
  - Normal rainfall is most likely over the remaining areas.

For more information and further updates on the southwest monsoon outlook on national scale, the respective NMSs may be consulted.



Consensus outlook for 2017 Southwest Monsoon Rainfall over South Asia

18

Preparation and dissemination of seasonal climate information

National Level: National Climate Outlook Forum (NCOF)

- **19-21 Oct 2015: 1st NCOF & National Stakeholder Consultation**
  - Regional experts and WMO delegates were the resource person for the forum.
  - Stakeholders from various priority areas of **agriculture, water, health, disaster risk reduction and energy** attended the forum.
- **12-13 May 2016: 2nd NCOF**
  - Financial assistance from RIMES. Resource persons from RIMES and IITM, India.
  - Local participants from various priority areas of **agriculture, water, health, disaster risk reduction and energy** attended the forum.
- **26 May 2017: 3rd NCOF**

19

Way forward for weather and climate services

- Provision of information on climate variability and change – model & projection
- Provision of medium range weather forecast
- Provision of sub-seasonal forecast
- Collaborative research with international, regional and national institutes

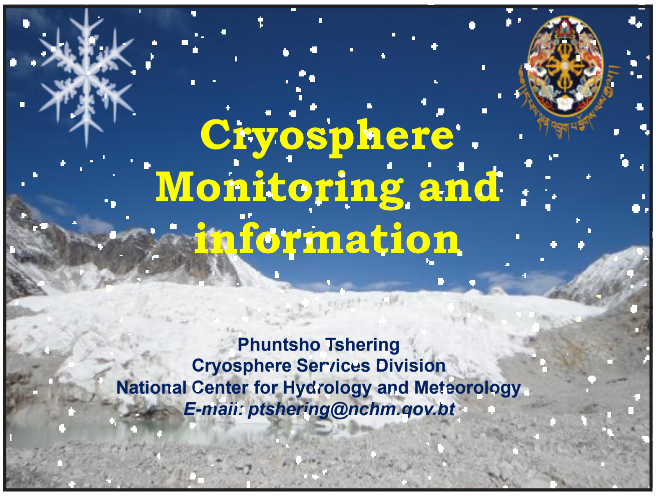
20

Education and awareness

- 10 days training workshop - **"Understanding of hydro-met ad cryosphere data and services"** funded under NAPA II Project
  - Total participants of 78 officials from various climate sensitive sectors.
- College student visits to National Weather and Flood Warning Centre.
- Celebration of World Meteorological Day 2017

THANK YOU FOR YOUR ATTENTION

22



Overview

- Introduction
  - Cryosphere Services Division, it's mandate
  - Cryosphere
- Activities
  - Glaciers
  - Glacial lakes
- Information
- Future plans

Introduction

- Under the ODA exercise

  – Glaciology Division (DGM)
  – Snow and Glacier Division (DHMS)

Merged to a new Division under NCHM
- Cryosphere Services Division

Introduction

- CSD mandates

Nation's focal Agency for Monitoring:
- *Cryosphere*
- *Mitigation of Cryosphere related hazards*
- *Understanding current and future Water Climate Scenario for food security*

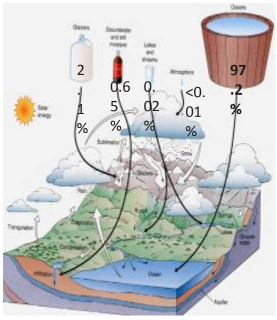
Introduction

→Cryosphere

Frozen part of the earth
- *Ice sheets, ice caps, lake*
- *Mountain glaciers*
- *Permafrost/frozen ground*
- *Snow*

Global importance of Cryosphere

Fresh Water Regime



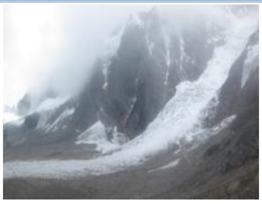
Cryosphere hold 75% of fresh water on Earth

Importance of Cryosphere in Bhutan

- Climate indicator
- Fresh water regime
- Disaster → GLOF & water supply During lean periods

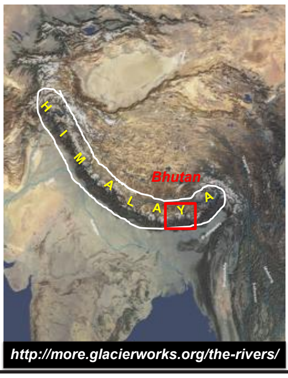
Glacier? And types?

- A slowly moving mass or river of ice formed by the accumulation and compaction of snow on mountains or near the poles

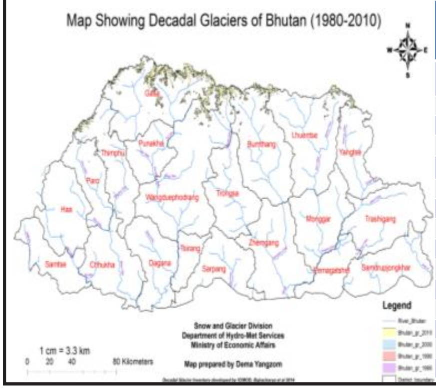


Glaciers in Bhutan

- Lies in eastern part of Himalaya
- Known to be Summer Accumulation type
- Such glaciers are more sensitive to climate change
  - *mainly driven by temperature*
  - *precipitation phase*

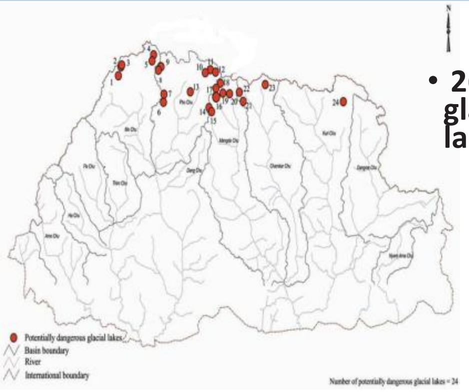


Glacier map of Bhutan



Sl.no	Basin	Total no of Glaciers	Area in Sq.km
1	**Wangchhu**		
a	Thimchhu	19	5.2
b	Pachhu	37	27.6
	Sub total(A)	56	32.8
2	**Punatsangchhu**		
a	Phocchu	256	247.9
b	Mochhu	180	113.7
	Sub total(B)	436	361.6
3	**Manas**		
a	Mangdechhu	150	107.8
b	ChamkharChhu	125	71.9
c	Kurichhu	96	61.4
d	Dangmechhu	22	6.7
	Sub total(C)	393	247.8
	Total(A+B+C)=	885	642.2

Glacial lakes

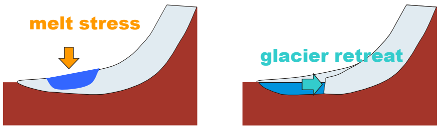


- **2600 plus glacial lakes**
  - 25 potentially dangerous

Glacial lake formation

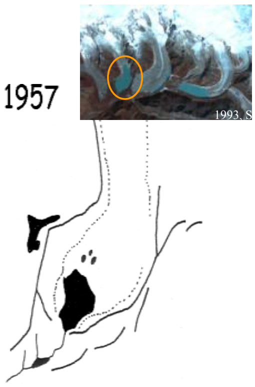
How are the glacial lakes formed?

- Melting process
  - as vertical thinning of glacier
- Glacier retreat
  - as horizontal expansion of lake



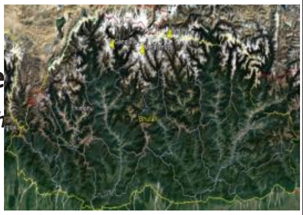
Glacial lake formation

- **Indicator of cli**



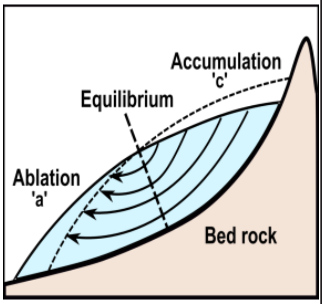
Cryosphere related activities

- **Glacier mass balance**
  - **- bench mark glacie**
  - *(Gangju La, Metatshota, Th*
- **Snow observation**
  - **- 20 Snow stations**
- **Disaster (direct/indirect) mitigation**
  - **- Studies on glacial lakes (GLOF)**



Glacier mass balance

- Change in mass of a glacier over a stated span of time
- *b = c + a ;   b: mass balance,   c: accumulation, a: ablation*

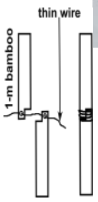


Mass balance*(b)* measurement methods

1. Direct/Stake method

(installation of stake network)

- Annual/seasonal



Mass balance*(b)* measurement methods

2. Geodetic method

(single/dual frequency GPS)

- satellite images

- Annual/season

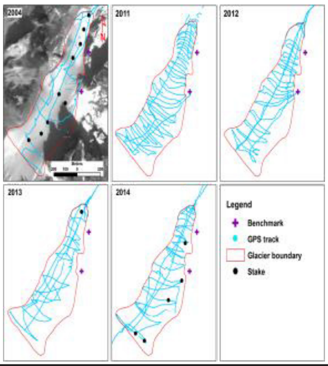
3. Energy balance

- meteorologica parameters

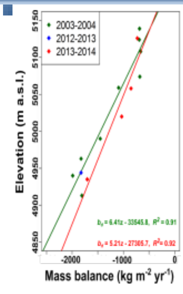
Mass balance Results

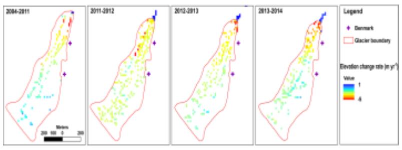
- An example from Gangju La Glacier
- C-type glacier

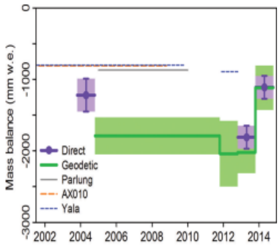
Area = 0.3 km^2
Max. elev ~ 5200m a.s.l.
Low. elev ~ 4900m a.s.l.



Mass balance Results

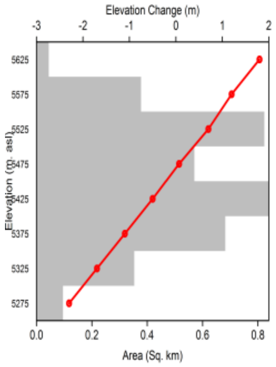






- 1550 mm w.e.a^{-1}

Mass balance Results



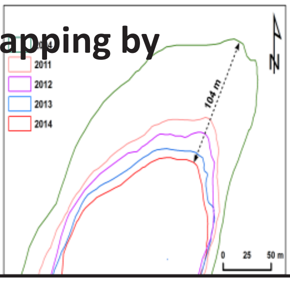
- preliminary result from Thana Glacier (2014-2015)

- 195 mm w.e.a^{-1}

Time series status of glacier terminus

- Glacier snout position

  - Mapping by DGPS



Snow Observations

Snow measurement

- Snow cover area
- Thickness/height
- SWE, Hardness, Den
- Temperature &
- Grain Size

Mitigation works

- Artificial lowering of lake water level
- Hazard zonation in the downstream
- Installation of Early Warning System

Information available

Site/location	Data		Remarks
	Direct	Geodetic	
Gangju La glacier	2003 – 2004*, 2012 – 2013**, 2013 – 2014***	2004, 2011, 2012, 2013, 2014	Analyzed: *Tshering P. and Fujita K. (2016)*
Thana glacier	2013-2016	2016	*Not Analyzed yet*

* 12 installed, 9 retrieved   ** 8 installed, 1 retrieved

*** 14 installed, 4 retrieved

Information available...(Cont.)

Station - Nos	Snow Data			Remarks
	Depth	SWE	incidence	
Paro-5	2013-2016	2013-2016	2013-2016	*In some no SWE*
Jakar-2	2013-2016	2013-2016		
Wangdue-1	2015-2016	2015-2016	2015-2016	
Gasa-2	2013-2016	2013-2016		
Chukha-1	2015-2016		2015-2016	*Shallow depth*
Haa-1	2013-2016	2013-2016		*In some no SWE*
T/yangtse-1				*No snow record*
T/gang-1	2015-2016	2015-2016	2015-2016	
Mongar-1	2013-2016	2013-2016	2013-2016	
Thimphu-2	2013-2016	2013-2016	2013-2016	

Future plans

- Continue with present activities
- Cryosphere in terms of water budget
- Verify and update potentially dangerous lakes
- Update GLOF hazard map along Punatsang Chhu
- *Prepare similar maps in other vulnerable basins*

Hydrological Observations and Flood Early Warning Systems in Bhutan

Karma Dupchu, Chief
Hydrology and Water Resources Services Division (HWRSD)
National Centre for Hydrology and Meteorology (NHCM)
www.hydromet.gov.bt

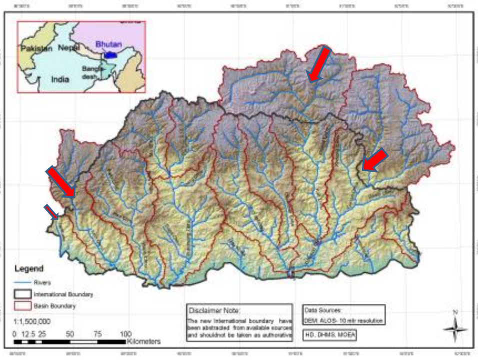
5/16/2017 50

Presentation Outline

a. Background
b. National Hydrological and Flood Warning Network
c. Hydrology and Water Resources Services and products
d. Flood/ Glacier Lake Outburst Flood (GLOF) Early Warning Systems
e. Data exchange and information sharing
f. Challenges
g. NCHM Draft ARKA for 12 FYP (NHCM)

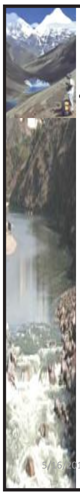
5/16/2017 51

River System of Bhutan



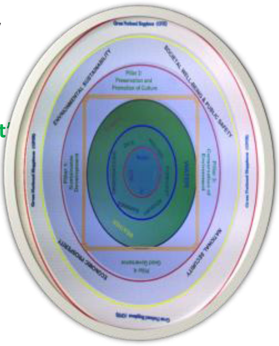
- **Four Major Basin**
  1. Ammochu/Toorsa
  2. Wangchhu/Radiak
  3. Punatsangchhu/Sankosh
  4. Manas
     - Mangdechhu,
     - Chamkharchhu;
     - Kurichhu and
     - Dangmechhu
- **Three Trans-boundary river**
  1. Ammochhu
  2. Kurichu and
  3. Gongri
  4. Jaldakha

Early Warning Systems: A Tool for Mitigation and Coordination

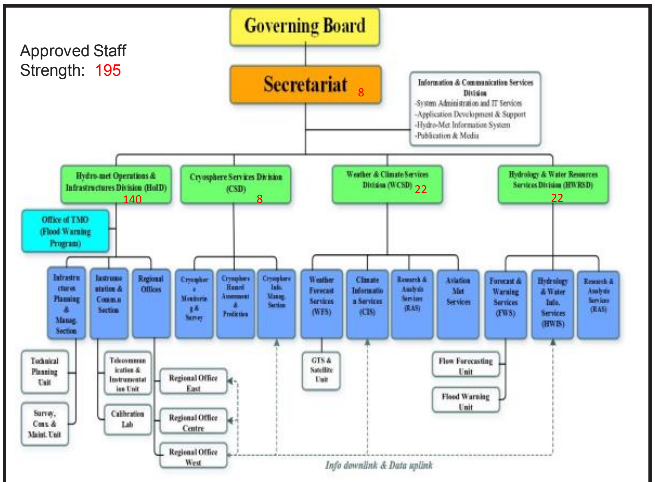


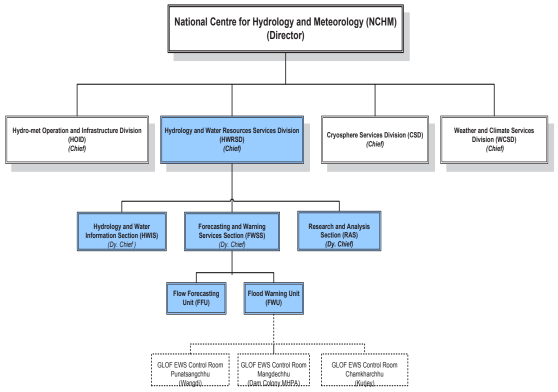
Mandala of Hydro-met Services

- National Centre for Hydrology and Meteorology (NCHM) support the national **"self-reliance and inclusive Green Socio-economic Development"** to achieve Gross National Happiness (GNH):
  a) National Security
  b) Economic Prosperity
  c) Environmental Sustainability
  d) Societal Wellbeing & Public Safety



5/16/2017 54





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NCHM
National Center for Hydrology and Meteorology

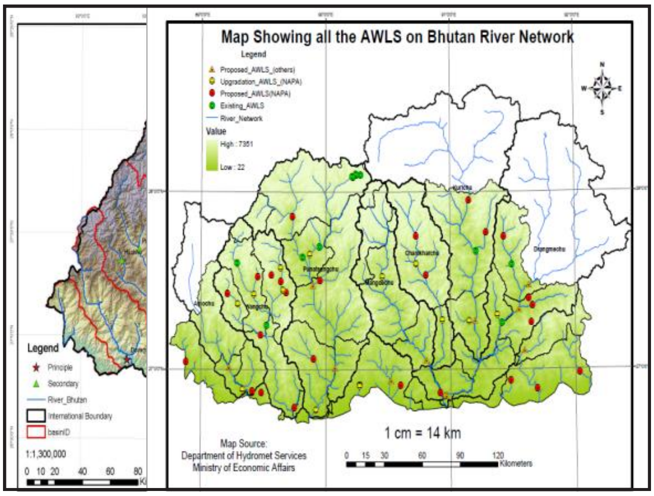
Hydrology and Water Resources Services Division (HWRSD), NHCM Mandates/Functions

a. Formulate polices, plans and programs related to hydrology, flood forecasting and warning services;
b. Hydrological/Water Resources - data, analyses and research, archival and dissemination
c. Hydrological modelling for inflow and flood forecasting and warning
d. Provide hydrological and water related data and information services;
e. Professional services related to hydrology, water resources and flood
f. Monitoring of flood/ GLOF EWS systems and dissemination of flood/GLOF information
g. Act as an official voice in issuing flood forecasting and warnings for public safety and sources of information related to hydrology and water resources,
h. Monitor flood events and issue warning/bulletins/advisories
i. Transmit flood information to the National Emergency Operation Centre (Department of Disaster Management), Hydropower Power Plants, and related agencies
j. Liaise with national, regional and international cooperation on hydrology, water resources on exchange and sharing of flood information.
k. Education, advocacy and awareness about flood and early warning

5/16/2017 57

Hydrological and Flood Warning Network Status

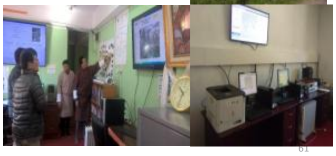
Sl N o.	Infrastructures	Unit	No. as of Dec 2016	Remarks
i	Principal Station	Nos.	16	
ii	Secondary Station	Nos.	9	
iii	Flood Warning Station	Nos.	24	Program funded by GoI through Central Water Commission (CWC), Ministry of Water Resources,
iv	Sediment Sampling Station	Nos.	13	
v	GLOF Early Warning System	Sub-basin	3	Punatsangchhu, Mangdechhu and Chamkharchhu



National Center for Hydrology and Meteorology

Hydrology and Flood Monitoring Facilities and Database System

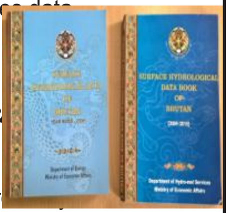
- Hydrological and flood warning network (upgradation to real time data under progress)
- HYDATA- National Hydrological Database
- SEDAT- Sediment Database
- EWS systems in different basins with real time data dissemination from remote stations to Control Rooms
- A Flood Monitoring and Command Room (FMCM) under NWFWC, Thimphu
- Hydrological Models and Modelling
  - IFAS
  - HBV
  - MIKE 11
  - HEC
  - IRIC
  - ARC GIS



5/16/2017 61

Hydrology and Water Resources Services and Products

- Historical hydrological time series data
- Flood monitoring
- Flood/GLOF early warning
- Flood advisory
- Flood/GLOF Hazard mapping &
- Hydrological Modelling
- Hydrological/flow forecasting
- Technical back stopping in hydr...



- Water Resource Assessment in future

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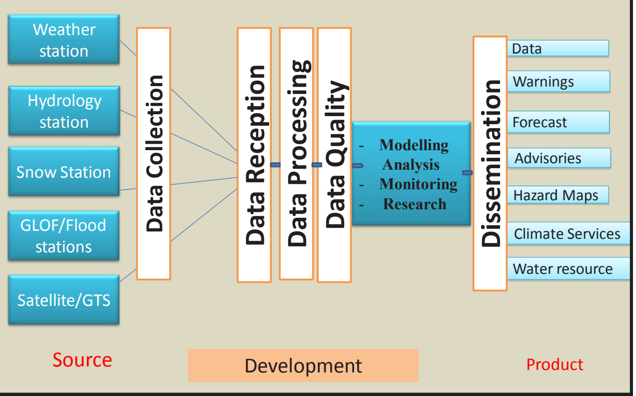
Central Database Management System (DMS) under development…...



Why we need Flood/GLOF Early Warning Systems in Bhutan?

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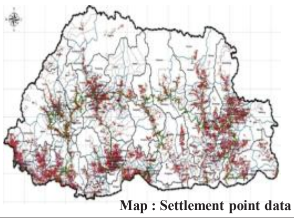
NCHM
National Center for Hydrology and Meteorology

Flood Hazards and Disaster Risks in Bhutan

1. Floods
   - GLOF
   - Flash Floods
   - LDOF
2. Landsides

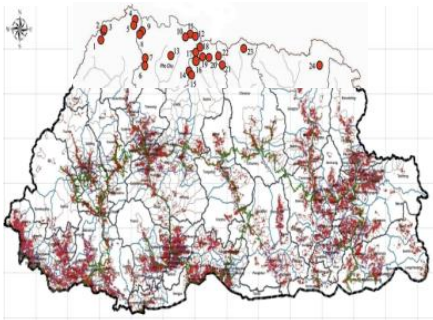
Flooding…in Bhutan

- Flooding is a recurrent phenomenon, especially during the monsoon season.
- Infrastructure (urban areas, hydropower plants, roads, airports, etc) and most of the settlements, fertile agricultural land are located along the valleys.
- Over 70 percent of the settlements are located along the main drainage basins and are therefore at high risk from flooding.



Map : Settlement point data of Bhutan (NSB, 2005)

Why flood mitigation is important for Bhutan??



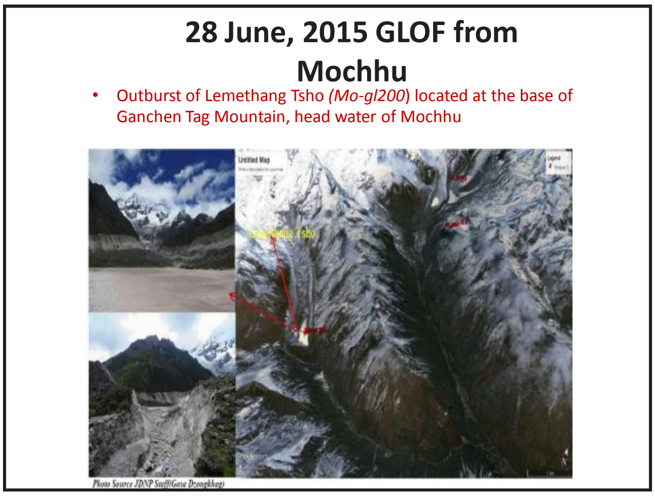
Source: NSB, 2005

Over 70% of the settlements are located along the drainage basins.

