National Water Symposium
Technical Presentations
2017

“Towards Ensuring Water Security for Bhutan’s Future”
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

Prepared by:
Dawa Yoezer, UWICER
Norbu Wangdi, UWICER
Tshering Dendup, UWICER

Copyright © 2017
National Environment Commission Secretariat and
Ugyen Wangchuck Institute for Conservation and Environmental Research

All rights reserved. Published 2017
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)

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1100</td>
<td>Water governance in Bhutan</td>
<td>Mr. Kunzang Rinzin, NECS</td>
</tr>
<tr>
<td>1130</td>
<td>Water resources and National Integrated Water Resource Management Plan (NIWRMP)</td>
<td>Ms. Tenzin Wangmo, NECS</td>
</tr>
<tr>
<td>1200</td>
<td>Local governments perspective of water resources management</td>
<td>Mr. Dorji Wangdi, Wangdue Dzongkhag</td>
</tr>
</tbody>
</table>

**Water Governance in Bhutan**

Kunzang Rinzin
Legal Services

**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 approach
- cross-sectoral
- 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. Abstraction requiring EC - concerned Dzongkhag Administration
  iii. Ground Water abstraction - concerned Dzongkhag Administration

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
Environmental Clearance for Water Abstraction

Offence to abstract water without EC

Exemptions
- Domestic use
- Small scale drinking water supply and irrigation schemes
- 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
- Abstraction not requiring EC - concerned Gewog Administration
- Abstraction requiring EC - concerned Dzongkhag Administration
- Groundwater abstraction - concerned Dzongkhag Administration

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
Rivers/streams/springs

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

Hydrological basins

River basins, area & flow

<table>
<thead>
<tr>
<th>River Basins</th>
<th>Basin Management</th>
<th>Area (km²)</th>
<th>Annual flow (MCM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaldakha</td>
<td></td>
<td>942</td>
<td></td>
</tr>
<tr>
<td>Amochhu</td>
<td>Amochhu</td>
<td>2310</td>
<td>9.375</td>
</tr>
<tr>
<td>Wangchhu</td>
<td>Wangchhu</td>
<td>4596</td>
<td>5.209</td>
</tr>
<tr>
<td>Punatsangchhu</td>
<td>Punatsangchhu</td>
<td>9645</td>
<td>19.125</td>
</tr>
<tr>
<td>Niewchu</td>
<td>Punatsangchhu</td>
<td>1937</td>
<td>6.988</td>
</tr>
<tr>
<td>Mangdechhu</td>
<td>Mangdechhu</td>
<td>7339</td>
<td>11.757</td>
</tr>
<tr>
<td>Drangmechhu</td>
<td>Drangmechhu</td>
<td>6447</td>
<td>13.564</td>
</tr>
<tr>
<td>Nyera Amachhu</td>
<td>Drangmechhu</td>
<td>2348</td>
<td></td>
</tr>
<tr>
<td>Jomori</td>
<td></td>
<td>642</td>
<td></td>
</tr>
<tr>
<td>Merak-Sakteng</td>
<td></td>
<td>137</td>
<td>4.500</td>
</tr>
</tbody>
</table>

10 5 38,394 70,576 MCM

Population 746,773
Per capita water available 94,508 m³/yr
Flow 2,238 m³/yr

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

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
  - 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)

NIWRMP- Methodology

NIWRMP 2016 contents

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

NIWRMP- Methodology

Climate Change Assessment

Hydrological Assessment

Physical, institutional and socio-economic realities

Capacity building

Historical Data Modeling Future Projection

NIWRMP Stakeholder participation

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
Key issues and challenges

4. Water availability versus accessibility

- Scarcity
- Plenty

Average

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
- 5 dimensions
- 57 indicators

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
WRM 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

Priority Areas

- Adoption of Water Security Index in the 12th FYP
  - NKRA B, KPI 8.8
  - Coordinated AKRA and KPI for NKRA B—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

How is progress tracked against the spiral IWRM learning process?