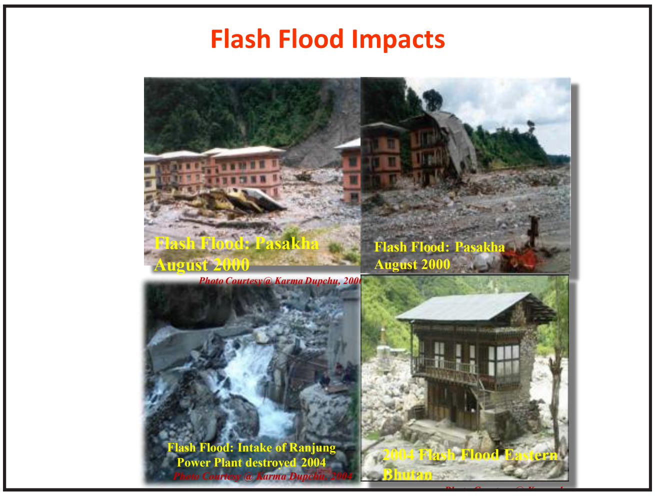
Early Warning Systems: A Tool for Mitigation and Coordination

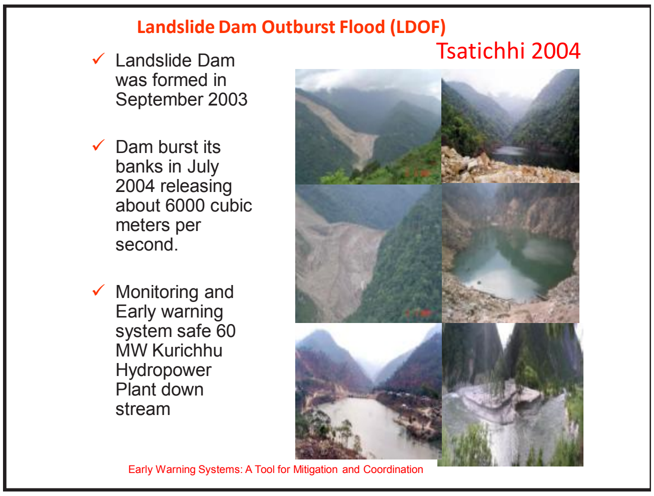
Vulnerability
Paro Airport
Monuments
Bumthang Domestic Airport
Agriculture land
Hydropower
Early Warning Systems: A Tool for Mitigation and Coordination

1994 GLOF Impact downstream
Scars of 1994 outburst: One woman and her two kids washed away by the flood from this house


28 June, 2015 GLOF from Mochhu
• Outburst of Lemethang Tsho (Mo-gl200) located at the base of Ganchen Tag Mountain, head water of Mochhu
Photo Source JDNP Staff/Gasa Dzongkhag

Flash Floods Impact
Thimchhu flood during cyclone Aila May 2009
Early Warning Systems: A Tool for Mitigation and Coordination


Flash Flood Impacts
Flash Flood: Pasakha August 2000
Flash Flood: Pasakha August 2000
Photo Courtesy@ Karma Dupchu, 2000
Flash Flood: Intake of Ranjung Power Plant destroyed 2004
2004 Flash Flood Eastern Bhutan


Landslide Dam Outburst Flood (LDOF)
Tsatichhi 2004
✓ Landslide Dam was formed in September 2003
✓ Dam burst its banks in July 2004 releasing about 6000 cubic meters per second.
✓ Monitoring and Early warning system safe 60 MW Kurichhu Hydropower Plant down stream
Early Warning Systems: A Tool for Mitigation and Coordination

Mochhu Landslide Dam

- Formed on 23 August 2012 after 21 June 2012 Mochhu Flood
- Volume of water storage behind the dam was estimated 51187.5 m^3.

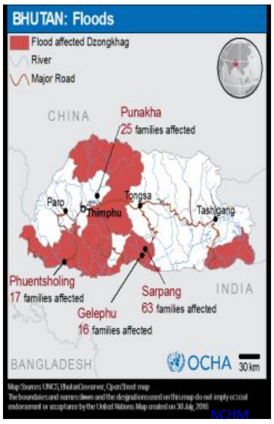
Flash Flood July 2016

•63 in Sarpang Market (21 of which have been relocated);

▪16 in Gelephu (two of which have been relocated);

▪17 in Phuentsoling;

▪25 in Punakha; and the remainder in other locations.



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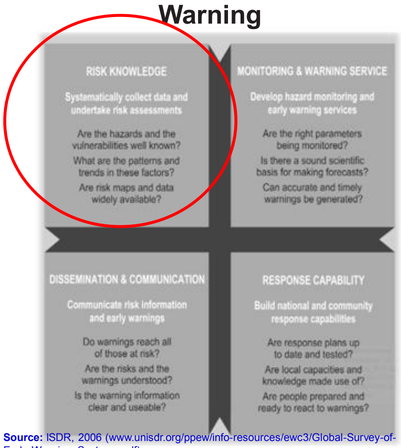
National Center for Hydrology and Meteorology

Early Warning Systems
A Fundamental Component of Disaster Risk Management

5/16/2017

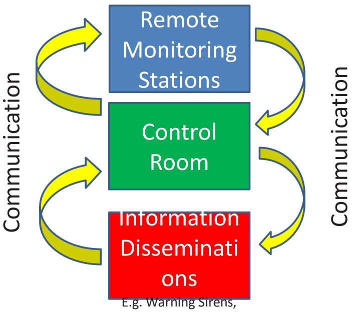
NCHM
National Center for Hydrology and Meteorology

Main Components of Early Warning

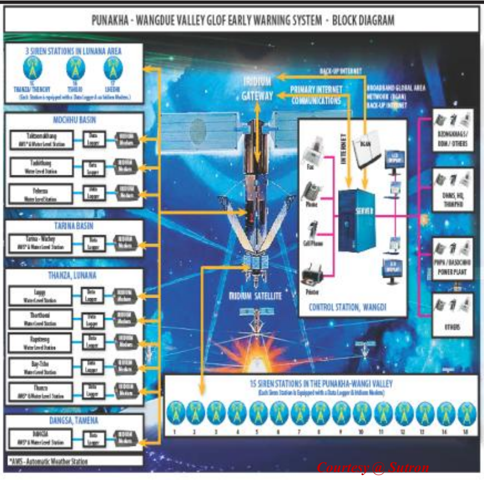


Source: ISDR, 2006 (www.unisdr.org/ppew/info-resources/ewc3/Global-Survey-of-Early-Warning-Systems.pdf)

Components of Monitoring and Warning Services



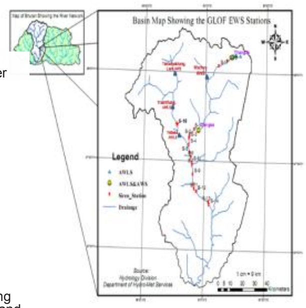
Early Warning Systems: A Tool for Mitigation and Coordination

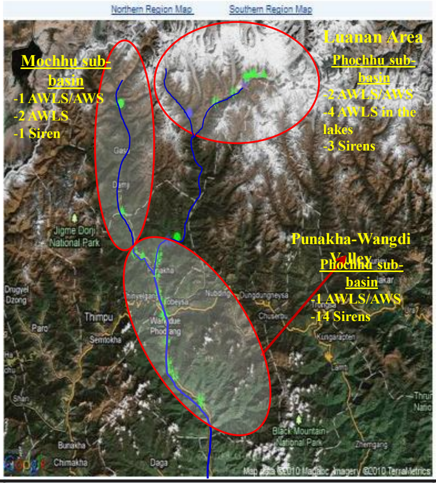


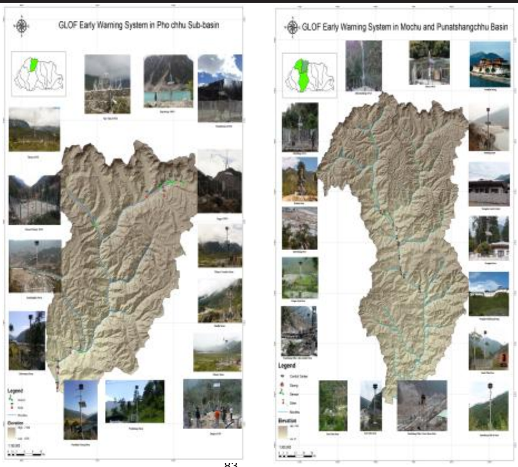
Courtesy @ Sutron

GLOF EWS

- **10 Remote** Automatic Water Level Stations (AWLS) /Automatic Weather Stations (AWS)
  - 4 AWLS in 4 lakes
  - 1 AWLS +AWS (dual), Thanza
  - 1 AWLS + AWS (Dual), Tarina
  - 1 AWLS + AWS (Dual) , Dangsa
  - 1 AWLS +AWS (Dual), Taktsemakhang
  - 1 AWLS+ Rainfall , Tashithang
  - 1 AWLS + Rainfall, Yebesa
- **18 Sirens** to warn vulnerable communities along the river valley downstream.
- **Iridium satellite** communication is used to transmit data from remote stations to control room for monitoring and detection of GLOF in real time, and linked to a network of sirens that are activated in the event of eminent GLOF threats.
- **Control Room 24x7** operators that can view the latest data from any of the 28 stations using custom developed software by M/s Sutron Corporation, USA

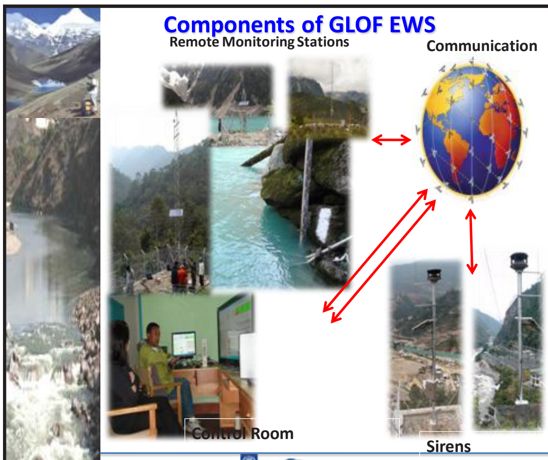






83

Components of GLOF EWS



Project funded by: PHPA-I and PHPA-II

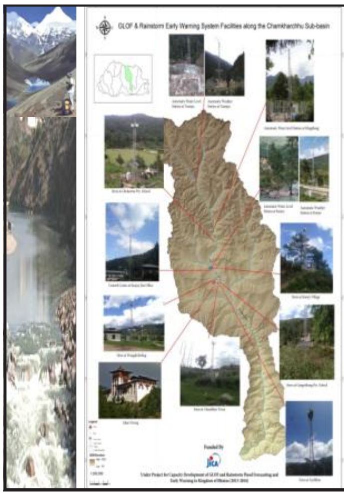
Why Flood/GLOF EWS in Mangdechhu and Chamkharchhu sub-basins ?

a. Out of 25 Potential Glacier Dangerous lakes in Bhutan:
   - ✓ 7 lakes are located in the headwater of Mangdechhu and
   - ✓ 3 lakes are located in the head water of Chamkharchhu
b. Bumthang is beautiful valley, emerging new town and tourist destination
c. Settlements and infrastructure along the river valley
d. Construction of Mangdechu Hydropower Project (720 MW)
e. Planned Hydropower Projects downstream on Chamkarchhu
f. Important historical and cultural sites downstream
g. Domestic airport, Bumthang
h. Cyclone Aila 2009 brought havoc and damages to infrastructures in the basin
i. No flood warning system in the basin

Early Warning Systems: A Tool for Mitigation and Coordination

Remote Monitoring Stations (AWLS/AWS)

Early Warning Systems: A Tool for Mitigation and Coordination



AWLS/AWS (Monitoring Stations):

1. Tsampa (AWS and AWLS)
2. Khagthang (AWLS)
3. Kurjey (AWLS/AWS)

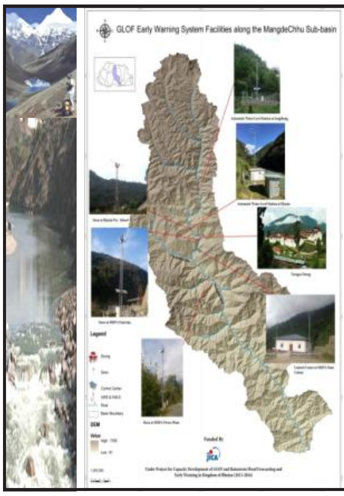
Control Room:

1. Kurjey Regional Office, Bumthang

Sirens:

1. 6 Sirens

Early Warning Systems: A Tool for Mitigation and Coordination



Automatic Water Level (AWS/AWLS):

1. Jongthang (Mangdephug)- AWLS/AWS
2. Bjizam (AWLS/AWS)

Control Room:

1. MHPA Dam colony

Warning Siren:

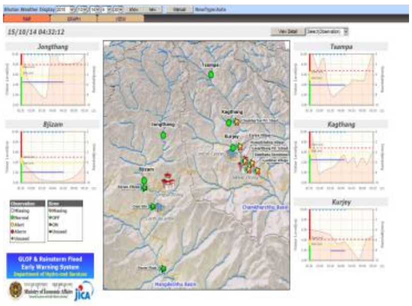
1. Bjizam
2. MHPA Dam
3. MHPA Power house

Basin Control Room

Control Room, Kurjey, Bumthang Chamkharchhu

Control Room, MHPA Dam Colony(Mangdechhu)

Monitoring System at Control Room

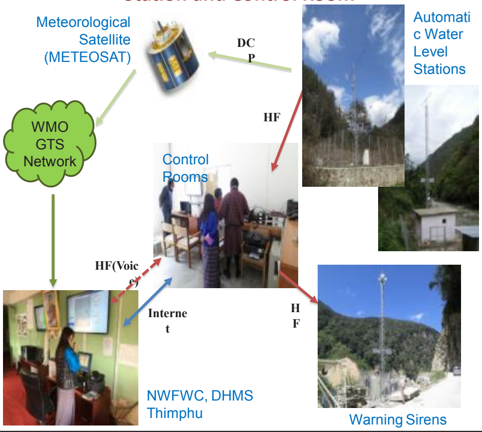


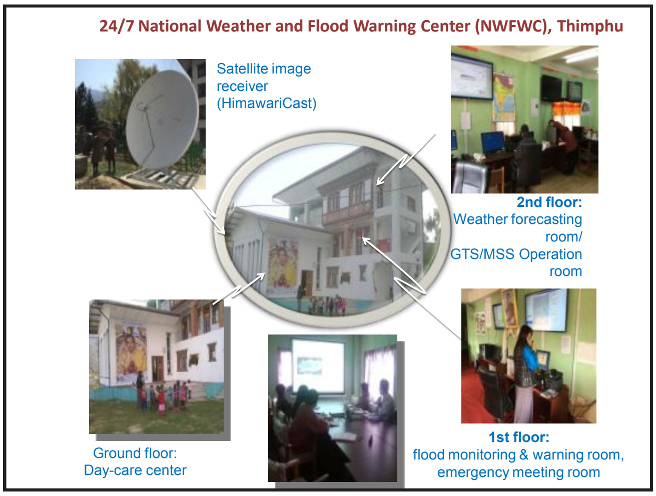
Monitoring Interface

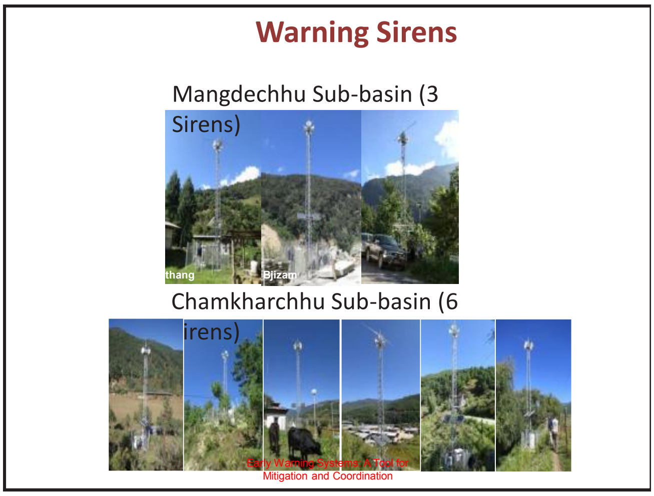
- Water level and rainfall of each AWLS can be monitored in the interface.
- Control Rooms and NWFWC are automatically synchronized via Internet.

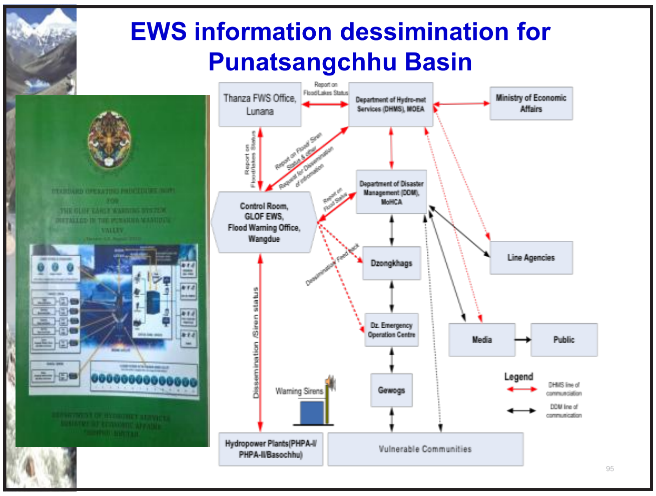
Early Warning Systems: A Tool for Mitigation and Coordination

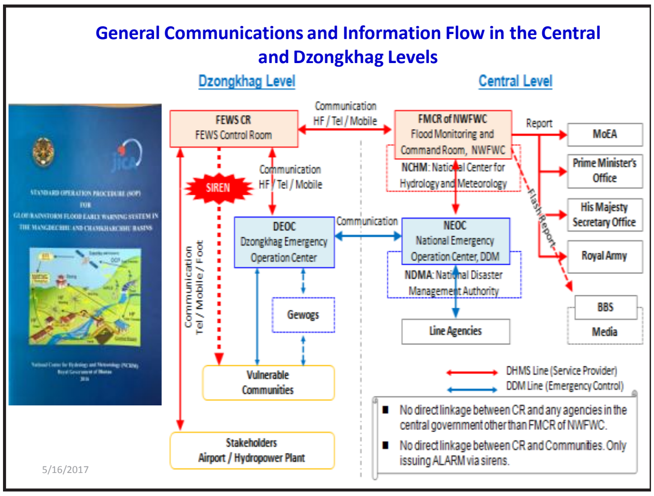
Communication between Remote Monitoring Station and Control Room

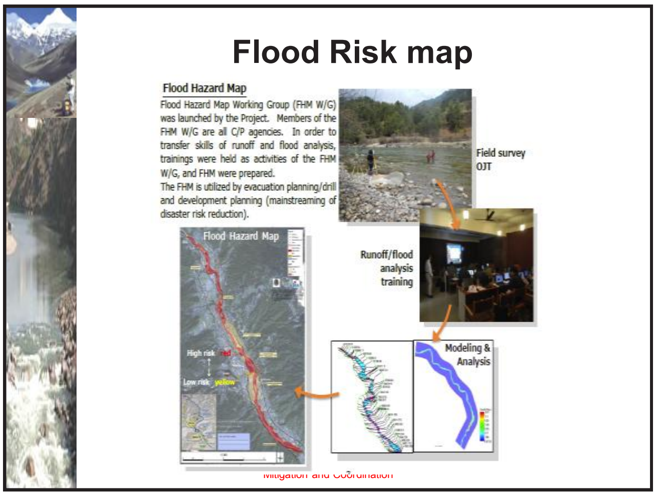


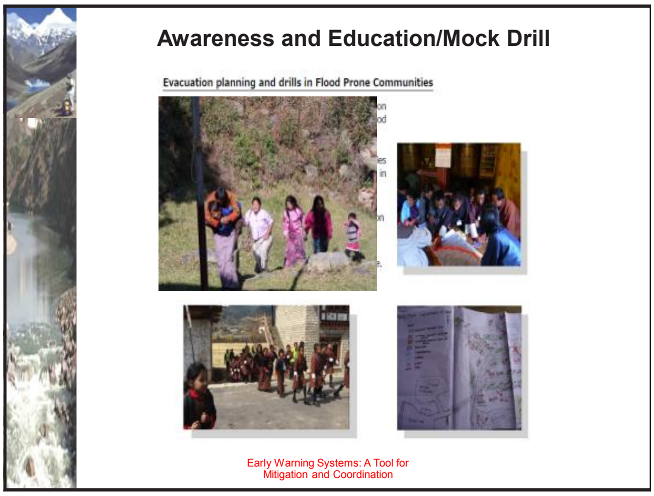

24/7 National Weather and Flood Warning Center (NWFWC), Thimphu
Satellite image receiver (HimawariCast)
2nd floor:
Weather forecasting room/
GTS/MSS Operation room
1st floor:
flood monitoring & warning room,
emergency meeting room
Ground floor:
Day-care center


Warning Sirens
Mangdechhu Sub-basin (3 Sirens)
Chamkharchhu Sub-basin (6 irens)
Early Warning Systems: A Tool for
Mitigation and Coordination


EWS information dessimination for Punatsangchhu Basin
Thanza FWS Office, Lunana
Department of Hydro-met Services (DHMS), MOEA
Ministry of Economic Affairs
Control Room, GLOF EWS, Flood Warning Office, Wangdue
Department of Disaster Management (DDM), MoHCA
Dzongkhags
Line Agencies
Dz. Emergency Operation Centre
Media
Public
Gewogs
Warning Sirens
Legend
Hydropower Plants(PHPA-I/ PHPA-II/Basochhu)
Vulnerable Communities


General Communications and Information Flow in the Central and Dzongkhag Levels
Dzongkhag Level
Central Level
FEWS CR
FEWS Control Room
Communication
HF / Tel / Mobile
FMCR of NWFWC
Flood Monitoring and Command Room, NWFWC
NCHM: National Center for Hydrology and Meteorology
Report
MoEA
Prime Minister's Office
His Majesty Secretary Office
Royal Army
BBS
Media
SIREN
DEOC
Dzongkhag Emergency Operation Center
NEOC
National Emergency Operation Center, DDM
NDMA: National Disaster Management Authority
Gewogs
Line Agencies
Flash Report
Communication
Tel / Mobile / Foot
Vulnerable Communities
Stakeholders
Airport / Hydropower Plant
DHMS Line (Service Provider)
DDM Line (Emergency Control)
No direct linkage between CR and any agencies in the central government other than FMCR of NWFWC.
No direct linkage between CR and Communities. Only issuing ALARM via sirens.
5/16/2017


Flood Risk map
Flood Hazard Map
Flood Hazard Map Working Group (FHM W/G) was launched by the Project. Members of the FHM W/G are all C/P agencies. In order to transfer skills of runoff and flood analysis, trainings were held as activities of the FHM W/G, and FHM were prepared.
The FHM is utilized by evacuation planning/drill and development planning (mainstreaming of disaster risk reduction).
Field survey OJT
Runoff/flood analysis training
Modeling & Analysis
Flood Hazard Map


Awareness and Education/Mock Drill
Evacuation planning and drills in Flood Prone Communities
Early Warning Systems: A Tool for
Mitigation and Coordination

Gangrithang Primary School, Bumthang GLOF/Flood evacuation Mock drill photos (12/03/2016)

Early Warning Systems: A Tool for Mitigation and Coordination

Mock drill

- DDM and DHMS also organized GLOF EWS mock drills, educational and awareness for all the vulnerability communities along the whole valley

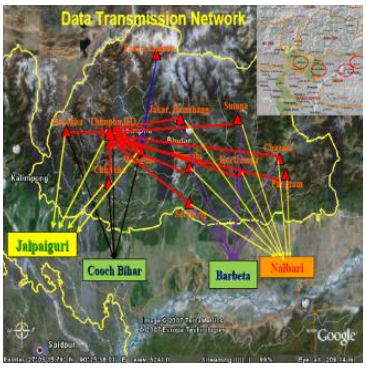
Flood/GLOF EWS

- Flood/GLOF EWSs were set up not only to warn vulnerable communities and infrastructure downstream in the events of flood/GLOF, but also for weather and climate data collection that are required for other purposes.
- Disaster risk management is not a single organization/agency's responsibilities but everyone responsibilities

101

Flood Data Exchange with Indian

- Bhutan as an upper riparian country, its shares and transmits the river water levels and weather information to the designated stations in India, on sub-daily, and sometimes on hourly, basis.
- HF Wireless Radio and other communication systems are used to transmit data directly from its FWS stations



HF Wireless Radio Communication schedule for Data Transmission from FWS Sites to India

Data Destination (CWC) Office in India	Summer Schedule (May to October) Monsoon Season	Non-Monsoon (November to April) Non-Monsoon Season	Data Origin Flood Warning Station in Bhutan
1. Berpeta, Assam, India	0645-0715 hrs 0945-1000 hrs 1545-1600 hrs	1030-1045 hrs 1530-1545 hrs	1. Tingtibi Station on Mangdechhu, Zhemgang 2. Jakar Station on Chamkarchhu, Bumthang 3. Sumpa on Kurichhu, Lhuntse 4. Kurizampa on Kurichhu, Mongar 5. Chazam on Gongrichhu, Trashigang 6. Sershong on Aiechhu/Maokhola, Gelephug
2. Nalbari, Assam, India	0710-0730 hrs 0940-1000 hrs 1530-1545 hrs 1900-1920 hrs	1030-1045 hrs 1530-1545 hrs	1. Pangzam on Nyra Amari/Bharanadi, Thrimshing, Trashigang 2. Deothang, Samdrup Jongkhar (only rainfall)
3. Cooch Behar in West Bengal, India 4. Jalpaiguri in West Bengal, India	0600-0630 hrs 0830-0900 hrs 1230-1300 hrs 1630-0900 hrs 2030-2100 hrs	1230-1300 hrs	1. Dorokha on Ammochu, Samtse; 2. Tendru, Sibsoo, Samtse (Only rainfall) 3. Chhukha on Wangchhu 4. Wangdi on Punatsangchhu/Sankosh, Wangdiphodrang; 5. Dubani on Punatsangchhu/Sankosh, Dagana