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/
• རྩེ་ཐོས་ཆུ་ཐོ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
• རྩེ་ཐོས་ཆུ་ལ་བཅོན་འབྲེལ་འོ། །བཅོན།
Session 2: Water and Ecology
Chair: Mr. Ugyen Lhendup, Bhutan Trust Fund for Environmental Conservation

<table>
<thead>
<tr>
<th>Time</th>
<th>Session Title</th>
<th>Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1400</td>
<td>Watershed management &amp; wetland conservation in Bhutan</td>
<td>Ms. Sonam Choden, WMD, DoFPS</td>
</tr>
<tr>
<td>1430</td>
<td>Freshwater macroinvertebrates biodiversity in Bhutan</td>
<td>Mr. Jigme Wangchuk, UWICER, DoFPS</td>
</tr>
<tr>
<td>1500</td>
<td>Brief account on freshwater biodiversity of Bhutan</td>
<td>Mr. Ugyen Dorji, CNR, Royal University of Bhutan</td>
</tr>
<tr>
<td>1520</td>
<td>Fishery resources of Bhutan: threats and opportunities</td>
<td>Mr. Gopal Prasad Khanal, NCCR&amp;LF</td>
</tr>
<tr>
<td>1540</td>
<td>Tea Break</td>
<td></td>
</tr>
<tr>
<td>1600</td>
<td>Study on minimum environmental flow for hydropower projects of Bhutan</td>
<td>Mr. Tenzin Khorlo, NECS</td>
</tr>
<tr>
<td>1630</td>
<td>Q&amp;A Session</td>
<td></td>
</tr>
</tbody>
</table>

End of Day 1

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

Landuse Landcover Map of Bhutan

Protected Areas (Including Rainforest Sites) of Bhutan
Policy Overview

2. Bhutan Water Vision 2025
5. Water Act (2011)
11. Electricity Act (2001)

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 Meteorological 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: Recommended a lead agency for watershed management (3/2009)
• Established in May 2009 because (Cabinet order No. C-02/In/07)

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 sustainable 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

Problem tree

Effect
Focal problem
Causes

Objective tree

Goal
Objectives
Outputs
Activities

Focal problem

Effects

Core Problem(s)
Springs, Rivers and Domestic Water supply contamination

Causes
- Dumping of waste in the watershed (rivers and streams)
- Water storage tank at household not cleaned regularly
- Dumping of sewerage and waste in Chamgang by (police and prison)
- Inadequate infrastructure for collecting household waste
- Lack of awareness of impact of dumping of waste
- Car washing
- Overflow of septic tanks
- Contamination by livestock
- Lack of monitoring of existing regulation related to dumping of waste
- Cremation ash dumped into river
- Inadequate treatment of sewage
- Dumping of construction waste (truck loads)
- Exposed pipe lines in the drains
- Open defecation in streams

EFFECTS
- Increase water borne diseases
- Bad effect on public health
- Decrease aquatic health (ecosystem health)
- Decrease in the ecotourism experience (aesthetic values)
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
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

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 policies - 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
Structural Presentation

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

Background

- World
  - There are over 45,000 species of insects, known to inhabit diverse freshwater ecosystems (Balaram, 2005).
  - Odonata over 5,680 species
  - Mollusca over 5,000 species
  - Decapoda over 1,863 species
  - Region (Eastern Himalaya)
  - Mollusca 186 species (112 gastropods and 74 bivalves)
  - Odonates 367 species
  - Decapoda 57 species

Importance of freshwater macroinvertebrates

- 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

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)
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 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-Diptera