3/15/2017 103

Challenges

1. Limited accessibility and remoteness of the project sites
   - ✓ All equipment must be transported on mules or yaks which takes more than 9 days to reach the project sites
   - ✓ Un-predictable weather condition and limited working season at high altitude
2. High recurrence cost for operation of automatic Hydrological Stations and GLOF EWS
3. No good Vendors/Suppliers dealing with hydro-meteorological equipment in Bhutan/No back up services;
4. Stations damaged by floods during the monsoon- Unable to maintain data continuity (time series data)
5. Limited fund for operational and maintenance
6. Unstable internet connectivity
7. Limited mobile network in river valley
8. Limited human capacity in hydrological/climate modelling
9. Limited coordination and support from line agencies and stakeholders

104

Conclusions

- Bhutan has more than 26 years of hydrological data in database,
- Data are shared with other agencies and individuals based on the request;
- 3 River Basins in Bhutan has Flood/GLOF EWS in operational
- Current hydrological network are located mostly on the North-South rivers and limited stations on the east-west tributaries;
- All the Flood Monitoring Control Rooms in the basins and NWFWC in Thimphu are operational for 24/7;
- Modernization of all the hydrological and flood monitoring stations to transmit real time data to NWFWC, HQ is under the progress;

12 FYP NHCM (DRAFT)

FORMAT FOR FORMULATION OF AGENCY KEY RESULT AREA (AKRAS)

NKRA: CARBON NEUTRAL, CLIMATE AND DISASTER RESILIENT DEVELOPEMENT ENHANCED

Under Disaster

Sl.No	AKRA	KPI(For AKPI)	Unit	Baseline	Target
1	Hydro-meteorological and cryosphere disasters assessed & reduced	No. of glacial lakes/glaciers investigated for GLOF Risk	No	21	44
		No. of flood/GLOF EWS installed in the basin (Wangchu and Ammochhu)	No	3	5
		No. of flood outlook/advisory issued by basin	No	0	5
		No. of basin wise flood hazard map developed	No	3	6
		Timely and accurate issuance of severe weather forecasts and warnings	%	50	70
		No. Aviation weather information, advisories and briefings for airports and airlines issued	No of services	1	3
		No. Critical Hydro-met infrastructure enhanced	No	208	253
		Emergency Management contingency plan developed	No	0	1

5/16/2017 NCHM National Center for Hydrology and Meteorology

12 FYP NHCM (DRAFT)

Under Climate					
2	End-to-end operational National Framework for Climate Services (NFCS)	No. of User Interface Platform (UIP) developed for weather and climate services	No	3	9
		No of Enhanced climate information services	No	5	17
		Capacity development for the enhancement of hydro-meteorological services	No	30	60
Under Water					
3	Enhance hydrological information for resilience and adaptation to hydrological variability and change (KPI)	National Water Resources Assessment (WRA) initiated	No	0	1
		Hydrological Modelling for Flow Forecasting installed and Operational in the selected river basin	No.	3	6
		Glacier mass balance, Areal and volumetric change in glaciers	No		
4	Water quality improved	Measurement of sediment loads in major rivers	No.	13	20

5/16/2017 NCHM National Center for Hydrology and Meteorology

Sherubtse College, Royal University of Bhutan — Royal University of Bhutan

Application of Environmental Isotopes as Tracers in Hydrological Studies

"2nd Water Seminar-Water-Securing Bhutan's Future"

Hotel Ariya, Thimphu
May 10th- 12th, 2017

Mr Tshewang Dendup
Sherubtse College, Royal University of Bhutan
Email: pelwanggatshel@gmail.com

109

Outline

- Introduction to isotopes
- Application of stable isotopes
- Mixing model
- Example: use of isotopes of water to evaluate glacier melt contributions to river

110

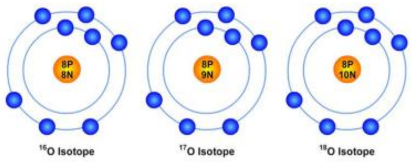
Isotopes Defined

Isotopes: Greek *isos topo s* = same place

Isotope = atoms of the same element with a different number of neutrons (different mass)

Example:

Oxygen Isotopes



111

Environmental Isotopes

Stable Isotopes | Radioactive Isotopes

Stable Isotopes

Do not decay spontaneously (stable over time)

Examples: ^{18}O, ^{2}H, ^{13}C

Used as Tracers

Radioactive Isotopes

Emit alpha and beta particles and decay over time

Examples: ^{3}H (Tritium), ^{14}C

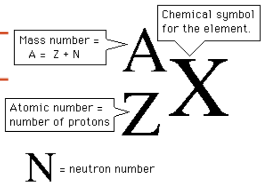
Used for Dating

(From Mark Williams, CU)

112

Environmental Isotopes

Element	Isotopes	Z	N	Atomic Mass	Abundance [%]
Hydrogen	^{1}H	1	0	1.0078	99.984
	^{2}H	1	1	2.0141	0.0156
Carbon	^{12}C	6	6	12.0000	98.892
	^{13}C	6	7	13.0034	1.108
Nitrogen	^{14}N	7	7	14.0031	99.635
	^{15}N	7	8	15.0001	0.365
Oxygen	^{16}O	8	8	15.9949	99.759
	^{17}O	8	9	16.9991	0.037
	^{18}O	8	10	17.9992	0.204
Sulfur	^{32}S	16	16	31.9721	95.02
	^{33}S	16	17	32.9714	0.76
	^{34}S	16	18	33.9676	4.22
	^{36}S	16	20	35.9671	0.014

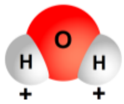


- More than 1700 isotopes
- Only 264 are stable
- Only 10 important for us!

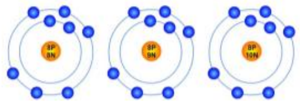
113

Isotopes of Water

Water isotope hydrology focuses on the isotopes that form water molecules:

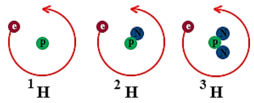


Oxygen isotopes



Oxygen-16 Oxygen-17 Oxygen-18

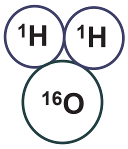
Hydrogen isotopes



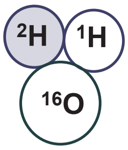
Protium Deuterium Tritium

114

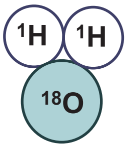
Stable Water Isotopes



Regular water



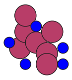
δD



$\delta^{18}O$

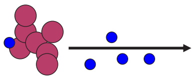
115

Stable Isotopes: Isotope Fractionation



^{16}O (Light Element)

^{18}O (Heavy Element)



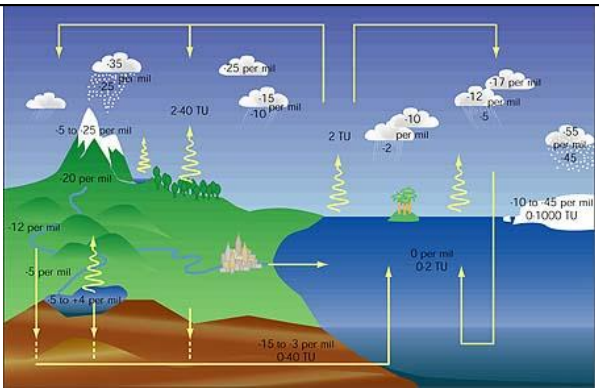
Phase changes can sort the light elements from the heavy elements

Fractionation

Change in $\delta^{18}O$ value

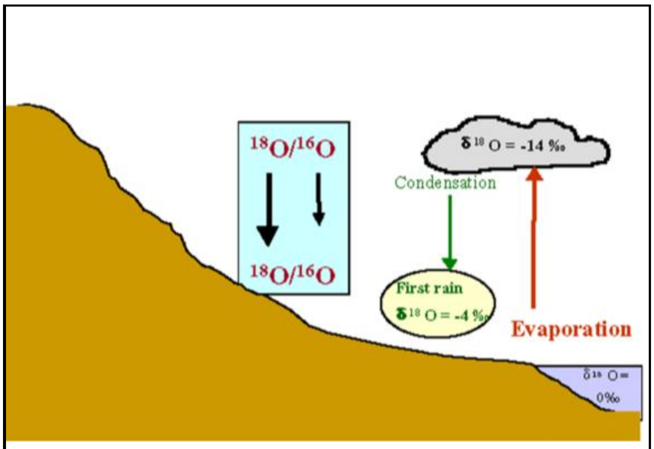
(From Mark Williams, CU)

116

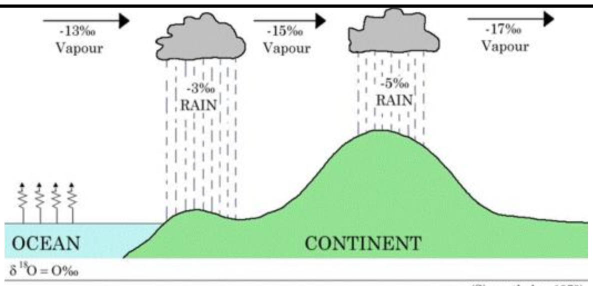


As a consequence of fractionation processes, waters often develop **unique isotopic compositions** (ratios of heavy to light isotopes) that may be indicative of their source or of the processes that formed them.

117



(From Mark Williams, CU) 118



(Siegenthaler, 1979)

- **Lighter (more negative) isotopes evaporate preferentially**
- **Clouds have a NEGATIVE $\delta^{18}O$ value**
- **Rain: heavier (less negative) isotopes preferentially condense from the cloud**
- **Water vapor in clouds get progressively more negative over time and distance**
- **Provide a unique "fingerprint" to source waters and flowpaths**

(From Mark Williams, CU) 119

Measuring Stable Isotopes

Stable isotope ratios are expressed as delta (δ) values in parts per thousand (per mil – ‰) relative to a standard:

General Expression:

δ (in ‰) = [Rx/Rs -1] x 1000 = per mil (‰)

Where:

Rx = heavy isotope / light isotope in sample
Rs = heavy isotope / light isotope in standard

Stable oxygen and hydrogen isotopic ratios are normally reported relative to the "standard mean ocean water" (SMOW) standard or the equivalent Vienna-SMOW (VSMOW) standard.

120

Isotopes of Water as Tracers

Isotopes of water can be used as tracers of waters in shallow low-temperature environments because:

(i) Waters that were recharged at different times, were recharged in different locations, or that followed different flow paths are often isotopically distinct; in other words, they have distinctive "fingerprints."

(ii) Isotopes of water are relatively **conservative** in reactions with the bedrock and soil materials. So, the they retain their distinctive fingerprints until they mix with other waters.

Water isotopes are ideal tracers of water sources and movement because they are constituents of water molecules

(Kendall and Doctor) 121

Isotopes of Water as Tracers in Hydrological Studies

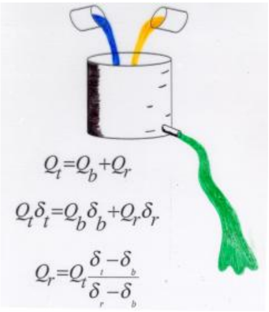
Examples:

1. To determine the source of the water
   (e.g., precipitation versus groundwater in streams).
2. In catchment research:
   Determining the contributions of "old" and "new" water to high flow (storm and snowmelt runoff) events in streams.

- **"Old" water:** water that existed in a catchment prior to a particular storm or snowmelt period (groundwater, soil water, and surface water)
- **"New" water:** rainfall or snowmelt, that triggers the particular storm or snowmelt runoff event.

(Kendall and Doctor) 122

Using Isotopes to Identify Source Waters: Mixing Models

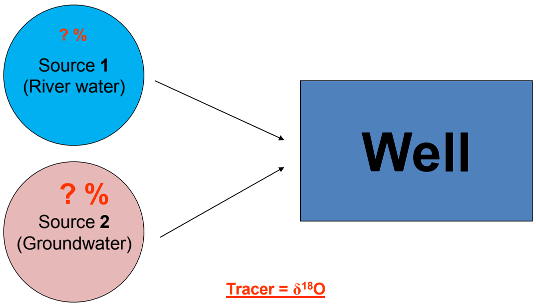


2-component mixing model:

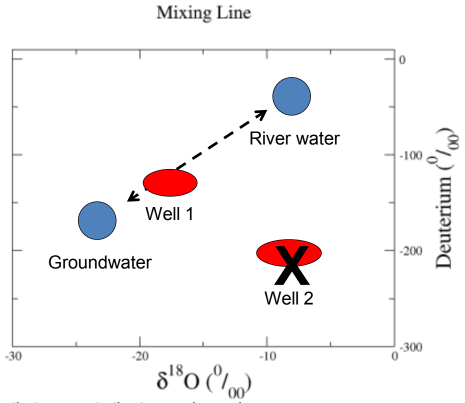
- One Conservative Tracer
- Mass Balance Equations

(From Mark Williams, CU) 123

2 Component Mixing Model: Concept



(From Mark Williams, CU) 124



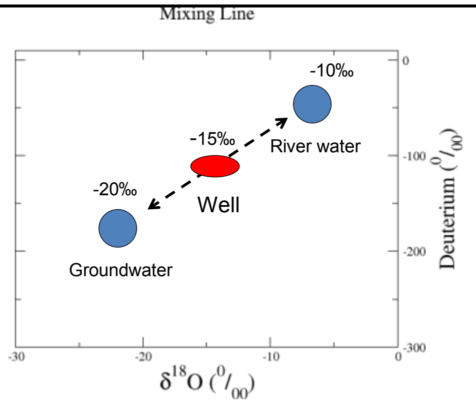
Mixing line that connects the two end-members:

a) sample must plot between the two end-members

b) sample must plot on or near the mixing line.

125

(From Mark Williams, CU)



Let's put in some actual tracer concentrations.

(From Mark Williams, CU) 126

Calculate the Fraction Contribution of Groundwater and River Water to Well

- Groundwater (g); River water (r), Well (w)
- Percent river water contribution to the well is:

$$\mathbf{C_w - C_g / C_r - C_g}$$

- Sampling only for the tracer concentration **(c)** allows us to calculate the fraction contribution of each end-member to our mixture
- We need only three samples!
- No water flow measurements

(From Mark Williams, CU) 127

2-Component Mixing Model: Calculation

$$\frac{Cw - Cg}{Cr - Cg} = \text{percent contribution of river water}$$

$$\frac{-15 - (-20) = +5}{-10 - (-20) = +10} = \mathbf{50\%}$$

(From Mark Williams, CU) 128

2-component Mixing Model: Assumptions

- Only 2 components in mixture (groundwater well in this example)
- Mixing is complete
- Tracer signal is distinct for each component
- No evaporation or exchange with the atmosphere
- Concentrations of the tracer are constant over time or changes are known

(From Mark Williams, CU) 129

Example: Application of Isotopes in Hydrological studies

Annals of Glaciology 57(71) 2016 doi: 10.3189/2016AoG71A068 1

Using geochemical and isotopic chemistry to evaluate glacier melt contributions to the Chamkar Chhu (river), Bhutan

Mark W. WILLIAMS,[1,2] Alana WILSON,[1,2] Dendup TSHERING,[3] Pankaj THAPA,[3] Rijan B. KAYASTHA[4]

USAID-funded Contribution to High Asian Runoff from Ice and Snow (CHARIS) research project

130

Site Description

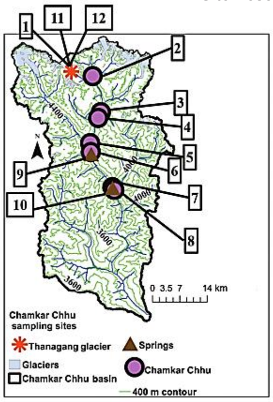


Fig. 1. Location and site map for the Chamkar Chhu (river), Bhutan. Sampling sites are shown for river, springs, glacial outflow, ice and snow. Site location code numbers are defined in Table 1.

- Altitude : 2600 m to >6000 m
- About 35% of the basin is covered by glaciers and snow
- The Chamkar/Bumthang Chhu flows predominantly north to south, with several minor tributaries
- At the headwaters of the river at 5500 m is the outflow of Thanagang glacier

131

Objective: To use geochemical and isotopic values of water samples to evaluate relative contributions of melting glacier ice and groundwater to discharge in Bhutan.

Methodology

Watershed methods:

- Sampling was carried out in July, August and late September 2014
- Samples collected: River water, Glacier ice and snow and Groundwater (spring water)

Laboratory methods:

Physico-chemical analysis: Solutes, $\delta^{18}O$ and $\delta^{2}H$.

132

Results

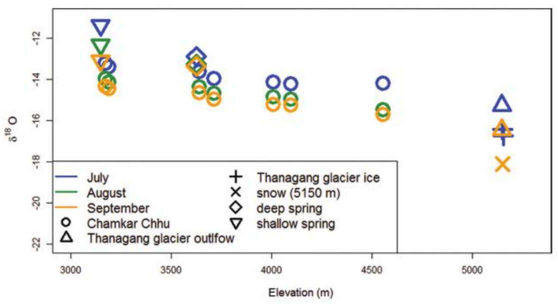


Fig. 2. Values of $\delta^{18}O$ of water (surface waters, glacier outflow, ice, snow and springs) as a function of elevation. There is a decreasing trend in $\delta^{18}O$ with elevation.

133

Results

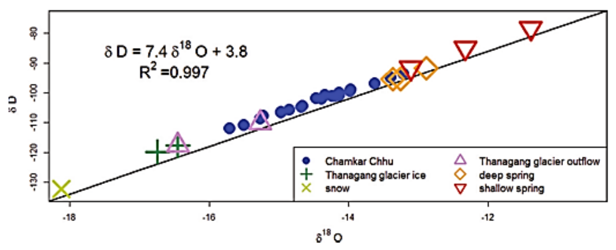


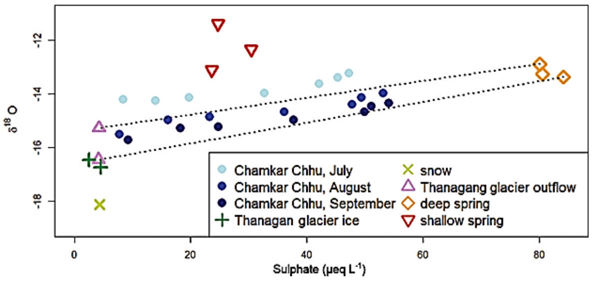
Fig. 3. $\delta^{18}O$ and δD values for all water samples are highly correlated (R^2= 0.997; n = 32). Isotopic compositions of the water follow closely the GMWL.

These results suggest very little loss of snow and ice to sublimation or evaporation since the equation is close to that for global precipitation.

134

Two-Component Mixing Model

To understand **source waters** that might contribute to flow in the river, $\delta^{18}O$ values are plotted against sulphate of stream waters along with potential end members



135

Results

- On average about 45% of river flow was glacier outflow and about 55% was groundwater
- The contribution of Thanagang Glacier decreased with decreasing elevation
- Glacier outflow contributions increased from **55%** of stream flow in July to **76%** of streamflow in September at 4500 m near the terminus of Thanagang glacier.
- At the lowest-elevation site (3100 m), the glacier outflow contribution increased from **14%** to **31%** between July and September.
- There was a significant increase in the contribution of glacial outflow to Chamkar Chhu from July to September (*$p < 0.002$).*

136

Results & Discussion:

- The two-component hydrologic mixing model results indicate that within 25 km downstream the flow in the Chamkar Chhu changes from a mostly glacier output system to one dominated by groundwater.
- The result demonstrate that regardless of the role that meltwater plays, rain runoff and baseflow may be important runoff compounds too, in particular when timing is similar to that of the meltwater hydrograph

137

Conclusion

- Results from the mixing model based on hydrochemistry can provide a quantitative evaluation of different source waters as contributors to streamflow in Bhutan if all potential end members are sampled.
- Traditional approaches to estimating glacial ablation, such as the glaciological and hydrological mass-balance methods, are particularly difficult to conduct in remote areas such as Bhutan where there is little infrastructure to support field studies.
- Hydrological modelling represents the most frequently applied approach to quantifying the proportional contribution of glacial meltwater to streamflow.

138

Lab staff and DAA of Sherubtse College.

From left: Jigme Wangmo, Punya Prasad Bhandari, Tenzin Wangchuk Ph.D., DAA, Dendup Tshering, Tshewang Dendup

140

Challenges

- To keep lab running?
  - Lack fund
- Lack capacity (e.g. hydrological models)

Way forward

- To strengthen existing linkages with agencies within and outside Bhutan
- Build new linkages/collaboration with agencies within & outside Bhutan
- Build capacity

141

TRASHI DELEK

142

References

Craig H (1961) Isotopic variations in meteoric waters. Science, 133 (3465), 1702–1703 (doi: 10.1126/science.133.3465.1702)

Hooper RP (2003) Diagnostic tools for mixing models of stream water chemistry. *Water Resour. Res., 39(3), 1055 (doi: 10.1029/* 2002WR001528)

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Williams, M. W., Wilson, A., Tshering, D., Thapa, P., & Kayastha, R. B. (2016). Using geochemical and isotopic chemistry to evaluate glacier melt contributions to the Chamkar Chhu (river), Bhutan. *Annals of Glaciology, 57(71), 339-348.*

143

Two-component mixing models: The glacier outflow (go) and groundwater (gw) water components of streamflow can be estimated using $\delta^{18}O$

$$Q_{stream} \times C_{stream} = Q_{go} \times C_{go} + Q_{gw} \times C_{gw}$$

$$Q_{stream} = Q_{go} + Q_{gw}$$

where Q is volume flow rate, C is $\delta^{18}O$ value, and the subscripts describe the water source.

$$Q_{go} = Q_{stream}\left[\frac{C_{stream} - C_{gw}}{C_{go} - C_{gw}}\right]$$

This equation allows calculation of the percent contribution of glacier outflow and groundwater to river discharge without the need to measure river discharge.

144

Reasons for isotopic fractionation

- Isotope fractionation occurs because the bond energy of each isotope is slightly different.
- Heavier isotopes have stronger bonds and slower reaction rates.
- The difference in bonding energy and reaction rates are proportional to the mass difference between isotopes.
- Thus, light elements are more likely to exhibit isotopic fractionation than heavy isotopes.

145

Typical uses of environmental isotopes

- Identification of sources of water and solutes,
- determination of water flow paths,
- Assessment of biologic cycling of nutrients within the ecosystem, and
- Testing flow path, water budget, and geochemical models developed using hydrologic or geochemical data.

146

Collaboration: The National Snow and Ice Data Center (NSIDC) University of Colorado, Boulder, & Sherubtse College, Bhutan

Objective: To assess the role of glaciers and seasonal snow cover in the Hhdrology of the mountains of high Asia

147

Climate Change Adaptation in Bhutan

National Water Symposium
11 May 2017

Sonam Lhaden Khandu
Climate Change Division
National Environment Commission

Outline

- ❖ Bhutan's Vulnerability to Climate Change
- ❖ Institutional Arrangements on Climate Change
- ❖ CC Scenarios for Bhutan
- ❖ Adapting to CC
- ❖ Next steps

Bhutan's Vulnerability to Climate Change

fragile mountainous landscape

landlocked & least developed country

Heavy dependence on climate sensitive sectors
Low level of economic diversification

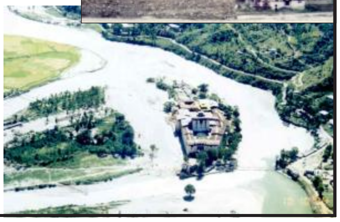
Agrarian society
(69% of population)

Large investments in hydropower

Large areas of glaciers and glacial lakes

Current Vulnerabilities

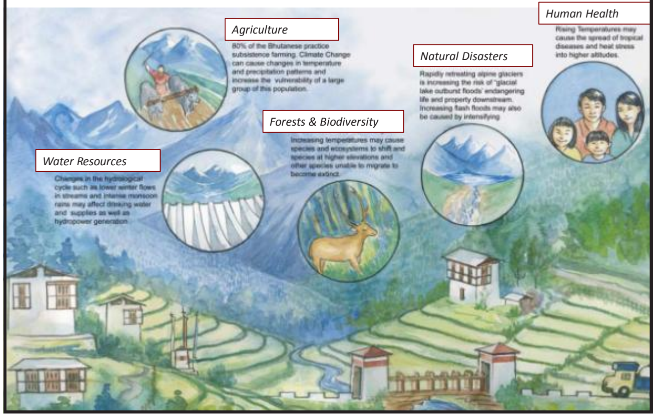
- Glacial Lake Outburst Floods
  - due to temperature rise
- Land Degradation
  - Landslides, erosion due changes in to weather patterns, high intensity rainfall, cyclones
- Flashfloods
  - Intense rainfall periods, cyclones



Current Vulnerabilities

- Droughts
  - Drying water sources due to temperature rise, longer intervals between rains
- Wind and Thunder storms
- Pests and diseases

Potential areas impacts of climate change in Bhutan



Institutional Arrangements on Climate Change

Background

- Bhutan signed UNFCCC at Rio de Janeiro in 1992
- UNFCCC was ratified during the 73rd Session of National Assembly in 1995

158

Institutional Arrangements

- NEC acts as High Level National Climate Change Committee (NCCC)
- NEC Secretariat is National Focal Agency for Climate change and UNFCCC as per NEPA 2007

- 27th NEC (13 Feb 2009) meeting approved
  – Establishment of Climate Change Unit at NECS
  – National Technical Level Task Force (MSTCCC) recently revamped as Climate Change Coordination Committee (C4)

- 32nd NEC (21 June 2011) Meeting approved
  – Establishment of Climate Change Division at NECS

159

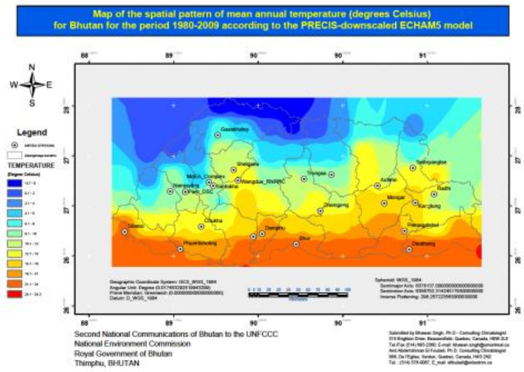
Climate Change Scenarios

Based on Chapter 4 (Vulnerability and Adaptation) of Second National Communication to UNFCCC

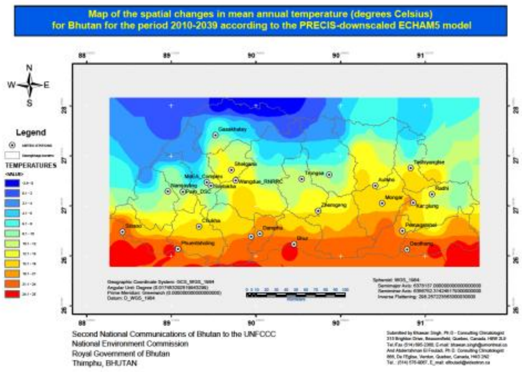
Generating climate change scenarios using PRECIS

- Scenarios based on:
  – A1B emissions scenario (Middle emissions projection)
  – 2 GCMs
    - ECHAM5
    - HADCM3
- Temperature and Rainfall
  – Annual mean
  – Monsoon mean
  – Winter Mean
- Time slices
    - 1980-2009 (synthetic baseline)
    - 2010-2039
    - 2040-2069

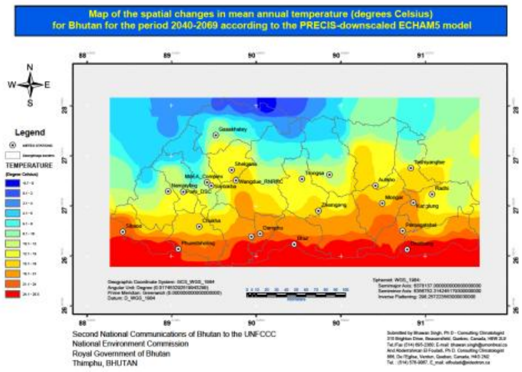
Spatial Changes: Annual temperature 1980-2009



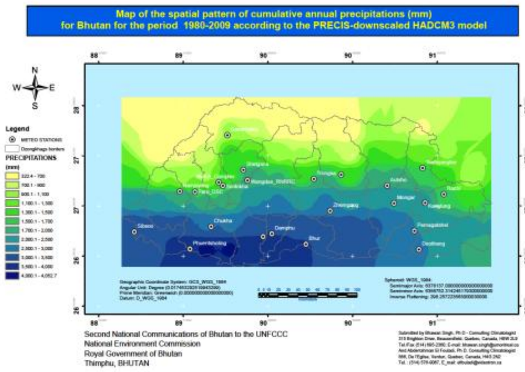
Spatial Changes: Annual temperature 2010-2039



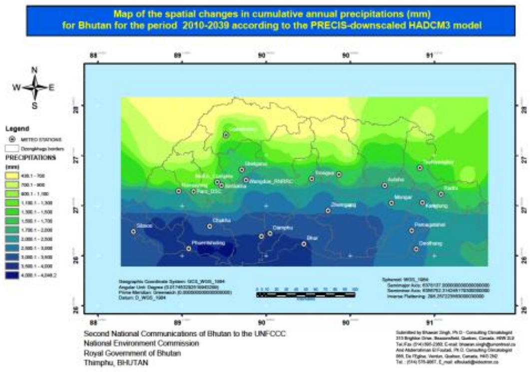
Spatial Changes: Annual temperature 2040- 2069



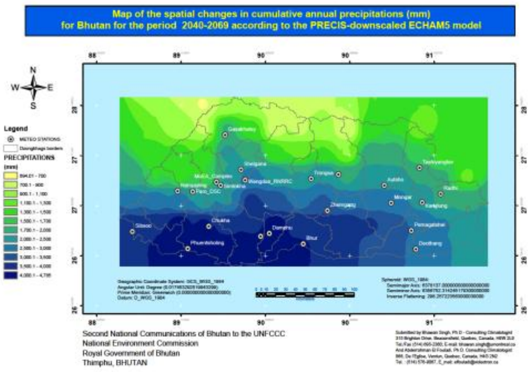
Spatial Changes: Annual rainfall 1980-2009



Spatial Changes: Annual rainfall 2010-2039



Spatial Changes: Annual rainfall 2040-2069



Summary of Climate Change Projections

Temperature changes compared to present (1980-2009)

- Annual Mean temperatures:
  - Increase of ~ 0.8 °C - 1.0 °C by 2010-2039
  - Increase of ~ 2.0 °C - 2.4 °C by 2040-2069
- Summer/monsoon season temperatures:
  - Increase of up to ~ 0.8 °C by 2010-2039
  - Increase of up to ~ 2.1 °C by 2040-2069
- Winter season temperatures:
  - Increase of ~ 1.2 °C by 2010-2039
  - Increase of ~ 2.8 °C by 2040-2069

Summary of Climate Change Projections

Rainfall Changes compared to present (1980-2009)

Annual Mean rainfall:

- Increase of ~ 6% by 2010-2039
- Increase of ~ 21% by 2040-2069

Seasonal changes:

- Summer are wetter for both future periods
- Winters will be drier in 2010-2039 and increasing slightly in 2040-2069

Caution!
Scenarios are not predictions!

The scenario presented is based on;

- one Global Emissions Scenario (A1B) only
- two Global Circulation Model (GCMs) for A1B emissions scenrio
  - ECHAM5 A1B
  - HadCM3Q A1B

Multi-model scenarios needed in next assessment

Adapting to Climate Change

Objective of NAPAs

NATIONAL ADAPTATION PROGRAMME OF ACTION (NAPA)

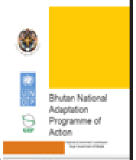
- To address urgent adaptation needs of Least Developed Countries (LDCs) to enhance adaptive capacity to "climate variability"
  - This in turn addresses adverse effects of climate change
- Focus on urgent and immediate needs
  - Those where delay could increase vulnerability or greater costs later stage
- Based on existing information – no new research
  - Including community level input through consultative process
- Action oriented and country driven and flexible

172

National Adaptation Programme of Action (NAPA)

NAPA document prepared in 2005 under UNFCCC process

- Participatory and consultative process (bottom up)
- Nine prioritised actions identified in 2005
- 3 actions implemented under 1st NAPA project



NAPA project profiles updated 2012

- Eight prioritised actions identified including those remaining from 2005

Ongoing Implementation of NAPA

- 2nd NAPA implementation project ongoing
- 3rd NAPA implementation project under formulation
- Funded by LDC Fund (under UNFCCC)

1st NAPA implementation project

Addressing Threats of GLOF from Thorthormi Tsho in Punakha - Wangdi Valley

First NAPA Project funded by LDCF

Reducing Climate Change-induced Risks and Vulnerabilities
from Glacial Lake Outburst Floods
in the Punakha-Wangdi and Chamkhar Valleys

Three Components

1. Artificial lowering of water level in Thorthormi Lake
2. Increase capacity for disaster risk management in affected valleys
3. Installing Technical Early Warning System for glacial lake outburst floods

Lowering water level of Thorthormi Lake

Early Warning System & Disaster Preparation

2nd NAPA Project

Project Budget: USD 11.49 million
Project Duration: 2014-2018
Overall Project Coordination: NECS with support from UNDP

Project Implementation Partners:

1. Phuentsholing Thromde
2. DGM. MoEA
3. Mongar Municipality
4. Tarayana Foundation
5. WRCD &CCD, NECS
6. DDM, MoHCA
7. DES, MoWHS
8. FFMS, DoFPS, MoAF
9. DHMS, MoEA

NAPA 2 Project Details

Outcome 1:
Risk from Climate-induced floods and landslides reduced in Bhutan's economic and industrial center, Phuentsholing and Pasakha Industrial Area

Outcome 2

Community resilience to climate-induced disaster risks (droughts, floods, landslides, windstorms, forest fires) strengthened in at least four dzongkhags

Outcome 3:

Relevant information about climate-related risks and threats shared across development sectors for planning and preparedness on a timely and reliable basis

Other sector projects

- RNR sector support
  - Sectoral Adaptation Program of Action (SAPA) to "Enhance the resilience of Bhutan's rural households to the effects of climate change" (EU GCCA project)
- 3rd NAPA project under formulation
  - Focus on market and food security and biodiversity conservation
  - From LDC Fund
- MOEA
  - Many projects to Dept of Hydromet Services to improve weather forecasting and early warning for users
  - GLOF and landslide projects with DGM and DHMS
- MOH
  - Assessment of health risks from climate change
  - Vector monitoring program
- Research institutes
- DLG
  - LoCAL (Local climate adaptive living facility)

What Next?

Future plans

3rd National Communication from Bhutan to UNFCCC (TNC)

- More focus on vulnerability and adaptation assessment (V&A) at the community level
- Climate change scenarios + socio economic scenarios
  - "Future climate + future society"
- Expect to have better information from
  - local level vulnerability information through water inventory and district level collaborators
  - Better climate scenarios from investments in NCHM

National Adaptation Plans (NAPs)

- As a process to enable LDCs to formulate and implement NAPs, building on NAPAs, as a means for:
  - Identifying medium- and long-term adaptation needs, and their integration into development planning;
  - Developing and implementing strategies and programmes to address those needs;

185

Objectives of the NAP Process

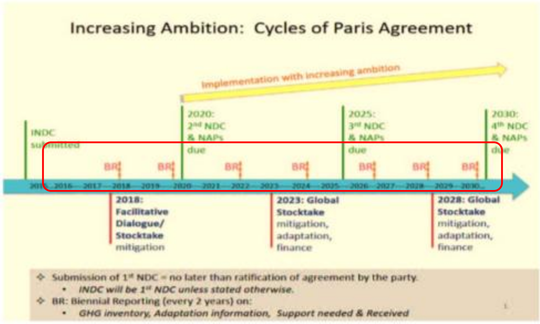
The objectives of the NAP process are:

a) To ***reduce vulnerability*** to the impacts of climate change, by building adaptive capacity and resilience;

b) To facilitate the ***integration of climate change adaptation***, in a coherent manner, into relevant new and existing policies, programmes and activities, in particular development planning processes and strategies, within all relevant sectors and at different levels, as appropriate.

- *Ref: Decision 5/CP.17, paragraph 1*

186



187

Status of Bhutan's NAP

- NAP was launched in May 2015 during a stakeholder consultation workshop "*Dialogue on Climate Resilient and Carbon Neutral Development*"
- CCD,NECS to take the lead on NAP development as per directives from NEC meeting held in February 2016
- NAP road map was presented and discussed during the workshop on "*Advancing Action on Climate Change for National Priorities and International Obligations*" held on 4th March 2016.
- NAP stakeholder consultation workshop held in June 2016 to validate draft proposal for NAP preparation.
- Preparation of NAP readiness proposal (USD 3 million) is ongoing with support from UNDP to access Green Climate Fund (GCF).

Potential sources of adaptation financing

- Regular GNHC and RGOB programming:
  - 12 Five Year Plan NKRA 6 (Climate resilient and Carbon Neutral)
- UNDP/GEF Small grants program
  - Up to US$50,000 per grass roots projects
- Bhutan Trust Fund for Environmental Conservation
  - For Environment Conservation initiatives including climate change
- Sectoral programming
  - Bilateral donors
- Green Climate Fund and other donors

Conclusions

Adaptation will need to take place at all levels from national to local level and integrate into development planning

Best available science, and data information required for informed planning and decisions making

•National Level: good climate scenarios and data for national level assessments and prioritisation

•Local level vulnerabilities and realities should inform national level planning and prioritisation

•But should not be a hindrance as adaptation planning is an iterative and continuous process

•Can use **"current vulnerabilities"** not just **"future vulnerabilities"**

THANK YOU

Ugyen Wangchuck Institute for Conservation and Environmental Research

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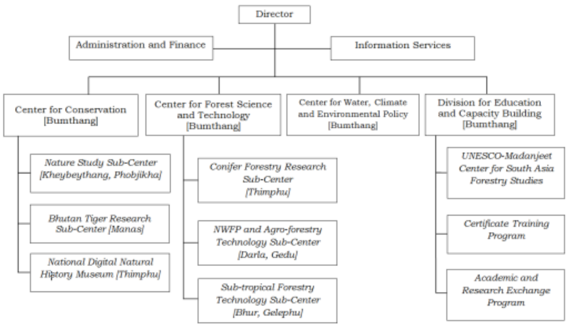
Overview

Center for Water, Climate and Environmental Policy

Dawa Yoezer
Forestry Officer
UWICER

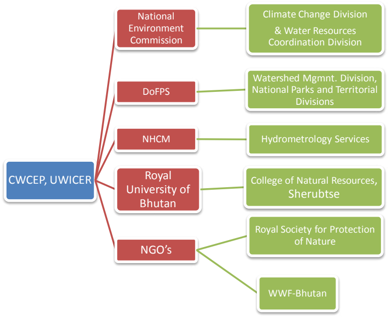
Ugyen Wangchuck Institute for Conservation and Environmental Research



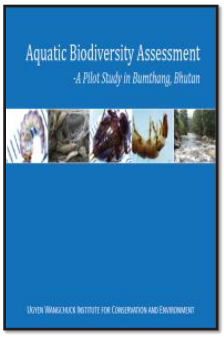
Main Focus Area: CWCEP

- Understanding Ecological Aspects
- Management &
- Policy aspects of water resources

Partners & Collaborators



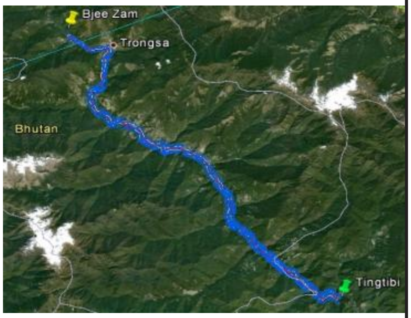
Research Activities and Outcomes



- Carried out Pilot Aquatic Biodiversity Assessment in Bumthang
- In Collaboration with University of Montana, USA
- Developed a Protocol and methodology for assessment of Macro-invertebrate Diversity in Bhutan

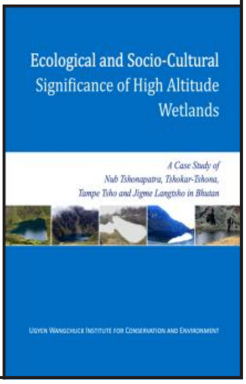
Research Activities and Outcomes

- Year 2014-2016
- Aquatic Biodiversity Assessment in Mangdechhu
- Established Aquatic Biodiversity baseline of Mangdechu



Research Activities and Outcomes

- Documenting Ecological & Socio-cultural Significance of HAWs

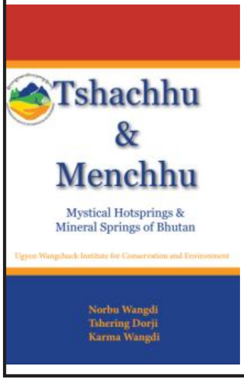


Research Activities and Outcomes

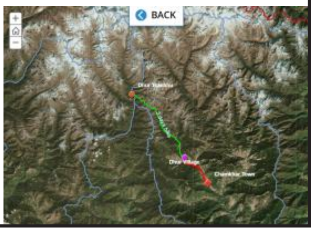
- The costs of adaptation : loss and damage associated with changing monsoon patterns in Punakha
- Published in Int. J. Global Warming

http://www.loss-and-damage.net/

Research Activities and Outcomes



- Inventory of the Tshachhus and Menchhus of Bhutan (Year 2013-2014)
- Develop mobile app.



On-going Activities

- Year 2015-2017
- **"Building Institutional Climate Analysis and Increasing Community Resilience to Climate Change"** in Wangchuck Centennial National Park WWF-Bhutan
  - Climate smart village initiatives
  - Hydrometeorology studies
  - Wetland assessment
  - Training and conferences

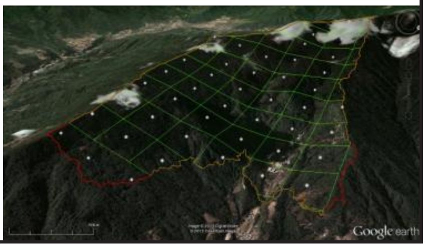
Climate Smart Village Initiatives

- Shawa and Nimshong in Lhuntse
  - Climate adaptation
  - agriculture diversification
  - Water source protection
  - Mitigate HWC
  - Climate monitoring

•Third village to assessed and established as CSV.

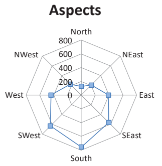
Longterm watershed and stream ecology assessment in the Research Preserve

•Longterm wildlife, tree biomass and climate and watershed assessment in in the preserve area
- Set up weather stations
- Stream flow and ecology studies
- Snowfall records



High altitude wetland Mapping

- Recorded 3339 HAWs
- Area: 0.26%
- Aspect
- Altitude
- Landcover



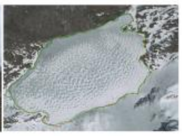


Figure 13. Comparison of field validation(right) and Google image(left) in Zhualathang(Base of Gangkar Phuensum)

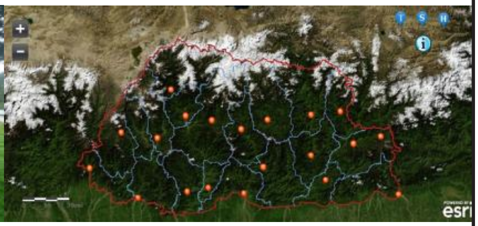
Longterm Hydrometeorology studies

- Longterm climate monitoring in the highland valleys of WCNP
- Set up three weather Stations

HEROES - Himalayan Environmental Rhythms Observation and Evaluation System

HOME NEWS RESOURCES PUBLICATIONS BLOG DATA VISUALIZATION SPECIES CONTACT US

- Citizen Science Project
- Record climate and plant data



Karuna Foundation Bhutan Foundation

Water and Climate research- Yusipang

- Background:
  - » Activities started from 1999 – tied with Life zone ecology III
  - » Overtook Hydromet stations from Wang Watershed Project in 2007
  - » Became full research program with the development of Research Road map 2015
- – Meteorology:
  - » AWS
- Hydrology:
  - Gauge station
  - Stream discharge

- **Outcome/ Status:**

  Life zone ecology of Bhutan III 2002 – incooperated
  - Synoptic and local analysis of relationship between climate and forest in Bhutan Himalaya 2011
  - Difference in Temperature between Shallow and Deep Valleys of the Bhutan Himalaya 2012.

Bhutan Climate Change Adaptation and Mitigation Potential Project

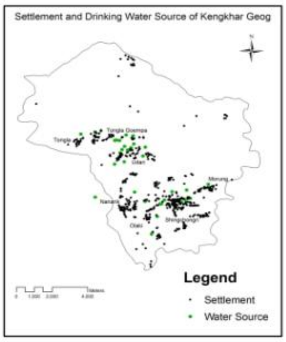
- 2014-2018
- Drought Stress Tolerance and Climate change adaptation & Mitigation potentials of main forest types in Bhutan (2014-2016)
- Funded by Austrian Govt.
- BCCAP:
  - Sap flux, Soil Moisture content, PMS (plant moisture stress), through fall, and stem flow are measured
  - Climate stations established
  - Major HRD component for the DoFPs
  - Drought tolerance (Monsoon exclusion experiment) by the two different forest go on till 2018

Outcome/ Status:

- BCCAP:
  - Major HRD component for the DoFPs
  - 2 Phds and 3 MScs specifically done thesis in climate related fields
  - Drought tolerance (Monsoon exclusion experiment) by the two different forest go on till 2018

On-going Research Activities

- Water use pattern and scarcity Survey
- Climate change vulnerability and Adaptation Assessment



Training & Conferences

- Bhutan Climate Summit 2011
- International Glacier Symposium 2015
- Tailor made trainings and Awareness programs

Way forward

- Institutional Linkages
- Capacity Development
- Climate impact studies
  - Energy. Economy. Biodiversity. Food.
- Water resources Assessments
  - Water quality - Biotic indicator
    - Scoping
- Policy guidelines

Tashi Delek

www.uwice.gov.bt

6.0 Session 4: Water and Livelihood
Chair: Dr. Phuntsho Thinley, Ugyen Wangchuck Institute for Conservation and Environmental Research

Session 4: Water and Livelihood		
1130	Rural drinking water supply and quality	Mr Karma, MoH
1150	Urban water supply	Ms. Dechen Yangden. MoWHS
1210	Water for irrigation	Mr. Kelzang Tenzin DoA, MoAF
1225	Water for community and its livelihood	Mr. Kinley Dorji, River Guides of Pangbang
1245	Rainwater harvesting	Mr. Jamyang Phuntsho, Tarayana Foundation
1300	Q&A Session	

Rural Drinking Water Supply & Quality

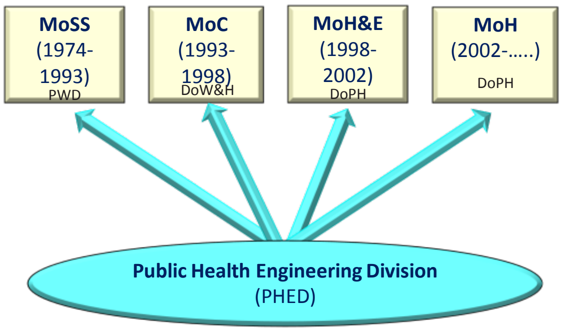
Presented
By

Ka r .bt
17618505

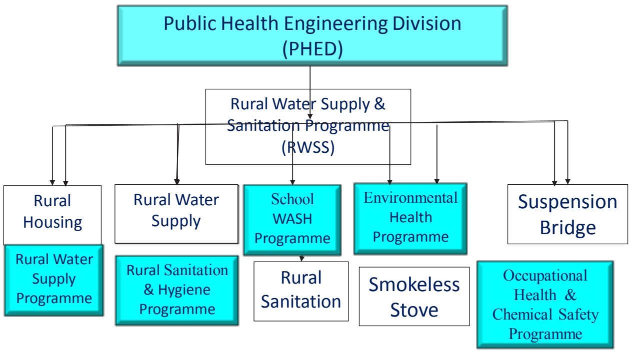
Contents

- Background
  - ➢RWS Programme, PHED
  - ➢RWS Construction
  - ➢RWS Decentralization
- Key Achievement in the 11th FYP
- Future plans in 12th FYP
- Key Issues and Challenges

BACKGROUND



BACKGROUND



RWSS construction

- **1st RWS Construction began- 1970**
- **Officially RWSS program initiated- 1974**
- **Standardized & Computerized RWS Design-1988**

RWS activities -Decentralized

- Spring protection estimating and sanctioning **-FY 1999-00**
- Cement procurement**—FY 2004-05**
- HDPE Pipe procurement**—FY 2006-07**
- GI pipe & GI fittings and other materials **—FY 2007-08**
- Officially Decentralized RWS Design from **August 2009**

Key achievement in the 11th FYP

- Piloted and scale up of Spring Shed Development (Source Reviving)
- Implemented WSP in 20 Dzongkhags
- Conducted In-house RWS survey training in 14 Dzongkhags
- RWS MIS developed and implemented
- Implemented of four stage pumping system at Zobel Geog, Pemagatshel
- Rehabilitation project *(National Resettlement project)*
- Piloted Water source mapping