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

Past studies on macroinvertebrates-other TAXA

- Trombidiformes
- Decapoda
- Hemiptera
- Megaloptera
- Gastropoda

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

<table>
<thead>
<tr>
<th>Order</th>
<th>Family</th>
<th>Species</th>
<th>New to science</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plecoptera</td>
<td>5</td>
<td>34</td>
<td>6 species</td>
<td>20 new</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichoptera</td>
<td>24</td>
<td>173</td>
<td>10 species</td>
<td>3 new</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Odonata</td>
<td>16</td>
<td>101</td>
<td>4 species</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diptera</td>
<td>3</td>
<td>28</td>
<td>5 species</td>
<td>1 new</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coleoptera</td>
<td>8</td>
<td>37</td>
<td>4 species</td>
<td>1 level</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decapoda</td>
<td>3</td>
<td>9</td>
<td>1 species</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemiptera</td>
<td>3</td>
<td>12</td>
<td>2 species</td>
<td>3 new</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Megaloptera</td>
<td>1</td>
<td>1</td>
<td>1 species</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gastropoda</td>
<td>6</td>
<td>11</td>
<td>1 species</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trombidiformes</td>
<td>1</td>
<td>5</td>
<td>2 species</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>70</td>
<td>411</td>
<td>93</td>
<td></td>
</tr>
</tbody>
</table>
Different Taxa Recorded in Bhutan from REPORTs and Unpublished Papers

- Order: 21
- Family: 109
  - Aeshnidae
  - Annicellidae
  - Aphrodesiidae
  - Arctopogidae
  - Astacidae
  - Atheridae
  - Atyidae
  - Baetiidae
  - Belostomatidae
  - Bledaridae
  - Brachycentridae
  - Calopterygidae
  - Calopterygidae
  - Campodidae

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
**Journals, Thesis**

- Different Taxa Recorded in Bhutan from REPORTs and Unpublished Papers
  
- **Order**
- **Family**

- 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

**GAPS**

- 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

---

**Results In MHPA**

HKHbios Water quality class boundaries and water quality for each sampling plot

<table>
<thead>
<tr>
<th>Class</th>
<th>Boundary 1</th>
<th>Boundary 2</th>
<th>Boundary 3</th>
<th>Boundary 4</th>
<th>Boundary 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor/bad</td>
<td>≥3.3</td>
<td>≥4.3</td>
<td>≥3.4</td>
<td>≥2.3</td>
<td>≥2.6</td>
</tr>
<tr>
<td>Moderate/Poor</td>
<td>≥4.3</td>
<td>≥5.3</td>
<td>≥4.7</td>
<td>≥4.6</td>
<td>≥4.3</td>
</tr>
<tr>
<td>Good/Moderate</td>
<td>≥4.1</td>
<td>≥6.5</td>
<td>≥5.7</td>
<td>≥6.3</td>
<td>≥6</td>
</tr>
<tr>
<td>Good</td>
<td>≥5.5</td>
<td>≥7.5</td>
<td>≥6.8</td>
<td>≥7.7</td>
<td>≥7.5</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Plot</th>
<th>HKHbios</th>
<th>Water quality class boundaries and water quality for each sampling plot</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>HKHbios</td>
<td>Water class fell much lower than the class boundaries (Poor/bad)</td>
</tr>
</tbody>
</table>
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

<<Interaction>>

Ecosystem

Major groups of freshwater biodiversity

<table>
<thead>
<tr>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anguillidae</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cyprinidae</td>
<td>26</td>
<td>43</td>
</tr>
<tr>
<td>Plecostomidae</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Balitoridae</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Botiidae</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Nemacheilidae</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Bagridae</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Deltidae</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Schilbeida</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Amblycipitidae</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

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.

THANKS
Many of the specimens are under the process of identification. The number is expected to be high, with Thoni, 2015 being the highest number of records of fishes from Bhutan. Gurung and Thon, 2005 reported 11 species from Bumdeling. Lei et al., 2008 found 49 species, while Gurung, 2015 reported 52 species. Petry, 1999 noted 41 species, and Day et al., 1889 added five species. Beavan, 1877 recorded three species, and the first specimen was from Griffith, 1838.

Major groups of freshwater biodiversity include:
- Aquatic plants
- Macroinvertebrates
- Fishes

Aquatic plants and macroinvertebrates are key indicators of aquatic ecosystems. Fishes are also highly sensitive to pollutions and contaminations. Approximately, macroinvertebrates belonging to 21 orders and 109 families are found in Bhutan.

Challenges include impacts on dams, fish migration, and illegal fishing. Sustainable solutions like fish ladders and e-flow systems and legal regulations are needed to mitigate these challenges.
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 sewage water, and enhancing local economy.

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 Opportunities

Gopal Prasad Khanal
National Research Centre for Riverine and Lake Fisheries (NRC&LF), Haa.
Department of Livestock (DoL),
Ministry of Agriculture and Forests (MoAF).
18th May, 2017.
THIMPHU, BHUTAN

**Aquatic flora**

<table>
<thead>
<tr>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoraceae</td>
<td>1</td>
<td>1</td>
<td>Lentibulariaceae</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Alismataceae</td>
<td>1</td>
<td>2</td>
<td>Limnocharitaeceae</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Aponogetonaceae</td>
<td>1</td>
<td>1</td>
<td>Lythraceae</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Brassicaceae</td>
<td>1</td>
<td>1</td>
<td>Menyanthaceae</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Elatitaceae</td>
<td>1</td>
<td>1</td>
<td>Nymphaeaceae</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Eriocaulaceae</td>
<td>1</td>
<td>2</td>
<td>Podostemaceae</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Haloragaceae</td>
<td>1</td>
<td>1</td>
<td>Polygonaceae</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hippuridaceae</td>
<td>1</td>
<td>1</td>
<td>Pontederiaceae</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Hydrocharitaceae</td>
<td>3</td>
<td>3</td>
<td>Potamogetonaceae</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Juncaginaceae</td>
<td>1</td>
<td>2</td>
<td>Schoenhofiaceae</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Lemnnaceae</td>
<td>1</td>
<td>2</td>
<td>Typhaceae</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

(Data: Dorji and Gurung, 2017)
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 (30,000 cubic meters).
- The inland water bodies mainly comprise 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 the country is yet to be done.

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 (NRC&LF), Haa.
- National Research Centre for Aquaculture (NRA), Gelephu.

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 ichthyofauna diversity during the recent years.

- John McCulloch (1837).
- Sir Francis Day (1865).


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

NRC&LF (DoL/MoAF): 109 SPECIES
(Species Composition and Distribution of Fishes in Western Bhutan) ITARF FUND STUDY

INDIGENOUS: 93 SPECIES
EXOTIC: 11 SPECIES
TOTAL: 104 SPECIES
Fishery Diversity of Neighbouring Countries and Regions

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

Fishery Resources Bhutan

1) Hydroelectric Dams
- The biological consequences: Obstruction of fish migration within feeding, spawning and refuge habitats.
  - Dams water flow environment for establishment of other non-native species.
- The physical consequences: include the accumulation of sediments and alteration of natural flow of water in dammed reaches of rivers.
  - The clearing 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 (fate) to stagnant (null) 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 favour the establishment of other non-native species.

Road Construction and Mining

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

Conservation Status of Fishes in Bhutan

- Golden mahseer, a globally endangered fish is totally protected in Bhutan.

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

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.
### (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 in aquaculture sources;
  - Achieve ecological impacts associated with irresponsible aquaculture practices &
  - Importance of aquaculture sector in achieving food, nutrition and economic
  - It is high time to adopt “Responsible Fish Farming Guidelines” so to reap the benefits
  - without compromising the environment.

### EXOTIC AND INVASIVE ALIEN SPECIES (IAS) OF FISH
- Invasive alien species of fish like African sharp-tooth catfish in Bhutan is presumed to be
  - introduced through Tse Chu.
- 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 to 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.

### (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.
- Dept. 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.

### EXOTIC AND INVASIVE ALIEN SPECIES (IAS) OF FISH
- a 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.

### G) FISHERIES CONSERVATION PROGRAMS BY MoAF (DoL)
#### (1) FISH FAUNA ASSESSMENT
- The “Fish Fauna Assessment of Bhutan” is a “BFRC Funded Project” and is
  - executed by NERCAL. It has 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 basines (Amo Chhu,
    Phuensholing and Wang Chhu).
- Second phase of the project has been initiated and will cover the main rivers and
  - tributaries of Manas, Nysara, and Aie Chhu and is scheduled to be
  - completed by 2015.
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 (DoA) in collaboration with WWF-Bhutan and Fisheries Conservation Foundation (FCF), USA for period of five years (2005-2010).