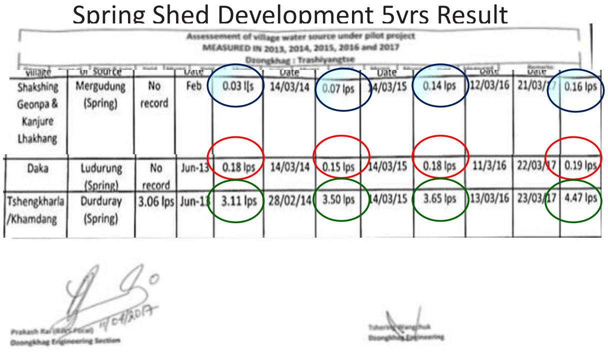
Future plans in 12th FYP

- Small scale water treatment system to be developed
- Water source mapping
- Scale up Spring Shed Development project
- Explore alternative technologies
- Community ownership

Key Issues and Challenges

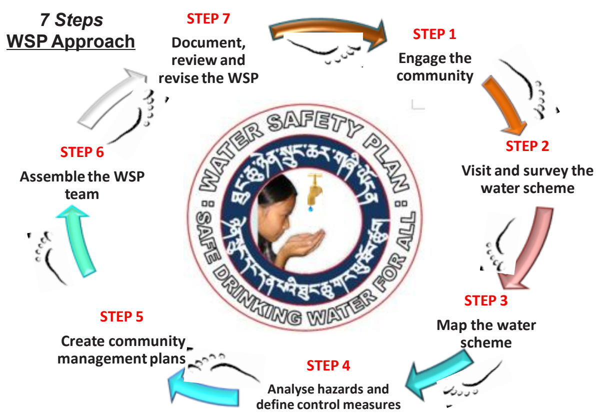
- Decline of community ownership
- Drying of spring source
- No dedicated RWS Engineer in the Dzongkhags
- Rationing of water supply- unequal distribution
- Reaching the Unreached
- To meet SDG
- Human Resource

Spring Shed Development 5yrs Result

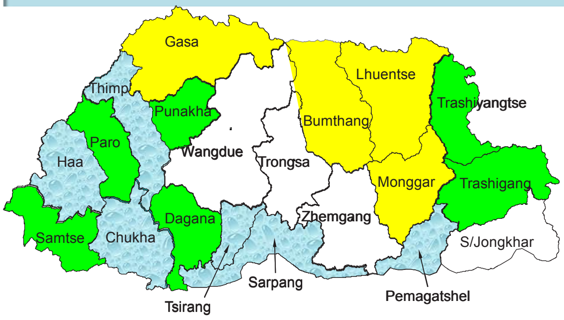

Assessement of village water source under pilot project
MEASURED IN 2013, 2014, 2015, 2016 and 2017
Dzongkhag : Trashiyangtse

Village	of Source		Date		Date		Date		Date	Date	
Shakshing Geonpa & Kanjure Lhakhang	Mergudung (Spring)	No record	Feb	0.03 l[s	14/03/14	0.07 lps	14/03/15	0.14 lps	12/03/16	21/03/17	0.16 lps
Daka	Ludurung (Spring)	No record	Jun-13	0.18 lps	14/03/14	0.15 lps	14/03/15	0.18 lps	11/3/16	22/03/17	0.19 lps
Tshengkharla /Khamdang	Durduray (Spring)	3.06 lps	Jun-13	3.11 lps	28/02/14	3.50 lps	14/03/15	3.65 lps	13/03/16	23/03/17	4.47 lps

11/04/2017
Dzongkhag Engineering Section



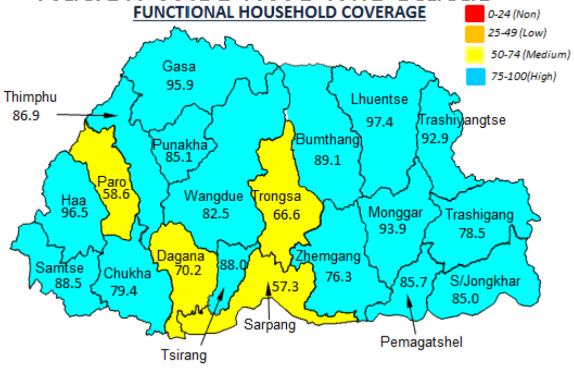
Water Safety Plan in Bhutan



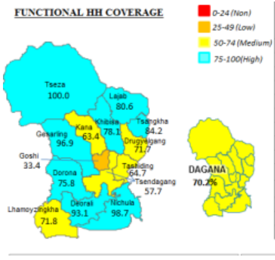
Overview Status of WSP

Activities	Scheme covered	Participants	Dzongkhag WSP trainer	Remarks
WSP in Phase II	38	956	12	7 Schools & Monastic Institutions
WSP in Phase III				
Rural WSP ToT	81	1864	118	
Rural WSP Scale up	212	3406	-	
Institutional WSP (school & Monastic)	37	1795	2	20school & 10monastic institutions
Total	**368**	**10381**	**132**	

Nation Wise RWS MIS status



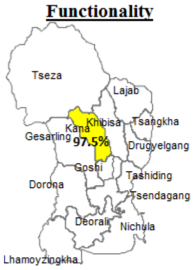
Dzongkhag wise RWS MIS status



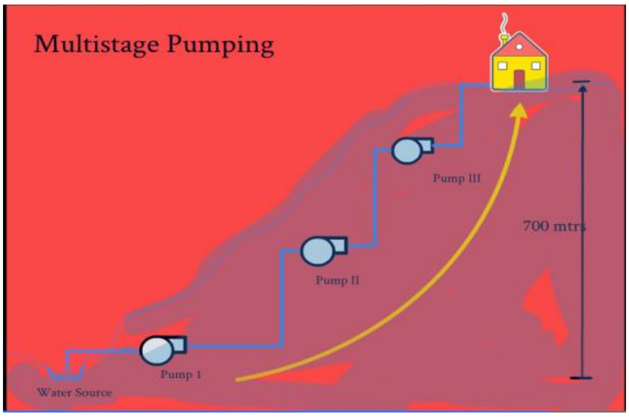
Geog	Total HH Coverage	Functional HH Coverage
DEORALI	93.6%	93.1%
DORONA	94.9%	75.8%
DRUGYELGANG	83.7%	71.7%
GESERLING	96.9%	96.9%
GOSHI	61.9%	33.4%
KANA	82.4%	63.4%
KHEBISA	99.6%	78.1%
LAJAB	95.1%	80.6%
LHAMOYZINGKHA	99.8%	71.8%
NICHULA	98.7%	98.7%
TRASHIDING	89.1%	64.7%
TSENDAGANG	73.7%	57.7%
TSEZA	100.0%	100.0%
TSHANGKHA	91.1%	84.2%
TOTAL	**86.2%**	**70.2%**

Gewog wise RWS MIS status

Functionality

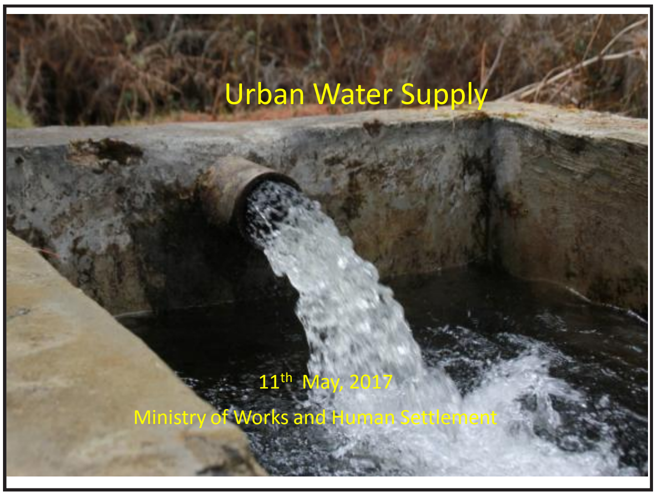


Total Household (HH) in a Geog	624
Total Household served	514
Total Household Unserved	110
Total Tap stand (TS)	449
Total Functional Tap stand (FTS)	421
Total Supply Line (SL)	404
Total Functional Supply Line (FSL)	394
Non-Functional Tapstand (NFTS)	28
Non-Functional Supply Line (NFSL)	10
Functional Supply Line without Tapstand	83
Functional Tapstand without Supply Line	110
Household without tapstand	65
Number of Water Caretaker	14
Number of Water Committee	13
Water Safety Plan (WSP) conducted	2



RWS Water Source Mapping

View in Google Earth



1. Achievements in the 11th FYP for water sector.
2. Key issues and challenges.
3. Plans and programs in 12th FYP.

Achievements in the 11th FYP

1. Preparation of Water and wastewater master plan for :

- Denchi(P/Gatshel)
- Paro
- Tsirang
- Bumthang
- Phuentsholing

Achievements in the 11th FYP

2. Implementation of water safety plan (WSP).

   "*WSP ensures safety of drinking water from catchment to consumer through a comprehensive hazard identification and risk assessment approach".*

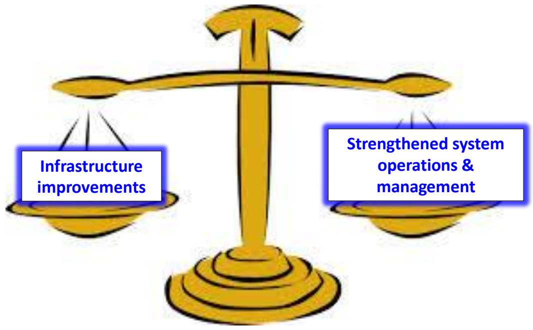
- Mandated by Water Regulations 2014
- 22 municipalities

Treated water reservoirs covered

Irrigation channel levee raised

Before WSP- exposed pipeline

After WSP- Re-aligned and buried



Achievements in the 11th FYP

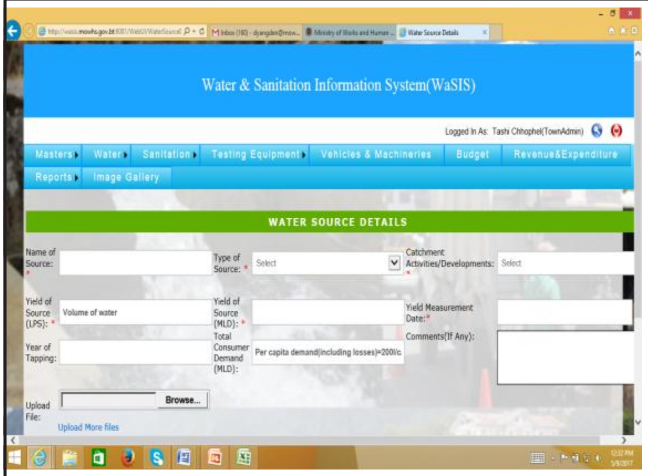
3. Assessment of water and sanitation scenario for Thimphu Thromde.

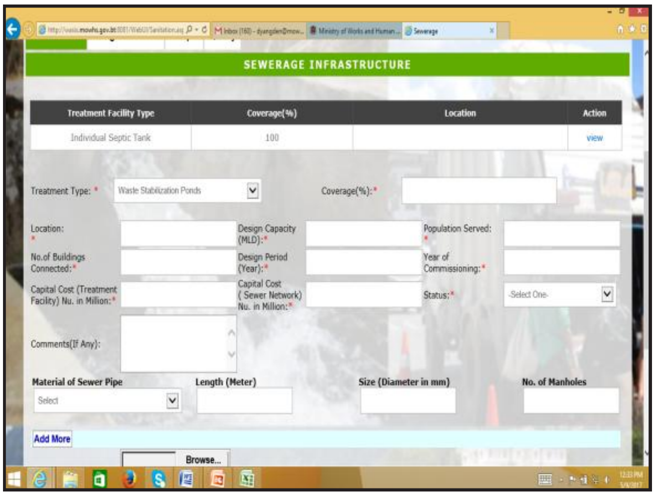
- Carried out household survey in Dec 2015 and issues relating to duration, adequacy and reliability of water supply and customer satisfaction were identified
- Preparation of action plan to address the issues.

Achievements in the 11th FYP

4. Water and sanitation information system (WASIS).

- Database on the inventory of urban water and sanitation infrastructure.
- Proper planning of infrastructure and provide timely support to the municipalities.
- Training provided to focal persons from 22 municipalities.





Achievements in the 11th FYP

5. Provision of water quality testing kits.

- Testing kits for pH, turbidity and residual chlorine were provided.

training provided to the technicians

Water quality testing equipment provided (Cl2, turbidity, pH)

Achievements in the 11th FYP

6. Capacity building of engineers and water operators.

- O&M of Treatment Plants
- Usage of testing kits
- Development of WSP

Achievements in the 11th FYP

8. Projects under GOI-PTA :

Town	Activities	
Tsirang	Providing and Laying of Drinking Water Supply Distribution Network for Damphu Town	On-going
	Rehabilitation of Existing Water Supply Scheme in Damphu Town	On-going

Achievements in the 11th FYP

8. Projects under GOI-PTA :

Town	Activities	
Paro	Providing and Laying Transmission Laying from Bondey WTP to Tshongdue	On-going
	Augmentation of Bondey WTP 2mld	On-going
	Distribution Network for Tshongdue	Tender on-going

Achievements in the 11th FYP

8. Projects under GOI-PTA :

Town	Activities	
Mongar	Rehabilitation and Augmentation of Existing Water Supply of Mongar Town	completed
	Construction of Compact Water Treatment Plant(1.5 MLD) at Kadam, Mongar	Work awarded
	Construction of Compact Water Treatment Plant(1.0 MLD) at Gyelposhing, Mongar	Work awarded

Achievements in the 11th FYP

8. Projects under GOI-PTA :

Town	Activities	
P/ling	Improvement of existing water supply system	completed
	Construction of borewell, laying of pumping main and reservoir tanks at Ammochu LAP	Work to be tendered

Achievements in the 11th FYP

9. Technical Backstopping

Sl. No	Activities
1	Planning, design and according technical sanction of intake and raw water main for Tingtibi, Zhemgang – completed
2	Planning, design and according technical sanction of distribution network including storage reservoir for Zhemgang – completed
3	Planning and design of distribution network for Haa – completed
4	Planning, survey, design and according technical sanction for the water supply scheme for Royal Academy, Pangbisa, Paro – completed
5	Survey, design and estimate for the water supply system (potable and irrigation/gardening) for Supreme court, Thimphu – completed
6	Planning, design and according technical sanction for the raw water supply for Gola town, Samtse – completed
7	Planning, design and according technical sanction for the water supply scheme at Takila (DrukOdhiyana Foundation) unluding distribution to the peripheral areas (Tangmachu middle and lower secondary schools, gewog administration offices, etc.- completed

Achievements in the 11th FYP

9. Technical Backstopping

Sl. No	Activities
8	Review the draft design report for the water supply works in Samdrupjongkhar under the ADB project - completed
9	Feasibility study and design of water supply scheme for Integrated check post at Bumpagang, Chukha - completed
10	Planning, design and technical sanction for the supply of raw water for Zhemgang town from Sershong source including design for the rehabilitation of the existing water supply system – completed
11	Planning, design and technical sanction for distribution network for new Duksum town, Trashiyangtse - completed
12	Preparation of specifications and tender documents for the water treatment plant at new Duksum towns, Trashiyangtse (DBOT modality) – completed
13	Preparation of terms of reference and review of reports for the design of water supply system for Shechamthang, Sarpang – completed
14	Preparation of terms of reference and evaluation for the design of water supply system for Kanglung and Nganglam regional hubs - completed

Key issues and challenges

1. Lack of coordination amongst stakeholder agencies and no single agency responsible for drinking water.
2. Lack of reliable data
3. Drying up of water sources
4. Conflicting water users
5. Lack of resources for O &M and capacity of technicians.
6. Poor Demand management
7. Lack of awareness on water source conservation and consumption

Future plans in 12th FYP

- Adequate, safe and sustainable urban water service improved

1. urban population with access to adequate (24x7) water supply.
2. urban population using improved drinking water free of fecal contamination (complying with BDWQS).
3. Recovery of operation and maintenance cost through reduction of Non-Revenue Water, improve demand management, regulation of tariff etc

Thank you!

"National Water Symposium"

10-12 May 2017

Water for Irrigation

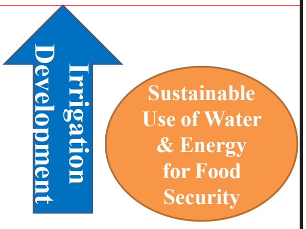
by

Kelzang Tenzin

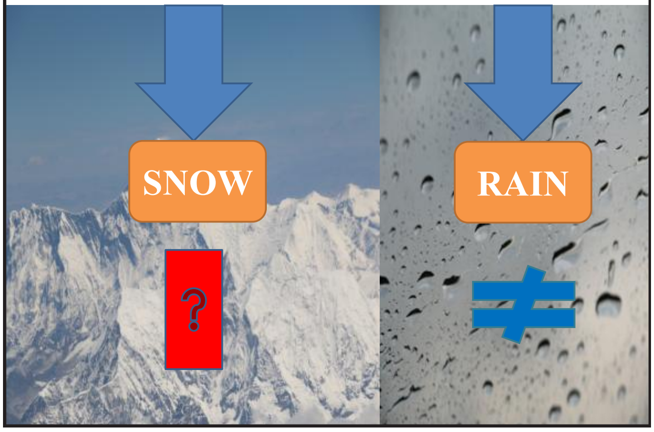
Engineering Division, DoA

Outline

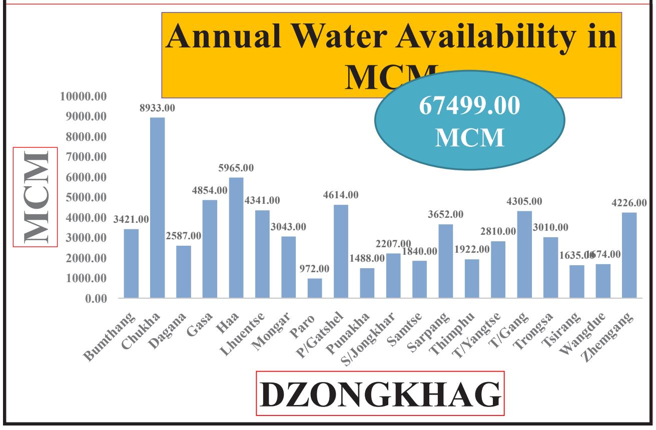
- Resources (Water & Land)
- Institution
- Policy Intervention
- Technology Intervention
- Challenges/Issues
- A Way Forward



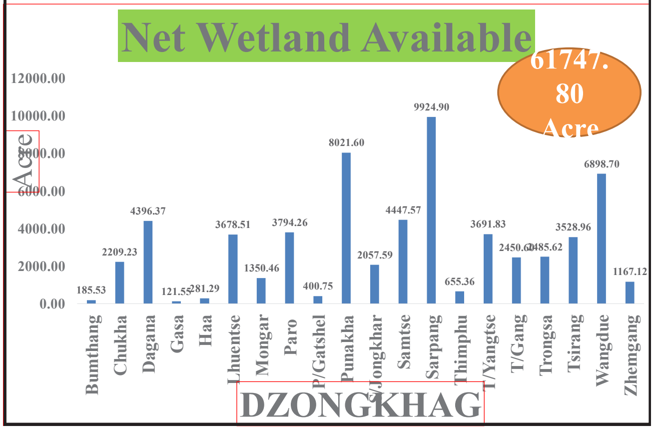
Water Source



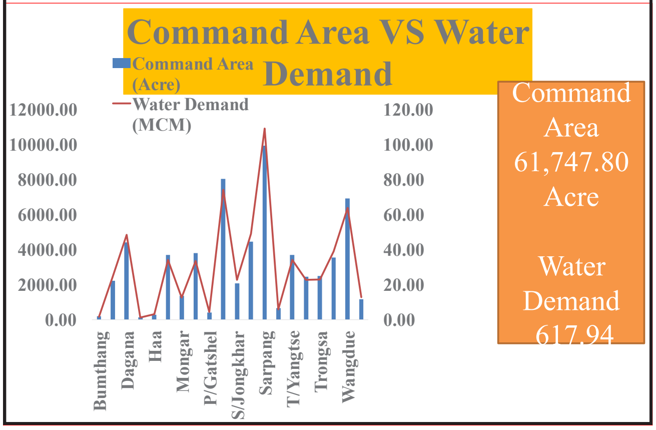
Water Availability



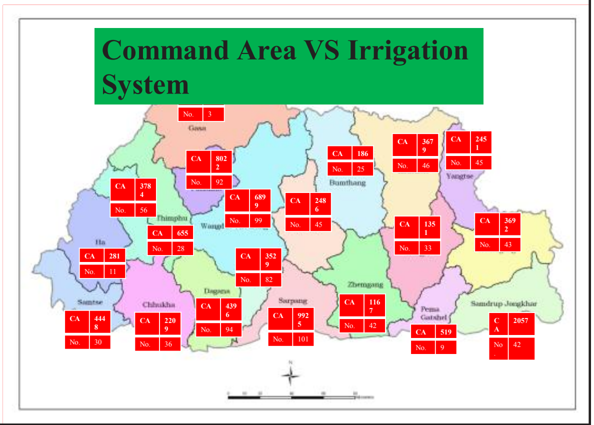
Land Availability/Use



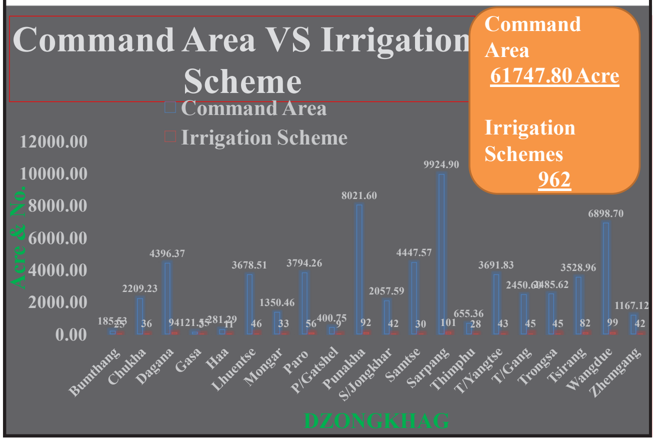
Command Area VS Water Demand



Command Area Vs Irrigation Scheme

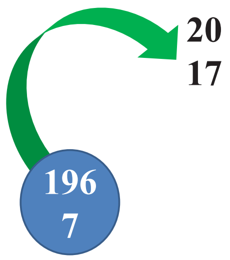


Command Area VS Irrigation Scheme

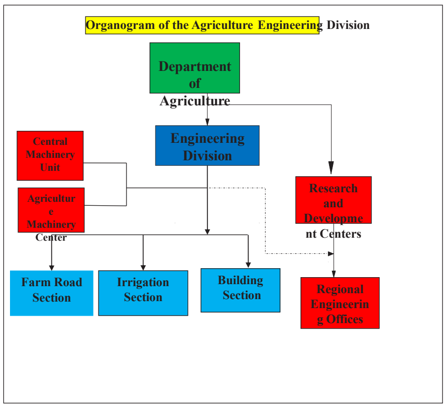


Institution

- Irrigation Division was Created in 1967 (Second FYP; 1966-1971)



Institution



Role & Responsibility

- Development of Sustainable Irrigation System.
- Promote Appropriate Technologies.
- R & D on Irrigation & Water Management.
- Plan & Implement All Large Irrigation Schemes.
- Provide Technical Support to Dzongkhags (LG).
- Review and Revise Policy.
- Issue Environmental Clearance (EC) for Construction of Irrigation Schemes.

Policy Intervention

- National Irrigation Policy (NIP) was Developed in 1992 (WUAs Manual & Irrigation Engineering Manual).
- Revised in 2012 for Holistic Irrigation Development.
- National Irrigation Master Plan (NIMP 2032) & Irrigation Engg. Manual were Developed in 2016 under ADB-TA.