The Manas river basin covering Mangdechhu, Chamkharhchu, Drangmechhu, Karichhu and Sanchhu, are chosen as the study site.

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?

- Radio transmitter: 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.

<table>
<thead>
<tr>
<th>River/Tributary</th>
<th>Receivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mangdechhu</td>
<td>3</td>
</tr>
<tr>
<td>Drangmechhu</td>
<td>3</td>
</tr>
<tr>
<td>Chamkharhchu</td>
<td>2</td>
</tr>
<tr>
<td>Lower Manas</td>
<td>2</td>
</tr>
<tr>
<td>Karichhu</td>
<td>1</td>
</tr>
<tr>
<td>Sanchhu</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>16</strong></td>
</tr>
</tbody>
</table>
Radio transmitter.

Each fish with the antenna trailing on the outside of the transmitter are surgically implanted into the body cavity.

Digital Cards) at every receiver (implanted in fish) and the receiver downloads the data.

It is a radio tag, programmed to emit some signals when a specific signal power is received by the receiver. To ensure that they are moving, a hand held receiver is used to track them.

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

Not all Mahseers migrate to India in winter.

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.

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

**WATER SUMMITS**

- Capture of fish and implantation of transmitter
- Recovery and release of fish
- How telemetry works?
- Current status
- Way forward
In order to study and mitigate the impact to fisheries resources by any major developmental undertakings, the NRCA, 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 Tangtsho Hydro Energy Limited (THyE).

The NRCA, Gelegphu is engaged in ex-situ breeding of golden mahseer since 2013.

- Developed standard breeding techniques.
- The centre with funding from Mangdechhu Hydropower 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 some project Conservation Centre for golden mahseer and other native species has been set up at NRCA facility.

- Around 3,000 hatchery bred golden mahseer fingerlings has been released by NRCA to further strengthen the golden mahseer population in Mangdechhu.

NRCA, Haa (Way Forward; 11th FYP)

- Monitor the capture fisheries program.
- Study the extent of brown trout establishment at Haechhu 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 NRCA, Haa.
- Develop breeding technologies for native fishes.
- Continue baseline fish fauna assessment of eastern Bhutan.
- Continue radio telemetry of golden mahseer.

National Water Symposium; Technical Presentations 132
**REFERENCES**


Bhutan’s Future: MoAF, Thimphu.

Challenges; and

Cont.

Development of Hydropower:

- Overall potential: 30,000MW
- Shortlists 76 projects
- Existing and pipeline projects

<table>
<thead>
<tr>
<th>Hydropower</th>
<th>Capacity (MW)</th>
<th>Nos.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commissioned</td>
<td>1606</td>
<td>5</td>
</tr>
<tr>
<td>Under construction</td>
<td>1658</td>
<td>5</td>
</tr>
<tr>
<td>Pipeline</td>
<td>1520</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>6784</td>
<td>13</td>
</tr>
</tbody>
</table>

Build national capacity for future assessments, monitoring and analysis; and

Ensure minimal environmental impact from development activities.
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

**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.

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

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.

Outcomes:
• Developed 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.
MEETROLOGICAL OBSERVATIONAL NETWORK

• AUTOMATIC WEATHER STATION (AWS) – 80 Nos

WEATHER INFORMATION SERVICES

Weather forecast – 3 days

• WRF Model
  - WRF – 72 hours forecast runs
  - Runs every 6 hours 00,18, 12 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

Snowfall on March 11 Thimphu

Source: Report from Office of the Resident Coordinator Bhutan

WRF model predicted more than 300mm in most of southern dzongkhags from 21st July 2016

Moderate to heavy precipitation was predicted on 11 March
Monitoring and Dissemination

- Weather monitored 24/7
- Disseminated:

Present status of climate services

Provision of historical climate data

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 NMs may be consulted.
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 persons 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