Policy Intervention

- As per NIMP 2032-a 15 years Planning Horizon;

▶ To Increase Irrigation Area from 64,000 acres (2014) to 91,000 acres (2032)

▶ Paddy Production from 75,000 MT (2014) to 145,000 MT (2032)

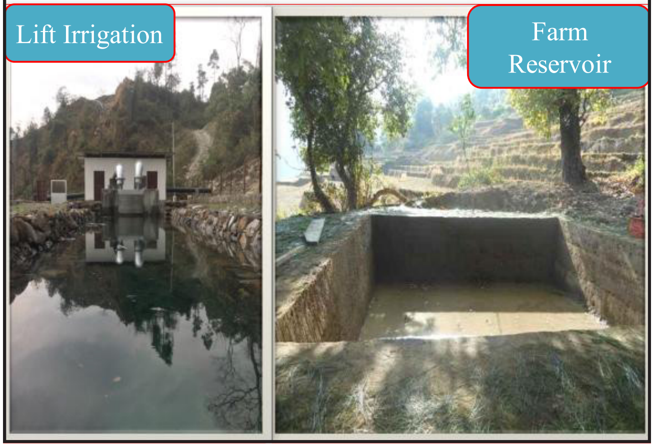
▶ To Achieve Food Self Sufficiency (Paddy) from 51% (2014) to 75% (2032)

Technology Intervention

- Pressurized/Conduit/Pipe Irrigation
- Lift/Pump Irrigation
- Micro Irrigation
- ✓ Drip Irrigation
- ✓ Sprinkle Irrigation
- Farm Reservoir
- Groundwater Exploration

Contd…

Contd…



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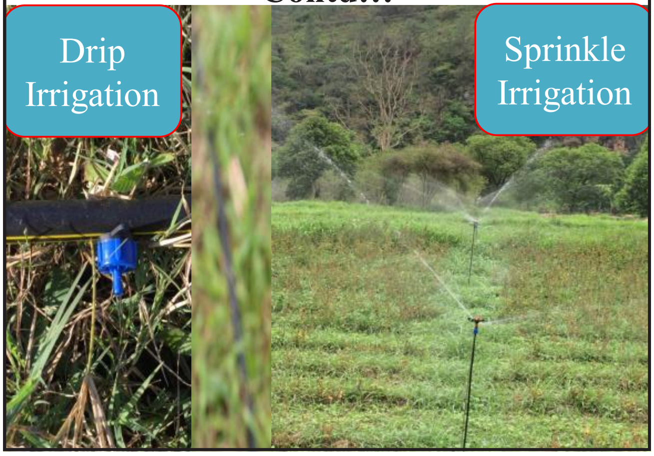


Challenges/Issues

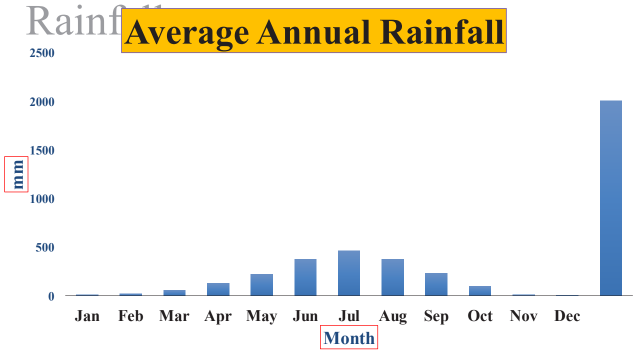
- Mountainous Terrain;
  - ✓ Insufficient suitable land for agriculture development
  - ✓ Most agriculture land are located at higher elevation than the water source
  - ✓ Soil in most area at foot hills are very porous

Contd…

- Large Variation in Discharge in the Streams & Rivers;
  - ✓ Limited perennial water resources
  - ✓ Unpredictable discharge at sources
  - ✓ High drainage density demanding a large number of structures consequently making irrigation inversion more expensive

Contd…

- Temporal & Spatial Variation of Rainf



Contd…

Contd…

- Limitation of Present Structure;
  - ✓ Limited number of manpower involved in the field of irrigation development.
  - ✓ The engineers working at the field level lack proper knowledge on irrigation system design and water management.
  - ✓ Farming is not considered a respected profession by the society. Hence attraction towards the profession is not high for the young generation.

A Way Forward

- Strengthening Staffs.
- Encourage R & D on Water Resources.
- Boring/ Tunnelling in Southern Dzongkhags.
- Develop High Efficiency Irrigation System.
- Upscale Lift Irrigation in Southern Dzongkhags (Solar/Electricity).
- Explore Groundwater.
- Land Development!!!

"Thank You"

"Water for Community and Its Livelihood"

kinlaydorji@gmail.com

Outline

- Our Donors
- Introduction
- Vision
- Objectives
- Our Services
- Conservation Mandates
- Organogram
- Our Strength
- Challenges

OUR DONORS

Introduction:

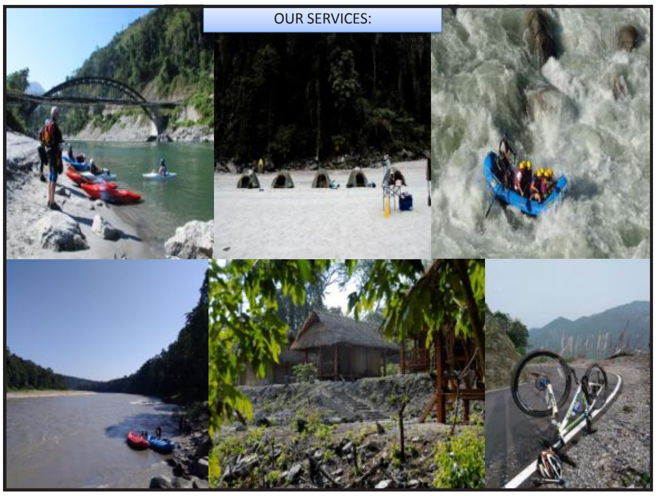
- 1ST Community Based ecotourism Company.
- Group venture business.
- Formed by School dropout youths.
- Established on 22/11/2012
- Initially started as Rafting company.

Our Vision

"TO BE THE PREMIER ECOTOURISM SERVICE PROVIDER IN THE COMMUNITY AND BEYOND"

OUR OBJECTIVES

- To promote ecotourism in the region.
- Promote swap means of livelihood to develop the local economy.
- To create employment opportunities in the community level.
- To ease the rural-urban migration problem.
- Work for the preservation of the rich biodiversity under the corridor of Royal Manas National Park.



Our Conservation Mandates

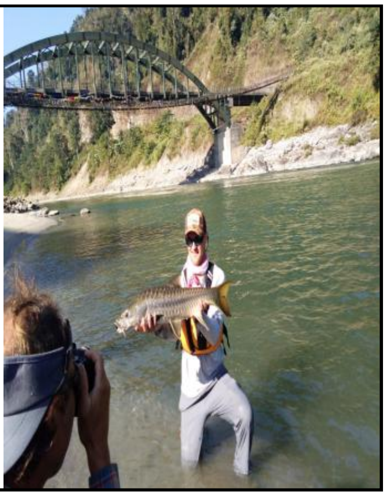
- Leave no Trace.
- Patrolling the Rivers.
- Adoption of creek rivers.
- Community Waste management.
- Conservation fee to Park.
- Community Initiative.
- Advocacy program

Organogram

- General Manager
  - Sales & Promotion
  - Operation
  - Resource
  - Finance

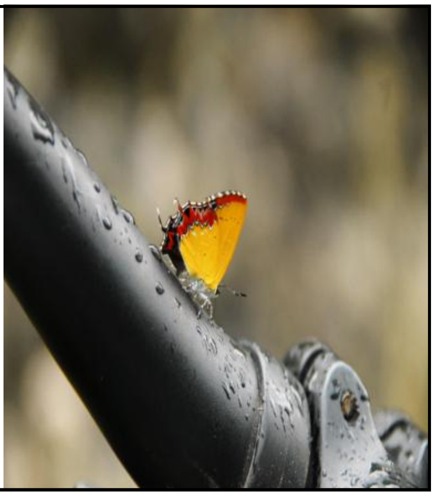
Our Strength

- We are professionally trained.
- Being under the buffer zone of RMNP.
- Free technical support from associated organization.



Challenges

- Not having Immigration office.
- Lack of Ecotourism Initiatives from Park.
- Impact of Climate Change.



Tarayana Foundation

Climate Resilient Water Harvesting

Water scarcity in rural communities

Water storage in rural villages

Water sources

Consultations with community & Govt. stakeholders

Baseline surveys (570 households)

Resource mapping

Water user committees formed

Plantation for slope stabilization

Plantation of water friendly plants

Removal of alien vegetation

Construction of check dams

Water source cleaning

Protection of water sources

Construction of reservoir tanks

Installation of rooftop water harvesting

Underground pipeline installed and restoration of water posts

Training in bamboo water filtration

Training in forest fire prevention and control

Training in plumbing

Learnings

- Strong community engagement has shown positive spin-offs such as:
- increased school attendance for kids
- reduced drop-out rates of girls
- improved health status
- reduced drudgery for women
- increased collective aspirations
- co-benefits in job creation
- additional days of labor/livelihoods support

Climate Resilient Water Harvesting

Sl.no	Dzongkhag	No. of reservoir tanks constructed	No. of Water User Committees formed	No. of rainwater harvesting tanks installed	No. of household beneficiaries
1.	Samtse	9	7	12	247
2.	Mongar	20	9	54	383
3.	Pemagatshel	4	8	12	198
4.	Tsirang	3	7	31	268
	Total	**36**	**31**	**109**	**1,096**

Service from the Heart

Thank you

Session 5: Water, Energy and Economy
Chair: Ms. Dechen Yangden, Ministry of Works and Human Settlement

Session 5: Water, Energy and Economy		
1430	Hydropower development in Bhutan	Mr. Passang, DHPS
1450	Hydropower energy	Mr. Pema Dorji, DGPC
1510	The Economics of Ecosystem and Biodiversity (TEEB) study in Bhutan	Mr. Sangay Wangchuk, UWICER
1530	**Tea Break**	
1600	Natural capital valuation in Chamkhar chhu sub-basin	Mrs. Nagdrel Lhamo, WWF-Bhutan
1620	Bhutan water risk scenarios and opportunities	Mrs. Sonam Choden, WWF-Bhutan
1640	Issues, challenges and opportunities of water supply system: Mawongpa Water Solutions	Mr. Sonam Dorji, Mawongpa Water Solutions
1700	Q&A Session	
	End of Day 2	

Outline

- Why Hydropower
- Projects under operation
- Hydropower Development Status
- Significance of Hydropower
- Opportunities & Challenges

His Majesty 's Address during 106th National Day Dec 17, 2013

"Hydropower is considered as the nation's most precious resource that belongs to all the people. Our focus has been to establish as many hydropower projects as possible, to generate enough revenue to become self-reliant"

Why Hydropower

The Government has declared Hydropower as the *"First Jewel"* amongst the "*Five Economic Jewels*"

Hydropower has two fundamental roles to play :

- It shall drive the economy of Bhutan by providing safe, reliable, affordable and abundant electricity to improve the lives of all Bhutanese and drive industrial growth.
- Surplus power shall be exported to enhance government revenue and achieve positive balance of payment.

Why Hydropower- Natures Gift

The steep and rugged Himalayan topography and swift rivers promise huge hydropower potential

- 30,000 MW potential
- 22,280 MW (71 sites of >10 MW) techno-economic potential as per PSMP 2003-2022

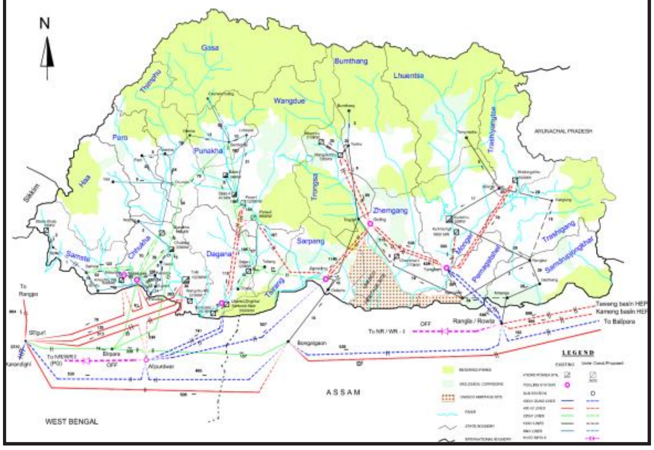
Huge Potential

SN	Basin	No of Projects	Capacity (MW/MU)
1	Basin-I	15	3463/20783
2	Basin-II	18	8118/25832
3	Basin-III	38	10699/52544
4	**Total**	**71**	**22280/91849**

Integration with Indian Grid

- ✓ Access to Indian power market
- ✓ Existing Transmission lines (HT) – 6,620 km
- ✓ 6 export transmission lines with 2,500MW capacity

Integration with Indian Grid (NTGMP)



Projects under Operation

Sl. #	Power Plant	IC (MW)	COD	Bilateral Assistance	Financing Mode
1	Chhukha	336	1986-88	GoI	60% Grant & 40% Loan at 5% interest rate
2	Kurichhu	60	2001-02	GoI	60% Grant & 40% Loan at 10.75% interest rate
3	Basochhu-I	24	2001	Austria	38% Grant & 49% interest free Loan and rest by RGoB
4	Basochhu-II	40	2005	Austria	Full Loan at 2.786% interest rate
5	Tala	1,020	2006-07	GoI	60% Grant and 40% Loan at 9% interest rate
6	Dagachhu	126	2015	DGPC/NPPF/ TATA Power	PPP
	TOTAL	**1,606**	**6.76% of the total Techno-economic potential**		

Projects under development

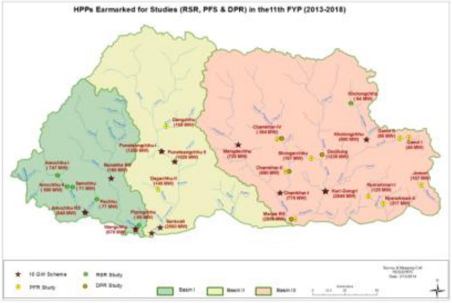
Sl. #	Project	IC (MW)	Implementation Model
1	Punatsangchhu-I	1,200	IG
2	Mangdechhu	720	IG
3	Punatsangchhu-II	1,020	IG
4	Kholongchhu	600	JV
5	Nikachhu	118	PPP (DGPC +)
	Total	**3,658 (15%)**	

Diversion Tunnel- Inlet end (PHPA-I)

Surge Shaft (PHPA-II)

Surge Shaft (MHPA)

11th FYP activities



Planning & investigation

1. RSR
2. PFS
3. DPR

1. Under Reconnaissance Studies – 7 projects
2. Under PFS – 9 projects
3. Under DPR – 4,902MW (~18%: 2,640MW Kuri-Gongri, 1,125MW Dorjilung, 410MW (125/285MW) Nyera Amari-I&II (Integrated)
4. Under construction – 3,658MW (>15%: 5 projects) to be commissioned from 2018-2022

Significance of Hydropower

- Clean and renewable energy
- Fuels the growth of Industries and Private sector.
- Earnings from this sector ploughed into the social sector.
- Hydropower is key to achieving economic self-reliance and prosperity
- Important for balancing trade
- Generates employment during construction and O&M.
- Infrastructure development like roads, bridges, schools, hospitals, township, etc.

14

Commissioning of Chukha in 1986/87 – RGoB able to finance current expenditure with revenue from the sale of Chhukha power to India and enabled industrial growth

Pasakha Industrial Estate, Phuentsholing

Penden Cement at Gomtu, Samtse

60 MW Kurichhu commissioned in April 2006

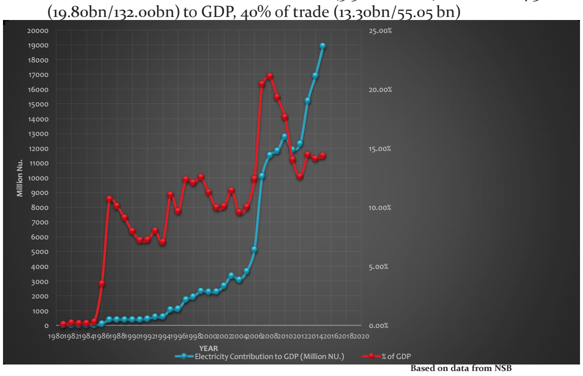
Ushered balanced regional development
(electricity supply to 10 eastern Dzongkhags)
Industrial growth in east

Upstream view of Kurichhu Dam

Hydropower Significance ... Contd.

Benefits

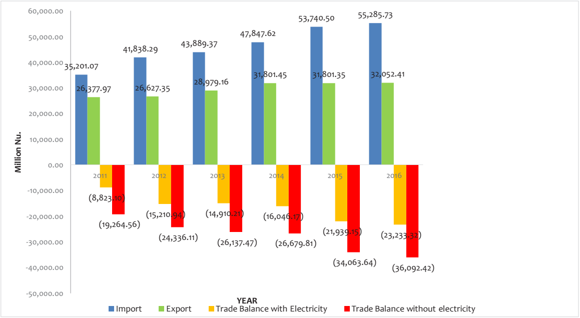
- Contribution of 20% of national revenue (5.5bn/28.8bn) and about 14.30% (19.80bn/132.00bn) to GDP, 40% of trade (13.30bn/55.05 bn)



Based on data from NSB

Hydropower Significance ... Contd.

Trade balance:
In 2016, trade imbalance with India is around Nu. 23.23 bn (around 36.00 bn without electricity)



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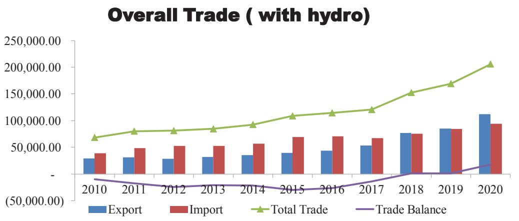
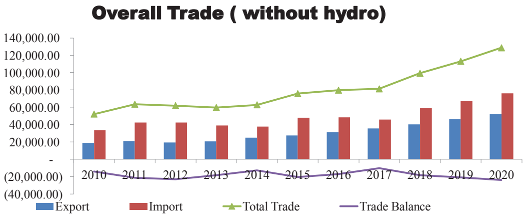
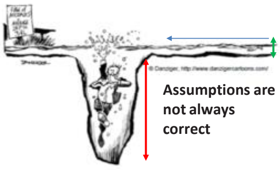
Based on trade statistics from DoT, MoEA





Challenges

1. **General**
   - ✓ Young and fragile Himalayan geology, rugged topography, high seismic zone (Zone-V)
   - ✓ High transportation costs due to mountainous terrain and limited connectivity
   - ✓ Impact of climate change on flow regime (glacier retreat, unpredictable monsoon) and Natural Calamities (GLOF, Flash Floods, etc.)
   - ✓ Sedimentation (high head power plant, high quartz content, etc.)
   - ✓ Lack of well developed private sector to provide services and goods



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Challenges

2. **Lean season deficit**

- Firm power of 315MW (production from 5 projects during lean months)
- Peak demand touched 363.50MW
- Affords to enhance lean season availability
- Currently imports from India during lean months

21

Challenges

3. Institutional Capacity of Energy Sector and related Agencies (DPR studies, review of DPRs – cost escalations in projects, etc.)
4. Limited contractors and experienced manpower
5. Limited domestic capacity, Investment size of projects
6. Limited domestic market for electricity
7. Absorptive capacity

22

Future Plans

- Updating of the Power System Master Plan 2003
- Undertake DPR, PFR and Reconnaissance studies
- Building in-house capacity
- Involvement of private and corporate sector in hydropower construction (e.g. CDCL)

23

Tashi Delek !

HYDROPOWER SECTOR

Druk Green Power Corporation Ltd.

2nd Bhutan Water Seminar
(Water – Securing Bhutan's Future)
May 10-12, 2017, Thimphu

Pema Dorji
Email: p.dorji1869@drukgreen.bt

Contents

- Hydropower & Bhutan
- Druk Green Profile
- Plants under operation
- Subsidiary companies
- Other Projects
- Challenges & Issues
- Being Green Initiatives

26

Hydropower in Bhutan

- Potential estimated at 30,000 MW;
  - 23,760 MW is techno-economically feasible.
  - Only over 5% harnessed ~ **1,614 MW**.
- Contributes over **23.2%** of government revenue and **14.15%** of GDP to RGoB.
- Embarked on a mission to achieve **10,000 MW by 2020** in co-operation with the Government of India.
- DGPC was formed to play a key role in this sector for **accelerated development** of the hydropower sector in Bhutan;

27

Druk Green Profile

- Incorporated on **January 1, 2008** through the amalgamation of the erstwhile Chhukha, Kurichhu and Basochhu Hydropower Corporations. Tala was taken over in April 2009;
- **Vision:** ***"promote, develop and manage renewable energy projects, particularly hydropower, in an efficient, responsible and sustainable manner, and to maximize wealth and revenue of the nation".***
- While Druk Green operates and maintains huge hydropower assets, its other key mandate is **to promote and develop new hydropower stations**.

Visit: www.drukgreen.bt

28

Mission Statements:

- ***Effectively and efficiently manage* hydropower plants**, and maximize returns;
- Take a ***lead role* in accelerating hydropower** development in the Kingdom by developing new hydropower projects independently, through joint ventures or through any other arrangements with domestic and international partners;
- ***Provide energy security*** for domestic consumption, fuel economic growth, and also explore other forms of renewable energy other than hydropower;
- ***Build capacity* in hydropower development and management** and**;**
- Be a ***responsible, proactive and progressive company*** with highly motivated professionals.

29

Plants under Operation

336 MW Chukha Hydropower Plant

1020 MW Tala Hydropower Plant

24+40 MW Basochhu Hydropower Plant

60 MW Kurichhu Hydropower Plant

30

Chukha Hydropower Plant

- Conceived in the early 1960s (by the 3rd King and spearheaded by 4th King)
- Agreement for implementation between Bhutan and India on **March 23, 1974;**
- The project's first 84 MW hydro-turbine Unit was commissioned on **September 7, 1986** and by **August 22, 1988** all the other three Units were commissioned.

- **Salient Features:**
- Installed Capacity: 336 MW (84*4 Units);
- Project Cost: Nu. 2,465 mi;
- 1,774 GWh or MU;
- 40 m high dam, 2 intake gates, 6.5 km HRT;
- Underground Powerhouse;
- **Diverted Tichhalunchhu** to reservior (right) & Lubichhu to Surge Shaft to gain additional **67 GWh** during the mean seasons.

31

Tala Hydropower Plant

- The Agreement for the implementation of the Tala Hydroelectric Project was signed by the two Governments on **March 5, 1996.**
  - The main works of the Project started in early 1999.
- First unit of the Project was commissioned on **July 31, 2006**, and the last unit was added on the bar on **March 30, 2007.**

- **Features:** Located downstream of CHP with 1020 MW, (6*170 Units);
- Project Completion Cost: Nu. 41,258 million;
- **23 km HRT** – one of the longest of its kind in this part of the world;
- Generation: 3,962 GWh;
- Tsibjalumchhu Diversion Scheme adds **93 GWh** additional energy (constructed at Nu. 280 million).

32

Basochhu Hydropower Plant

- The Basochhu/Rurichu Rivers were identified in the mid 1970s by hydropower engineers as a potential source of energy production in the medium-size range.
- In **1993 and 1994, a team of Austrian Engineers** carried out the preliminary design of the project.
- On ***April 14, 1995, the Financing Agreement was signed*** between the Royal Government of Bhutan and the Government of Austria.

- **Features:** 64 MW (24 MW Upper Stage + 40 MW Lower Stage – commissioned in **2001 & 2004** respectively) under Wangduephodrang;
- Project Cost: Nu. 3,261 million (financed by Government of Austria & RGoB);
- **Upper Stage:** 2.6 km HRT, 1.4 km penstock, 12 MW * 2 Units, with annual generation of 106 GWh.
- **Lower Stage:** Water available through a pondage scheme from upper stage delivered via 2.53 km penstock; Surface PH (2*20 MW); Mean annual generation - **186 GWh**

33

Kurichhu Hydropower Plant

- **Features:** 60 MW (15*4), at Gyelopzhing, Mongar in the East;
- Construction started in ***1998*** & first unit, 15 MW commissioned in April, **2001**. Rest 3 units were commissioned by **May 2002**;
- Project Completion Cost: Nu. 5,600 million;
- Has **55 m concrete** gravity dam, 282.5 m crest length;
- Mean annual generation: 400 GWh;
- Has ***Fish Ladder*** for migration of fish.

- The Kurichhu Hydropower Plant was formally inaugurated by HRH Trongsa Poenlop Jigme Khesar Namgyel Wangchuck and H.E Shri Sudhir Vyas, Ambassador of India to Bhutan, on **April 26, 2006.**

34

Subsidiary Companies

- **BHSL** - At Jigmeling, Gelephu;
- Is a **JV between Druk Green (51%) & ALSTOM , France (49%);**
- Operation commenced since **October 2014** – repair & reclamation of hydro runners and allied underwater components;
- Project Establishment Cost: Nu. 1,137 million;

- **DHPC - 126 MW** in south-western part of Dagana;
- Commissioned in March 2015;
- Designed for annual mean generation of **515 GWh**;
- First Public-Private-Partnership venture in hydropower sector;
  - **DGPC – 59%,** Tata Power Company – 26% and NPPF – 15%;
- Was financed by ADB, RZB, Austria & RGoB (total estimated cost – Nu. 12,227 million);
- Is the ***first Trans-boundary CDM Project in the world***;

- **THyE – fully DGPC owned** subsidiary company since **April 2014;**
- Manages **118 MW Nikachhu Hydropower Project** in Trongsa under construction;
- Estimated Project Cost: Nu. **11.96 million**.