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

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

Overview
• Introduction
  – Cryosphere Services Division, it’s mandate
  – Cryosphere
• Activities
  - Glaciers
  - Glacial lakes
• Information
• Future plans

THANK YOU FOR YOUR ATTENTION
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

http://more.glacierworks.org/the-rivers/

### 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

### Cryosphere related activities
- Glacier mass balance
  - bench mark glaciers
  - (Gangji La, Metatsnhot, Thana)
- 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

\[ b = c + a; \quad b: \text{mass balance, } c: \text{accumulation, } a: \text{ablation} \]

Mass balance(b) measurement methods

1. Direct/Stake method
   (installation of stake network)
   - Annual/seasonal

2. Geodetic method
   (single/dual frequency GPS)
   - satellite images
   - Annual/seasonal

3. Energy balance
   - meteorological parameters

Mass balance Results

• An example from Gangju La Glacier
  • C-type glacier
  
  Area = 0.3 km²
  Max. elev ~ 5200m a.s.l.
  Low. elev ~ 4900m a.s.l.

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

Mitigation works

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

Information available

<table>
<thead>
<tr>
<th>Site/location</th>
<th>Data</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thana glacier</td>
<td>2013-2016</td>
<td>2016, Not Analyzed yet</td>
</tr>
</tbody>
</table>

* 12 installed, 9 retrieved
*** 14 installed, 4 retrieved
** 8 installed, 1 retrieved

Information available ...(Cont.)

<table>
<thead>
<tr>
<th>Station - Nos</th>
<th>Snow Data</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Depth</td>
<td>SWE</td>
</tr>
<tr>
<td>Paro-5</td>
<td>2013-2016</td>
<td>2013-2016</td>
</tr>
<tr>
<td>Jakar-2</td>
<td>2013-2016</td>
<td>2013-2016</td>
</tr>
<tr>
<td>Wangdue-1</td>
<td>2015-2016</td>
<td>2015-2016</td>
</tr>
<tr>
<td>Chukha-1</td>
<td>2015-2016</td>
<td>2015-2016</td>
</tr>
<tr>
<td>Haa-1</td>
<td>2013-2016</td>
<td>2013-2016</td>
</tr>
<tr>
<td>Tyangtse-1</td>
<td>2013-2016</td>
<td>2013-2016</td>
</tr>
<tr>
<td>Tyang-1</td>
<td>2015-2016</td>
<td>2015-2016</td>
</tr>
<tr>
<td>Mongar-1</td>
<td>2013-2016</td>
<td>2013-2016</td>
</tr>
</tbody>
</table>
### 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](http://www.hydromet.gov.bt)

---

### 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 (NHCN)

---

### River System of Bhutan

- **Four Major Basin**  
  1. Ammochu/Torsa  
  2. Wangchhu/Radiak  
  3. Punatsangchhu/Sankosh  
  4. Manas  
  - Mangdechhu,  
  - Chamkharchhu,  
  - Kurichhu and  
  - Dangmechhu

- **Three Trans-boundary river**  
  1. Ammochu  
  2. Kurichu and  
  3. Gonghi  
  4. Jaldakha

---

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

a. Formulate policies, 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

Hydrological and Flood Warning Network Status

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Infrastructure</th>
<th>Unit No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Principal Station</td>
<td>Nos. 16</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Secondary Station</td>
<td>Nos. 9</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Flood Warning Station</td>
<td>Nos. 24</td>
<td>Program: Eeralted by GoI through Central Water Commission (CWC), Ministry of Water Resources.</td>
</tr>
<tr>
<td>4</td>
<td>Sediment Sampling Station</td>
<td>Nos. 13</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>GLOF Early Warning System</td>
<td>Sub-basin 3</td>
<td>Paro, Mongeaba, Mangdechhu and Chamkharchhu</td>
</tr>
</tbody>
</table>

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
Hydrology and Water Resources Services and Products

- Historical hydrological time series
- Flood monitoring
- Flood/GLOF early warning
- Flood advisory
  - Flood/GLOF Hazard mapping & Modelling
  - Hydrological/flow forecasting
  - Technical back stopping in hydro
- Water Resource Assessment in future

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

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.