ADB is the lead financer USD 120.5 million committed), with additional financing from SBI & EXIM Bank, India (INR 2.5 billion & 1.03 billion respectively);

- Currently: Completed infrastructure works; main works under progress (dam, PH, etc);

- **KHEL** -600 MW, under Trashiyangtse Dzongkhag;
- First SPV to be established amongst 4 JV Projects:
  - Undertaking between DGPC & SJVNL, India (50% holding each);
- Infrastructure works undergoing since June 2015;

35

DrukGreen

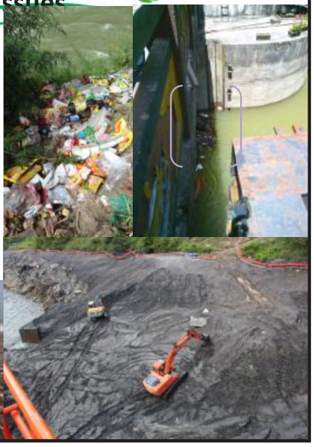
❑ Druk Green Projects

Under Investigation (DPRs/PFSs)		
3	Dorjilung DPR completed	1,125 MW
4	Nyera Amari (1+2) DPR	442 MW
5	Druk Bindu DPR	18+8 MW
6	Gamri (1+2) PFR	45+85 MW
	Total	**1,717 MW**

36

Challenges & Issues

- Addressing ***Environmental and Social*** Concerns
  - *E-flow & Fish ladder debates;*
- ***Low flow*** during lean seasons – diversion of streams into existing plants;
- ***Waste*** into rivers & water bodies – high maintenance costs;
- ***Sedimentation issues*** - reduction of reservoir capacity and machine life;



INITIATIVES

Avenues for institutional collaboration!

38

CO employees in action – Cleaning of Chubachhu

Segregation of Wastes

Separate bins for separate wastes in Druk Green Premises

Also, contribution to schools in Thimphu

Race against Waste (Price Award Day: 8th December, 2013)

Price Award Day graced by Hon'able Prime Minister of Bhutan & Minister for Agriculture & Forests

Also, DGPC Board Directors

Druk Green's *Being Green* Booth, Clock Tower - Thimphu

Participation in BES Fair

Sensitization Programs

- Publication and broadcast of advocacy messages in media, book covers;
- Awareness at larger scale and greater audience;
  - Video and Radio broadcasts in BBS;

Themes

- ✓ River Catchment Protection;
  - ✓ Plantations;
- ✓ Waste Management;
- ✓ Hydropower and Revenue Generation;

✓ Plantations/collaboration;

Pamphlets

THANK YOU LA

The Economics of Ecosystems and Biodiversity

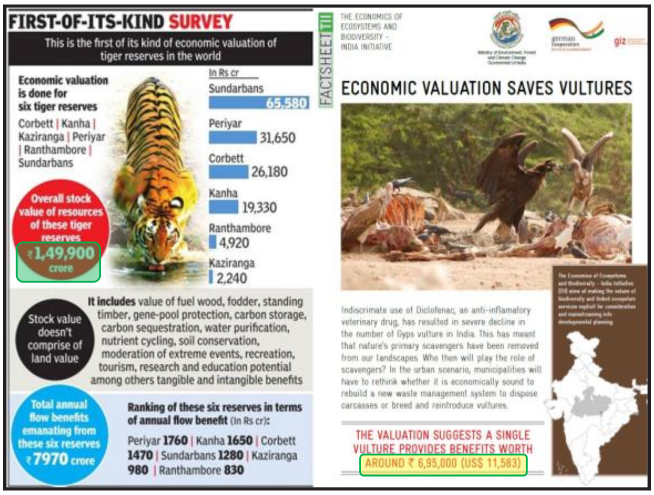
[TEEB – Bhutan]

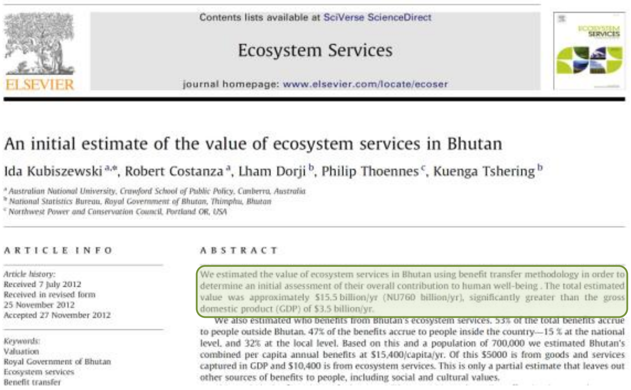
www.uwice.gov.bt

TEEB is an international initiative that provides evidence of economic and social benefits of ecosystem services and biodiversity, consequently, highlighting the tremendous costs of their loss and degradation.

TEEB was initiated in 2007 at the G8+5 meeting in Potsdam, Germany, where Environment Ministers from eight developed countries (G8) and five developing countries (Brazil, China, India, Mexico and South Africa) called for a study to analyse the global economic benefits of biodiversity, costs of biodiversity loss, and costs of failing to take protective measures versus conservation.

As a result, four reports were released over 2008 – 2012, targeting various audiences – national and international policymakers, local and regional policy makers, businesses, and academia The reports build conceptual arguments for valuing nature, and also synthesize practical experience of doing so for each of these actors. The reports have been instrumental in highlighting the tremendous loss of natural capital in recent times.





Contents lists available at SciVerse ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

An initial estimate of the value of ecosystem services in Bhutan

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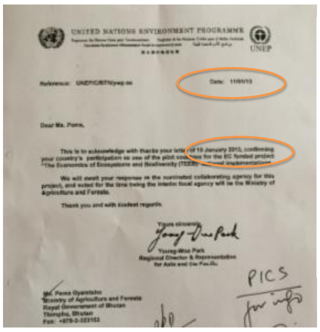
ABSTRACT

We estimated the value of ecosystem services in Bhutan using benefit transfer methodology in order to determine an initial assessment of their overall contribution to human well-being . The total estimated value was approximately $15.5 billion/yr (NU760 billion/yr), significantly greater than the gross domestic product (GDP) of $3.5 billion/yr.

We also estimated who benefits from Bhutan's ecosystem services. 53% of the total benefits accrue to people outside Bhutan. 47% of the benefits accrue to people inside the country—15 % at the national level, and 32% at the local level. Based on this and a population of 700,000 we estimated Bhutan's combined per capita annual benefits at $15,400/capita/yr. Of this $5000 is from goods and services captured in GDP and $10,400 is from ecosystem services. This is only a partial estimate that leaves out other sources of benefits to people, including social and cultural values.

TEEB- Country Studies

- Bhutan
- Equador
- Liberia
- Philippines
- Tanzania



UNEP

The Economics of Ecosystems and Biodiversity (TEEB)
National Scoping Workshop for Bhutan

WORKSHOP REPORT

10 – 13 March, 2014
Thimphu, Bhutan

TEEB- Bhutan

- Assess changes in ES under different hydropower diversification scenarios

  Each Scenario would seek to achieve RGoB's goal for 2020

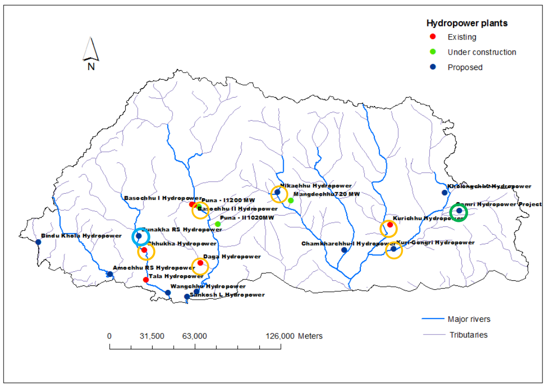
- Inform:

1. Sustainable Hydropower Development Policy 2008
2. Alternative Renewable Energy Policy 2013

Policies call for diversification of energy sources and sustainable expansion in hydropower capacity

Box 1: Ecosystem Services affected by proposed hydropower development in Bhutan

1. *Provision of food/fuel wood* – Hydropower development may change land-use in the surrounding areas. Both dam related infrastructure and transmission infrastructure are likely to lead to encroachment of agricultural/forest land that may provide food (e.g. areas used for collection of Non Timber Forest Products)
2. *Provision of medicinal resources* – Site specific and examined if applicable.
3. *Provision of raw materials* – Raw materials required to construct production facilities and distribution networks
4. *Provision of fresh water (quality and quantity)* – Any changes in fresh water provisioning to downstream communities due to dam construction – both from upstream deforestation, and from damming the rivers would be assessed. Furthermore, changes in land-use in the surrounding areas (habitat conversion and land degradation), may lead to changes in water availability which may in turn affect hydropower operations
5. *Habitat for species*– Changes in riverine ecosystems, assessed in part based on base flow ecological requirements and fluvial transport
6. *Regulation of local climate and air quality* – Air quality may be negatively affected during the construction phase of hydropower development, whereas and the energy mix at the household level may move away from fuel wood consumption and lead to positive gains in local air quality
7. *Regulation of carbon sequestration and storage* – Emissions from reservoirs (methane), emissions from deforestation due to land use change, and emissions reduction due to a move away from fuel wood consumption to hydro-electricity
8. *Regulation of extreme events* – The reduction in forested area (due to construction and transmission related infrastructure) may lead to destabilization of sediments and lead to higher incidences of flash floods etc.
9. *Regulation of soil erosion and soil fertility* – Forest degradation leading to soil erosion which affects communities and power companies
10. *Pollination* – Site specific and examined if applicable
11. *Biological control* – Predators are particularly important to control agricultural pests like wild boars and other herbivores (a common human –wildlife conflict). Changes in the size of their population might impact agricultural productivity.
12. *Habitats for species* – Endemism is high in Bhutan. Endemic species in Bhutan are listed under the Forest Nature Conservation Act. Any hydropower facilities need to undertake EIA, which addresses the protection of endemic species. While the EIA process may minimize direct impacts on key species, land fragmentation impacts on migratory species.
13. *Maintenance of genetic diversity* – Wild crop varieties, animals and aquatic diversity might be impacted on through hydropower development (such as effects on biological corridors) interference, with potentially irreversibility.
14. *Recreation and tourism* – Site specific and examined if applicable.
15. *Aesthetic appreciation and inspiration for culture, and spiritual experience* – Particularly important in the Bhutanese context.



Scenario

Business As Usual

Dam Construction

Dam Construction and Conservation Interventions

TEEB –Bhutan - assess changes in ecosystem services provisioning (with a focus on watershed services from forests) arising from the construction of five hydropower plants.

There are three main technical components to the TEEB assessments in Bhutan:

1. Spatial models at the watershed level are used to understand how land use changes due to hydropower development relate to environmental changes downstream.
2. Spatial models are used to understand how upstream land use changes impact the quality of water delivered to hydropower stations.
3. This spatial analysis is linked to a systems model that includes social and economic variables to ensure that relationships between hydropower and socio-economic development are also captured.

TEEB study recommends instruments, such as Payments for Ecosystem Services (PES) and royalty fee change to ensure benefits sharing with communities and mitigation of the loss of ecosystem services.

Biophysical Models

Scenario Generator Proximity Based

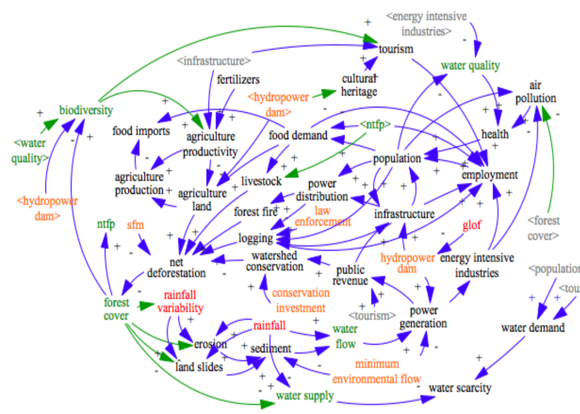
Habitat Quality

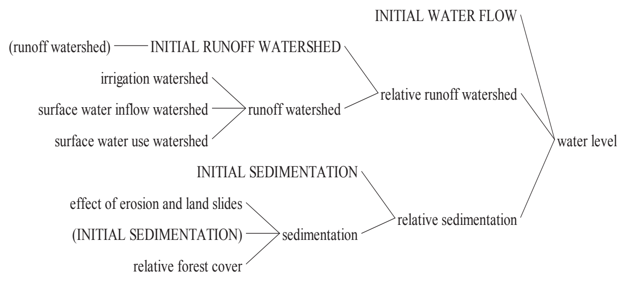
Water Yield Model

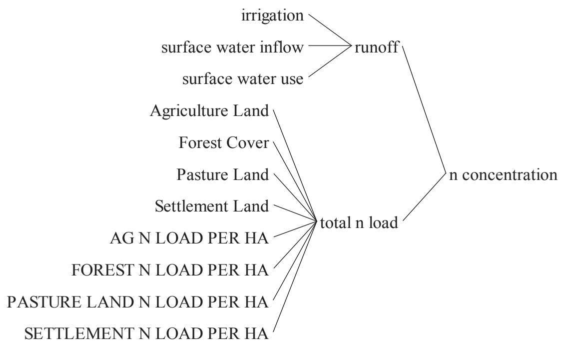
Carbon Model

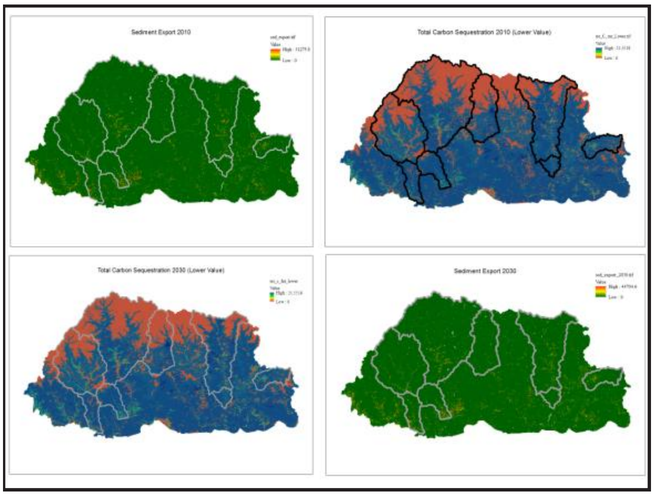
Sediment Delivery Ratio

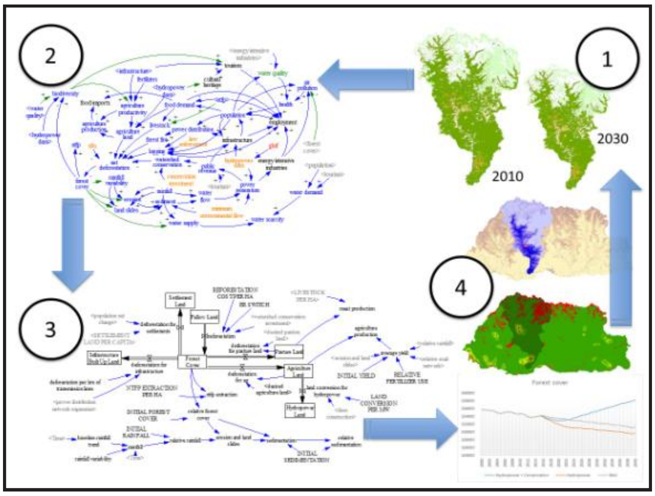
Nutrient Delivery Ratio





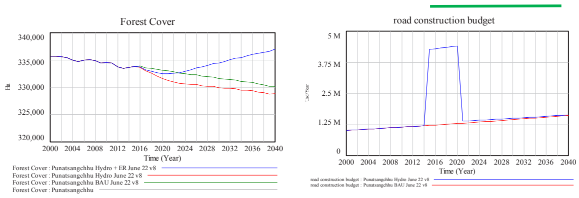






Ecosystem Services [Results]

- Bio-physical Changes projection for 2030 for the scenarios
  - BAU
  - Hydropower Construction
  - Hydropower Construction with Ecosystem Services
- Value of ES projection for the scenarios [By How Much]



ES	Estimation			Biophysical change (2010-2030): BAU	Hydro vs BAU	ES vs BAU	Economic value per unit	Economic valuation (year 2030)		Comments
	InVEST	SD	Benefit transfer					Hydro vs BAU	ES vs BAU	
Provision of food		X		1,319 ton	-76	-80	739.86 US$/ton	-$421,692	-$424,088	Systemic approach, with endogenous changes to population and land use
					1,159	1,151		$814,442	$808,675	Sectoral approach with no change to land use, only yield
Provision of freshwater (quality) - nitrogen		X		0.0410 mg/l	-1.96%	-1.92%	-	Below health threshold	Below health threshold	Assumes that all the land-related N loadings take place in 20% of the area (concerning the estimation of concentration)
Provision of freshwater (quality) - phosphorus		X		0.0435 mg/l	-3.69%	-3.67%	-	Below health threshold	Below health threshold	Assumes that all the land-related N loadings take place in 20% of the area (concerning the estimation of concentration)
Habitat for species			X	802 ha	-26	590	5,192 US$/Ha	-$133,045	$3,065,470	Economic value per unit obtained from Kubiszewski et al. (2010)
		X		91,633 persons	-3,535	-3,511	576 US$/person	-$2,036,106	-$2,022,201	Assumes that a reduction in habitat quality has a proportional impact on tourism visits (it could also be assumed that expenditure per visit might change)
Regulation of carbon sequestration and storage	X	X		-2,211,105 ton	-81,350	154,884	43 US$/ton	-$3,498,050	$6,660,012	Upper values of carbon coefficients from IPCC Report 2006
	X	X		-123,059 ton	-2,292	52,794	43 US$/ton	-$98,556	$2,270,142	Lower values of carbon coefficients from IPCC Report 2006
Genetic resources			X	802 ha	-26	590	19 $US/ha/year	-$487	$11,218	Economic value per unit for temperate forest obtained from Kubiszewski et al. (2010)
Timber			X	802 ha	-26	590	44 $US/ha/year	-$1,128	$25,979	Economic value per unit for temperate forest obtained from Kubiszewski et al. (2010)
Biological control			X	406 ha	-164	-163	28 $US/ha/year	-$4,599	-$4,566	Economic value per unit for cropland obtained from Kubiszewski et al. (2010)
			X	802 ha	-26	590	9 $US/ha/year	-$231	$5,314	Economic value per unit for temperate forest obtained from Kubiszewski et al. (2010)
Pollination			X	406 ha	-164	-163	19 $US/ha/year	-$3,121	-$3,099	Economic value per unit for cropland obtained from Kubiszewski et al. (2010)
			X	802 ha	-26	590	376 $US/ha/year	-$9,635	$221,999	Economic value per unit for temperate forest obtained from Kubiszewski et al. (2010)

[Possible 'Recommendations']

- Land use type practices up-stream
- Institution of PES to up-stream land users
- Scale of hydro-power project and influence on ES

Tashi Delek

UNEP

European Commission

Bhutan context

- Rich natural capital with very less information on the ecosystem services it provides
- Environment is one of the 4 pillars and 9 domains in the GNH framework
- Ecosystem services valuation as an integral input to the efforts to start a system of GNH accounting which can support policy analysis and actions that can guide progress towards achieving GNH
- An initial study has estimated the value of Bhutan's Ecosystem Services to be worth US$ 15.5 billion per year. (Kubiszewski et al, 2013).

InVEST- Integrated Valuation of Ecosystem Services and Tradeoffs

- InVEST is designed to inform decisions about natural resource management
- Information on how changes in ecosystems are likely to lead to changes in the flows of benefits to people
- InVEST models show how these alternative futures influence ecosystem processes, and how such changes affect biodiversity and the flows and values of ecosystem services
- The general approach combines ecological production functions with economic valuation approaches (such as market valuation, avoided costs, and production economics).

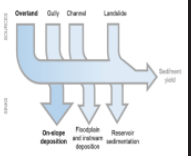
Model outputs can inform decisions on:
- Payments for Ecosystem Services (PES) mechanisms,
- Developing management plans for watersheds
- Developing spatial plans to enhance sustainable development and also in
- Climate adaptation strategies by showing how future changes in climate patterns will influence the delivery of services that affect human well-being.

InVEST

- Himachal Pradesh :PES program around ecosystem services that support hydropower production to address sedimentation issues with activities aimed at improving the condition of watersheds by implementing soil and water conservation practices.
- Latin America: Water funds similar to PES, but targeted for watershed management to gather investments for conservation activities
- Myanmar and Mozambique: conducting the Natural Capital valuation for the whole country to take stock of their natural resources. Myanmar using information for development of green economy approach
- Indonesia and Mozambique: Spatial planning for some of their critical landscapes to protect key species and landscapes and for watershed protection

The SDR (Sediment Delivery Ratio) model

- Understanding where the sediments are produced and delivered allows mangers to design improved strategies for reducing sediment loads.
- Changes in sediment load can have impacts on downstream irrigation, water treatment, recreation and reservoir performance
- SDR is based on the Universal Soil Loss Equation (USLE), which is a standard method for estimating the amount of erosion generated by the landscape; and the Sediment Delivery Ratio (SDR), which estimates how much of that generated erosion is likely to enter the stream, instead of being retained by the landscape
- The outputs from the sediment model include the sediment load delivered to the stream at an annual time scale (**sediment export**), as well as the amount of sediment eroded in the catchment and retained by vegetation and topographic features (**sediment retention**.)



Significance of modeling Sediment/Erosion

Mass wasting due to natural processes

Land slips caused by roads across steep hillslopes

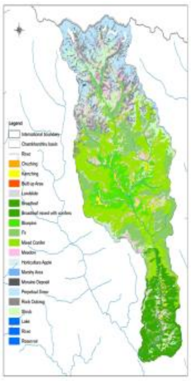
Growing evidence of land degradation in Bhutan

Sustainable land management practices (NSSC, 2015).

Objectives of the study

1. Study the extent of sediment retention services that the different land cover types in the ChamKhar chhu Basin can offer.
2. Plan interventions such as soil and water conservation programs around the areas which shows high sedimentation
3. Contribute towards design and plan of a PES model.
4. Demonstrate the kind of study and results that can be expected from an InVEST model for use in conservation related activities in priority areas.
5. Develop capacity in of the government as well as in WWF on ecosystem service valuation.

Study Area: Chamkharchhu Sub Basin



Hydropower plans in Chamkharchhu sub basin (Source: DGPC, 2015)

Sl.	Project	Installed Capacity (MW)	Annual Energy (MU)	Tariff (Nu/kWh)	Annual Revenue (Nu. Millions)	Remarks
1	**Chamkharchhu-I**	**770**	**3344**	**4.78**	**15,984.32**	**DPR completed**
2	Chamkharchhu-II	590	2420.28	3.87	9,366.48	PFR completed
3	Chamkharchhu-III	1217	4727.05	4.77	22,548.04	Desktop study
4	Chamkharchhu-IV	364	1491.87	4.65	6,937.20	PFR completed
5	Chamkharchhu-V	97	423	4.43	1,875.30	Desktop study
6	Gumthang	108	520	4.43	2305.33	Desktop study
7	Gizamchhu	53	241	4.43	1,068.43	Desktop study
	Total				60,085.10	

PES WITH HYDRO

- Study shows that sediment flowing into rivers that feed hydropower projects could be cut roughly in half (44) by performing specific conservation activities in targeted areas upstream.
- Hydropower sector accounts for more than 20 percent of government revenue and has the potential to grow.(target of 10,000 MW by 2020)
- Most of the hydropower plants designed as a run-of-river system- vulnerable to high sediment concentrations.
- Certain problems of sedimentation can be addressed through investment in conservation activities up stream such as watershed management, sustainable land use practices etc.

Tools & Data

Tools:

- InVEST version 3.1.3
- ArcGIS 10.3
- ArcHydro Tools

Data:

- LULC – current Landcover (LCMP, 2010) & future scenarios
- DEM – 30 meter ASTER
- Erosivity & Erodibility
- Biophysical parameters

InVEST Sediment delivery ratio (SDR) model data requirements

Data	Description	Source
DEM	Digital Elevation model, with elevation values across the area of interest.	ASTER GDEM v2 was used.
Rainfall erosivity	A measure of the intensity of rainfall, such that stronger rains produce more erosion.	Erosivity(R) was derived using Worldclim current climate precipitation data (Hijmans et al, 2005). Roose's method (R=Average total annual rainfall x 0.5) was used as given in (FAO, 1996).
Soil erodibility	Soil property indicating how easily each soil type detaches and becomes erosion.	Available ISRIC 1km resolution dataset was used.
Land use land cover map	Location of different land uses and land covers in the area of interest.	National Land cover map of 2010 was used (NSSC, 2010).
Watersheds	Basin that contributes to a point of interest where water quality will be analysed.	Watersheds were delineated including the location of proposed Chamkharchhu-1 dam and Kurjey Sediment sampling station.
Biophysical table	Parameters required for the USLE corresponding to each of the land use classes.	Values were mapped using values from WAVES Study on "Managing Catchments for Hydropower Services", 2015.

SDR Outputs

- Generating proof-of-concept for how InVEST can model changes in the ecosystem
- Understanding where erosion is being generated in the watershed to help target restoration programs that can reduce erosion at its source. (Restoration)
- Knowing where existing vegetation is playing a role in retaining sediment in place, and keeping it from eroding, (Conservation)

Two scenarios
Restoration scenario: improvements are made to the areas in the watershed that generate high levels of sediment which flow downstream

Degradation scenario- areas currently providing high levels of sedimentation service upstream are allowed to degrade

SDR Modelling Results

Top 3 sediment exporting land-cover types.

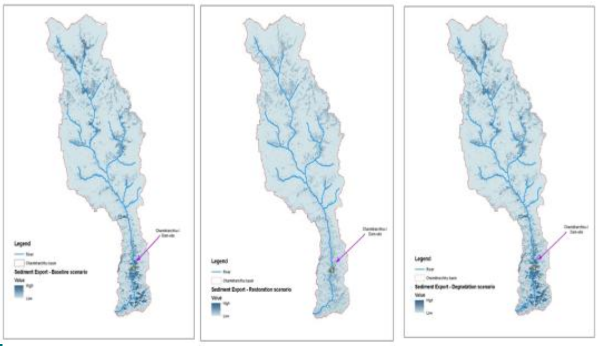
SL	Land Cover (Code)	Total annual sediment export (tons)	% of Total annual sediment export	Area (ha)	% of High sediment export area
1	Shrubs (SH)	361,271.00	69.14	6556.59	60.226
2	Meadows (GP)	76,683.60	14.67	2276.19	20.908
3	Agriculture Dryland (AK)	36,954.10	7.07	844.47	7.757
		474,908.70	90.88	9,677.25	88.891

Top 3 sediment retention land-cover types

Sl.	Land Cover Code	Total annual sediment retention (tons)	% of Total annual sediment retention	Area (ha)	% of High sediment retention area
1	Forest Broadleaf (FB)	242515	43.70	4365.27	45.11
2	Shrubs (SH)	88,088	15.87	1132.56	11.71
3	Meadows (GP)	62024	11.18	697.77	7.21
		392,627	70.75	6,195.6	64.03

SDR Model results

Area of Interest (AOI)	Baseline scenario	Restoration scenario			Degradation scenario		
	Amount (tonnes per year)	*Amount (tonnes per year)*	*Percent change (%)*	*Absolute change (tonnes per year)*	*Amount (tonnes per year)*	*Percent change (%)*	*Absolute change (tonnes per year)*
Sediment export for Whole basin	631,339.62	101,324.58	-83.95	-530,015.04	3,459,594.36	447.97	2,828,254.74
Sediment export for Dam basin	300,249.44	78,543.48	-73.84	-221,705.96	1,635,185.97	444.61	1,334,936.53
For Kurjey basin	113,072.47	33,211.40	-70.63	-79,861.07	251,893.01	122.77	138,820.54
Sediment retention index for Whole basin	82,938,210.75	83,471,276.94	0.64	533,066.19	80,113,007.17	-3.41	-2,825,203.58
Sediment retention index for Dam basin	47,774,413.49	47,999,218.32	0.47	224,804.83	46,442,575.84	-2.79	-1,331,837.65
For Kurjey basin	1,965,517.29	1,856,103.68	-5.57	-109,413.61	2,056,432.86	4.63	90,915.57



Discussion

- The InVEST SDR modeling results for Chamkharchhu basin, appear to indicate that the sediment production processes in the Chamkharchhu basin are quite sensitive to changes in the land cover
- More erosion in the area near Chamkhar-I dam-site so focus should be there esp. focused on agricultural land management; also scope in upstream areas which may be due to barren exposed areas;
- Comparison with available erosion data shows broad level of agreement which will improve with input data refinement.
- Currently at biophysical modeling stage. More work needed on economic valuation component.

Challenges

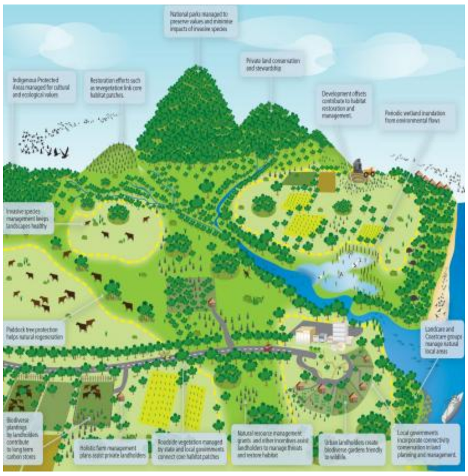
- Multiple expertise required: Hydrology, meteorology, soil science, economics + GIS/RS –only GIS/RS expertise used with support from NatCap/Stanford
- Data of better quality and higher resolution required – available coarse data was used
- Localized parameter values needed – values of biophysical tables were inferred from other studies
- InVEST models only sheet-wash sediment only (only half of total sediment, as per the study). Therefore this is an under-estimate of actual sediment production taking place in the landscape/basin.

Future steps

- Share outputs with stakeholders esp. with DGPC, WMD/MoAF & GNHC
- Technical collaboration to improve input data and parameters to the model: Hydromet, NSSC, DGM
- A more detailed work in terms of valuation of water yield, socioeconomic studies could allow for a holistic consideration of development impacts and land-use change
- This exercise would involve multiple stakeholders from Government and non government organizations including local communities.
- PES schemes with hydropower project which would directly benefit the communities in terms of improved livelihoods would go a long way in sustainable and improved management of the CHamkhar Chhu basin.

Additional services:

- Seasonal water yield with new InVEST version or SWAT
- Carbon (with availability of future LC scenarios)



+100

WWF is in over 100 countries, on 6 continents

1961

WWF was founded In 1961

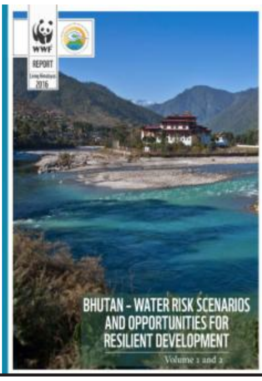
+5M

WWF has over 5 million supporters

+16M

WWF has over 16 million followers on Facebook, Twitter and Google+

Photo: © NASA



BHUTAN WATER RISK SCENERIOS AND OPPORTUNITIES For Resilient Development

National Water Symposium
10-12 May 2017

Key Objectives

- To provide a sound understanding of current and future ecological and biophysical opportunities and risks in Bhutan – Eastern Himalayas
- To highlight the social and economic implications and interconnections of these risks for Bhutan
- To describe resilient development pathways in the Himalayan stretches of the Brahmaputra basin
- To convene diverse actors across Bhutan towards commitment for shared management, development and conservation of water resources.

91

Who's been on the journey

National Environment Commission (NEC) and WWF leading, with support from Pegasys consultancy

1. Department of Roads , Department of Human Settlement, Department of Engineering Services under the Ministry of Works and Human Settlement.
2. Department of Hydropower and Power Systems, Department of Hydromet Services, Department of Geology and Mines and Department of Cottage and Small Industries under the Ministry of Economic Affairs.
3. Department of Forests and Park Services, Department of Agriculture, National Biodiversity Center and Policy and Planning Division under the Ministry of Agriculture and Forests
4. Department of Disaster Management, Ministry of Home and Cultural Affairs
5. Department of Public Health under the Ministry of Health.
6. Gross National Happiness Commission
7. National Land Commission
8. Druk Green Power Corporation Limited
9. Tourism Council of Bhutan
10. Royal Society for Protection of Nature
11. Bhutan Foundation
12. Bhutan Trust Fund for Environmental Conservation
13. The World Bank
14. United Nations Development Programme

15 Asian Development Bank and Integrated River Basin Management team leader

The process in Bhutan

Risk Narratives Nov 2014 to April 2015

- Scoping of water and the economy for Bhutan
- Developing draft risk narratives
- **Collaborative narrative building process with key influencers**
- **Identifying compelling issues and levers to drive futures**

Scenario Development May to Sept 2015

- Collaborative scenario building process with key influencers
- Identifying compelling scenarios and levers to drive action per basin
- Production of a major report to communicate insights

Communication & Engagement Oct to Dec 2015 & beyond

- Dissemination of findings to a broader stakeholder group
- Engage ongoing policy initiatives
- Convene and mobilise collective action initiatives

Threats to Bhutan's Water Resources

Climate Change

Inadequate Watershed Management

Linear Infrastructure Development

Hydropower Expansion

Agricultural Intensification

Urbanization and Industrialization

Institutional Capacity Challenges

Range of Risks Arising from the Threats

Flash Floods

Landslides

GLOFS

Water Shortages

Reputational / Brand Risk

Loss of Biodiversity

Sedimentation

Drying Streams / Dry Season Low Flows

Water Quality Challenges / Pollution

Three plausible Scenarios

Hydro Bhutan

- Centralised growth
- Hydropower driving economy
- 20GW by 2035
- Increase in storage dams
- Environmental impacts rise
- Cumulative Impact Assessments key
- Distributed micro hydro

Brand Bhutan

- Decentralised growth
- Agriculture and tourism driving the economy
- Happy/natural brand leveraged for commodity export
- Nature and ecotourism key
- Watershed impacts grow

Green Bhutan

- Growth in hubs
- Industry driving growth
- Industrial parts and surrounding settlements draw water
- Water quality impacts grow
- Industry is green and low carbon

96

HYDRO BHUTAN

Assumptions:
- 20 GW by 2035
- Growth of storage
- Regional market
- Hydro receives major consideration in decision making

Zonation *Finance* *Markets*

2015 - 2020
- 7 GW complete
- Mainly Run of River
- No Multipurpose
- Built across many basins
- India = primary investment + offtake

2020 - 2025
- Implementation of CIA, basin and spatial optimization
- Conversations emerge about local benefit sharing
- Environmental and social consequences
- Move towards redistributive model

2025 - 2035
- Rethinking of financing + supply; move to regional markets
- Long-term trade goals (peak sales)
- Hydro as support to other econ. sectors
- Disaster Mngmt = river floods, GLOFs

Impacts/ benefits

97

BRAND BHUTAN

Assumptions:
- Decentralization
- Growth in tourism
- Retain emphasis on high value tourism
- Commitment to food self-sufficiency
- Nature-based econ.

Investment *Models* *Incentives*

2015 - 2020
- Tourism grows, moves to decentralized model
- People leave land
- Rural-urban shifts
- Govt. places emphasis on creating opportunity in Ag.

2020 - 2025
- Linear infra grows to support tourism
- Forest cover and watershed impacts (sediment for hydro)
- Shift to market-based ag + niche products
- Ag subsidies + irrigation investment
- Hydro as support; circumspect growth

2025 - 2035
- Mechanized ag with niche exports to global markets
- Strong rural development model; more water supply
- Regional dry ports
- Impacts on forest cover + watersheds
- Disaster Mgmt = landslides

Markets / crops

98

GREEN BHUTAN

Assumptions:
- Nodal growth
- Cheap electricity is competitive adv. for industry
- Value-addition and processing receive consideration in decision making

Siting *Regulation* *Stewardship*

2015 - 2020
- Shift from cottage industries to value-addition, processing
- Growth in agro-based industries + minerals beneficiation
- Industrial sector drives job growth

2020 - 2025
- Urban demand for processed goods
- Hydro plays supporting role
- Shift towards Green Economy (transformational low carbon economy)
- Export-orientation; competitive adv.

2025 - 2035
- Impacts on water quality
- Strong regulation of water quality; need for better siting
- Investment in water technology + infra
- F&B partnerships
- Industrial brand
- Equity tensions
- Disaster mngmt = flood zoning

Markets / sectors

99

Future trade-offs

Water related tradeoffs

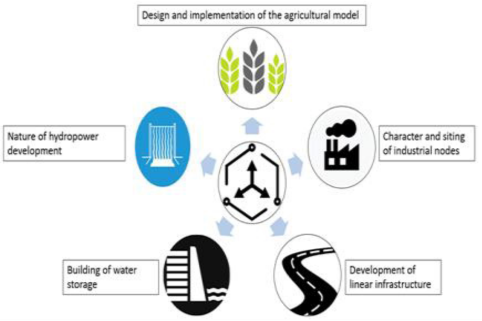
- ✓ Assurance of water supply / reliability / access
- ✓ Downstream protection against water degradation
- ✓ Watershed integrity and stability
- ✓ Disaster management
- ✓ Spatial overlays / conflicts

Context constraints

- ✓ Information on impacts
- ✓ Maintaining the Bhutan brand
- ✓ Source of finance / investment
- ✓ Institutional capacity / fragmentation
- ✓ Export focus versus Domestic consumption

Key Decision Points

WWF



101

Key decision points / interventions

- Shift and investment in a new agricultural model
- Understanding social and economic alternatives – water for growth and development
- Storage for rural development and hydropower
- Regional markets, dry port and comparative advantage linked to water and products
- Spatial planning, standards and differentiation of development nodes linked to water
- Energy export and agreements and domestic supply for production
- Capping and optimising hydro development in line with this

Recommendations

103

Opportunities for integration

- Bhutan's next five-year plan (2018-2023)
- Revision of Bhutan's Vision 2020 and formulation of Bhutan's Vision 2030
- Revision of the National Environment Strategy and Environmental Assessment Act
- Revision of the Power Sector Master Plan
- Revision of the Irrigation Master Plan
- Revision of other sector development plans

Next Step:
- Platform for continued engagement and partnership.
- WWF committed to continuing the process of engagement and using the Water Risks and Scenarios process and outcomes as launching pads for defining projects, research and partnerships.

104

Key message

- Different sectors decisions have implications directly or indirectly for the country's water resources.
- These decisions are, in effect, decisions about the future of Bhutan's most vital economic resource " **Freshwater** " hence about Bhutan's economic future.
- Understanding the key implications is important to take decisions with foresight, and with a strong understanding of trade-offs between any one chosen pathway and another.
- In order to minimize the chances of unintended consequences on Bhutan's natural capital – **particularly its freshwater systems** – there is a need for more holistic, inter-connected economic planning, and for actively integrating considerations about Bhutan's water resources into different sectors decision-making processes.

105

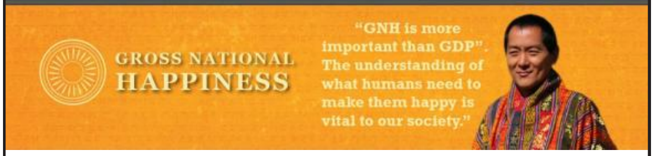
Reports available on WWF Bhutan and NEC website

http://www.wwfbhutan.org.bt/news_stories.cfm?278150/WATER%2Din%2DBhutans%2Deconomy

106

Mawongpa Water Solutions, Machineries & Equipment

Prefabricated water tanks and other water infrastructures.



Mawongpa Water Solutions MACHINERIES & EQUIPMENTS

By Sonam Dorji
May 2017

INTRODUCTION

Zincalume tanks

Fast installation

Reliability.

- Earthquake/ Natural calamities.
- Easy to dismantle and relocate.
- Sturdy alloy.
- Expandable volume.
- Fast installation.
- Last up to 60 years.
- Secure.
- Water and steel.
- Cyclonic pressure 88M/S
- Suitable for zone iv.
- Location friendly.

Liners

Liners.

- Multi layer food grade anti algae.
- UV stabilized.
- Stretch resistant.
- 3 layers of PVC fabric.
- Tested up to $2 kg/cm^{2}$.
- Liner will not affect taste and odor.

Accessories

Nozzles

Turbine Vent

Other applications.

		ZA02	ZA03	ZA05	ZA08	ZA12	ZA15	ZA20	ZA25	ZA30	ZA40	ZA45	ZA50
No. of rings	wall height	Dia. 1.84	Dia. 2.77	Dia. 3.69	Dia. 4.61	Dia. 5.53	Dia. 6.46	Dia. 7.38	Dia. 8.30	Dia. 9.23	Dia. 10.15	Dia. 11.07	Dia. 12.00
R1	1.12	2.98	6.75	11.97	18.68	26.89	36.69	47.89	60.57	74.90	90.58	107.74	126.60
R2	2.08	5.53	12.53	22.23	34.70	49.93	68.14	88.93	112.48	139.10	168.22	200.09	235.12
R3	3.03	8.05	18.25	32.39	50.55	72.74	99.26	129.55	163.86	202.64	245.04	291.48	342.51
R4	4.00	10.63	24.09	42.75	66.73	96.02	131.04	171.02	216.31	267.51	323.49	384.79	452.16
R5	4.95	13.16	29.81	52.91	82.58	118.83	162.16	211.64	267.69	331.04	400.32	476.18	559.55
R6	5.90	15.68	35.54	63.06	98.43	141.64	193.28	252.25	319.06	394.57	477.15	567.57	666.94
R7	6.87	18.26	41.38	73.43	114.61	164.92	225.06	293.72	371.52	459.44	555.60	660.88	776.58
R8	7.82	20.78	47.10	83.59	130.46	187.73	256.18	334.34	422.90	522.97	632.42	752.27	883.97
R9	8.80	23.39	53.00	94.06	146.81	211.25	288.28	376.24	475.89	588.51	711.68	846.54	994.75
R10	9.76	25.94	58.79	104.32	162.83	234.30	319.73	417.28	527.81	652.71	789.32	938.89	1,103.27

		ZA60	ZA70	ZA80	ZA90	ZA100	ZA110	ZA120	ZA130	ZA140	ZA150	ZA160	ZA170	ZA180	ZA190	ZA200
No. of rings	wall height	Dia. 12.92	Dia. 13.84	Dia. 14.77	Dia. 15.69	Dia. 16.61	Dia. 17.53	Dia. 18.45	Dia. 19.37	Dia. 20.29	Dia. 21.21	Dia. 22.16	Dia. 23.08	Dia. 24.00	Dia. 24.90	Dia. 25.85
R1	1.12	146.76	168.41	191.80	216.44	242.56	270.18	299.28	329.87	361.95	395.52	431.74	468.34	506.42	545.11	587.50
R2	2.08	272.56	312.76	356.20	401.96	450.48	501.76	555.81	612.62	672.20	734.54	801.81	869.77	940.5	1,012.35	1,091.07
R3	3.03	397.04	455.60	518.89	585.54	656.22	730.93	809.66	892.42	979.21	1,070.72	1,168.02	1,267.02	1,370.04	1,474.72	1,589.40
R4	4.00	524.15	604.45	685.00	772.99	886.30	964.92	1,068.86	1,178.12	1,292.69	1,412.57	1,541.95	1,672.64	1,808.64	1,946.83	2,098.22
R5	4.95	648.63	744.30	847.69	956.58	1,072.05	1,194.09	1,322.72	1,457.92	1,599.70	1,748.06	1,908.16	2,069.89	2,238.20	2,409.20	2,596.55
R6	5.90	773.12	887.14	1,010.38	1,140.16	1,277.79	1,423.26	1,576.57	1,737.72	1,906.71	2,083.55	2,274.37	2,467.14	2,667.74	2,871.58	3,094.87
R7	6.87	900.23	1,033.00	1,176.49	1,327.62	1,487.87	1,657.26	1,835.77	2,023.42	2,220.19	2,426.09	2,648.29	2,872.75	3,106.34	3,343.68	3,603.70
R8	7.82	1,024.71	1,175.84	1,339.18	1,511.20	1,693.62	1,886.43	2,089.63	2,303.22	2,527.21	2,761.58	3,014.50	3,270.00	3,535.90	3,806.06	4,102.02
R9	8.80	1,153.13	1,323.20	1,507.00	1,700.58	1,905.86	2,122.83	2,351.50	2,591.86	2,843.91	3,107.66	3,392.28	3,679.80	3,979.01	4,283.03	4,616.08
R10	9.76	1,278.92	1,467.55	1,671.40	1,886.10	2,113.77	2,354.42	2,608.03	2,874.61	3,154.16	3,446.68	3,762.35	4,081.23	4,413.08	4,750.27	5,119.65

Existing client.

- HIDD, Serbithang.
- Mongar Dzongkhag.
- Phuensum Builders.
- Samthang VTI.
- Gelephu Thromde.

Rentals

Charges: Nu:15-25/Month/std

I/ Bag filter

- Filters up to 5 micron.
- Housed in SS 304.
- Minimum 30 years lasting.
- Yearly services.

II/ Cartridge filter

- Filters up to 1 micron.
- Housed in SS 304.
- Minimum 30 years lasting.
- Yearly services.

III/ UV sterilizer

- Chemical free disinfectant.
- User friendly.
- Less energy consumption.
- Inactivates microbe.
- Made in Stainless steel 304.
- Lamp will last up to 8000 Hrs.

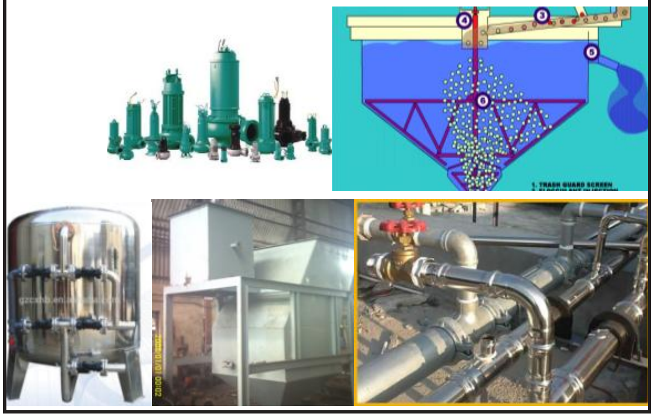
IV/ Water Dispenser.

- Lead free taps..
- Insulated SS 304 material.
- Available in different sizes.
- Integrate additional taps.
- Food grade piping, fitting and accessories after the treatment.
- Filters can be enclosed with dispenser.
- Cooling and heating can be integrated.

7/ Applications

Hostels.
Assembly ground.
MP hall.
Sport and recreational center.
Hostels.
Dining hall.
Academy block.
Other public places

Other products on rental.



3/ We

Production unit

Tashi Delek

Sonam Dorji
301, building No.7, Olakha, Thimphu; Bhutan
Mobile: 17115539
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Mawongpa Water Solutions
MACHINERIES & EQUIPMENTS

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We are immensely grateful to His Excellency Lyonchhen Dasho Tshering Tobgay for gracing the opening session of the symposium. Our gratitude to Honorable Ministers Lyonpo Yeshey Dorji, Ministry of Agriculture and Forests and Lyonpo Leki Dorji, Ministry of Economic Affairs for their gracious presence. We are thankful to Special Advisor to NECS, Dasho Paljor J. Dorji and Honorable Secretary, Dasho Chencho Norbu, NECS for chairing the concluding session of the Symposium.

Finally, we would like sincerely acknowledge all our session chairs and presenters for their time and contribution to the successful conduct of the three day symposium. We would also like to thank all the participants, representatives from the media houses and stakeholders for their active participation during the symposium.

The National Environment Commission is a high level multi-sectoral body. It is the highest decision making and coordinating body on all the matters relating to the protection, conservation and improvement of the natural environment.

The mandate of the National Environment Commission is to:

Develop, review and revise environmental policies, plans and programmes, formulate, review and revise environment related Laws/Acts and monitor enforcement of the same.

Mainstream environment into the country's developmental policies, plans and programmes promote environmental awareness amongst all levels of Bhutanese society, including dissemination of environmental policies, strategies, acts, rules, regulations and standards through print, audio visual and other appropriate means, institutionalize the Environmental Assessment (EA) process as an integral part of the development planning process through enforcement of EA Act 2000, adopt, review and revise environmental standards for the country, monitor ambient air and water quality and land-use changes and inform all sections of the society through print, audio visual and other appropriate means.

Promote and ensure an efficient system of gathering and sharing environmental information, publish State of Environment Reports and report/submit to the Lhengyal Zhungtshog/Parliament once every 5 years and disseminate the findings to the general public, promote and conduct environmental research, coordinate and facilitate the implementation of bilateral and multilateral environmental agreements, conventions, treaties or declarations.

receive representations on environmental matters from members of the Civil Society, develop and facilitate the implementation of the National Sustainable Development Strategy (NSDS), coordinate and monitor cross-sectoral issues related to water, forestry and mineral resources and waste management in the country. The line ministries/agencies shall be responsible for their Implementation and enforcement functions, participate in all environment related regional, sub-regional and international conferences and negotiations.

The Ugyen Wangchuck Institute for Conservation and Environmental Research is a Government based research and training institute. We strive to foster better stewardship of our natural heritage – land, water, air and species therein – through rigorous science based research and transmission of cutting-edge science results to field practitioners, environmental leaders and policy makers.

Our current focus areas are defined by needs and challenges within Bhutan and outside. We recognize interlinkages between the way forestry is practiced to the dynamics of species conservation and persistence. We understand the implications of landuse practices and global climate change on water resources and energy requirements. Above all, we appreciate and seek to understand human impacts and impacts on humans by studying social patterns and economic implications of management and policy interventions.

In addition to conducting research, we provide a two-year certificate course in environment, forestry and conservation. We also offer tailor made course within the field of conservation biology, sustainable forestry and water resources for professionals working in these fields. We also offer opportunities for undergraduate students to conduct research projects as part of their Honours program.

As part of our initiative to encourage discourses and dialogue within the environmental community, we regularly organize seminars and host conferences at both national and international level.

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