Why flood mitigation is important for Bhutan??

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

28 June, 2015 GLOF from Mochhu
- Outburst of Lemethang Tscho (Mo-g2000) located at the base of Ganchen Tag Mountain, head water of Mochhu

Flash Floods Impact

Flash Flood Impacts

Landslide Dam Outburst Flood (LDOF)
- 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 80 MW Kurichhu Hydropower Plant down stream
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 m³.

Flash Flood July 2016
- 03 in Sarpang Market (21 of which have been relocated);
- 10 in Gelephu (two of which have been relocated);
- 17 in Phuentsoling;
- 25 in Punakha; and the remainder in other locations.

Early Warning Systems
A Fundamental Component of Disaster Risk Management

Components of Monitoring and Warning Services

Main Components of Early Warning
Components of GLOF EWS
Remote Monitoring Stations
Communication
Sirens
Control Room
Projects 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 headwater of Chamkharchhu
b. Bumthang is a 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

**Automatic Water Level (AWS/AWLS):**
1. Jongthang (Mangdephug)- AWLS/AWS
2. Bjizam (AWLS/AWS)

**Control Room:**
1. MHPA Dam colony
   1. Bjizam
   2. MHPA Darm
   3. MHPA Power house

Bumthang

20 AWLS/AWS

- Remote Monitoring Stations
- Control Room
- Communication
- Sirens

**Basin Control Room**

Control Room, Kurjey, Bumthang
Chamkharchhu

**Communication between Remote Monitoring Station and Control Room**

- Meteorological Satellite (METEOSAT)
- WMO GTS Network
- HF Voice
- DC
- HF

**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.

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

- Out of 25 Potential Glacier Dangerous lakes in Bhutan:
  - 7 lakes are located in the headwater of Mangdechhu
  - 3 lakes are located in the head water of Chamkharchhu

- Bumthang is beautiful valley, emerging new town and tourist destination

- Settlements and infrastructure along the river valley

- Construction of Mangdechu Hydropower Project (722 MW)

- Planned Hydropower Projects downstream on Chamkarchhu

- Important historical and cultural sites downstream

- Domestic airport, Bumthang

- Cyclone Aila 2009 brought havoc and damages to infrastructures in the basin

- No flood warning system in the basin
Ground floor:
- Day-care center

1st floor:
- Flood monitoring & warning room
- Emergency meeting room

2nd floor:
- Weather forecasting room
- GTS/MSS Operation room

24/7 National Weather and Flood Warning Center (NWFWC), Thimphu

Satellite image receiver (HimawariCast)

Ground Floor: Day-care center
1st Floor: Flood monitoring & warning room, emergency meeting room
2nd Floor: Weather forecasting room, GTS/MSS Operation room

Warning Sirens

Mangdechhu Sub-basin (3 Sirens)

Chamkharshhu Sub-basin (6 Sirens)

EWS information dissemination for Punatsangchhu Basin

General Communications and Information Flow in the Central and Dzongkhag Levels

Flood Risk map

Awareness and Education/Mock Drill
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

Mock drill

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

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.

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 Vendor/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
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)

12 FYP NHCM (DRAFT)

Outline

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

Isotopes: Greek *isos topos* = same place
Isotope = atoms of the same element with a different number of neutrons (different mass)

Example:

![Oxygen Isotopes](image)

Environmental Isotopes

- Stable Isotopes
- Radioactive Isotopes

Do not decay spontaneously (stable over time)
- Examples: \(^{16}\)O, \(^{2}H, ^{13}\)C

Emit alpha and beta particles and decay over time
- Examples: \(^{3}H\) (Tritium), \(^{14}\)C

Used as Tracers

Used for Dating

Isotopes of Water

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

- Oxygen isotopes
- Hydrogen isotopes

Stable Isotopes: Isotope Fractionation

Phase changes can sort the light elements from the heavy elements

Change in \(\delta^{18}\)O value

 ejemplo
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.

• 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

δ (in ‰) = \[\frac{R_x}{R_s} - 1\] x 1000 = per mil (‰)

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

**General Expression:**

\[\delta (\text{in} \ \%e) = \left[ \frac{R_x}{R_s} - 1 \right] \times 1000 = \text{per mil (‰)}\]

Where:

- \(R_x\) = heavy isotope / light isotope in sample
- \(R_s\) = 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.

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.

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.
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.

- 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

$\delta^{18}O$ (in $‰$) = \[ \frac{R_x}{R_s} - 1 \] x 1000

- $R_x = \text{heavy isotope} / \text{light isotope in sample}$
- $R_s = \text{heavy isotope} / \text{light isotope in standard}$

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.

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

1. 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.
2. Isotopes of water are relatively conservative in reactions with the bedrock and soil materials. So, they retain their distinctive fingerprints until they mix with other waters.

Isotopes of water are ideal tracers of water sources and movement because they are constituents of water molecules.

Isotopes of water as tracers in hydrological studies:

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.

Using Isotopes to Identify Source Waters: Mixing Models

2-component mixing model:
- One Conservative Tracer
- Mass Balance Equations

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.

Let’s put in some actual tracer concentrations.

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:
  \[ \frac{C_w - C_g}{C_r - C_g} \]
- 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

2-Component Mixing Model: Calculation

\[ \frac{-15 - (-20)}{-10 - (-20)} = \frac{5}{10} = 50\% \]
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)

Example: Application of Isotopes in Hydrological studies

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

Site Description

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

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.

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

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.

$\delta D = 7.4 \delta^{18}$O + 3.8
$R^2=0.997$

Fig. 3. $\delta^{18}$O and $\delta D$ 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.
### Two-Component Mixing Model

To understand **source waters** that might contribute to flow in the river, δ¹⁸O values are plotted against sulphate of stream waters along with potential end members.

![Graph](image)

### 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 ($p < 0.002$).

### 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.

### 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.
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

References


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

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

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

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

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

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.

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.
Challenges

- 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

References

143
Two-component mixing models:
The glacier outflow (go) and groundwater (gw) water components of streamflow can be estimated using

\[ Q = \frac{C}{\delta^{18}O} \]

where \( Q \) is volume flow rate, \( C \) is \( \delta^{18}O \) value, and the subscripts describe the water source. 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.
Large areas of glaciers and glacial lakes

Current Vulnerabilities

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

Potential areas impacts of climate change in Bhutan

Agriculture
Water Resources
Natural Disasters
Human Health
Forests & Biodiversity

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
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

Generating climate change scenarios using PRECIS

• Scenarios based on:
  – A1B emissions scenario (Middle emissions projection)
  – 2 GCMs
    • ECAM5
    • 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

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
    • ECAM5
    • 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

Climate Change Scenarios

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

Caution!
Scenarios are not predictions!

The scenario presented is based on:
- one Global Emissions Scenario (A1B) only
- two Global Circulation Models (GCMs) for A1B emissions scenario
  - ECHAM5 A1B
  - HadCM3Q A1B

Multi-model scenarios needed in next assessment

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
Adapting to Climate Change

Spatial Changes: Annual rainfall

1980-2009

2010-2039

2040-2069

Summary of Climate Change Projections

Temperature changes compared to present (1980-2009)

- Annual Mean temperatures:
  - Increase of ~ 0.8 oC - 1.0 oC by 2010-2039
  - Increase of ~ 2.0 oC - 2.4 oC by 2040-2069

- Summer/monsoon season temperatures:
  - Increase of up to ~ 0.8 oC by 2010-2039
  - Increase of up to ~ 2.1 oC by 2040-2069

- Winter season temperatures:
  - Increase of ~ 1.2 oC by 2010-2039
  - Increase of ~ 2.8 oC by 2040-2069

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 scenario
  - ECHAM5 A1B
  - HadCM3Q A1B

Multi-model scenarios needed in next assessment

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

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

Ongoing Implementation of NAPA

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

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. DGM, 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)
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;

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

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"

Overview

Center for Water, Climate and Environmental Policy

Main Focus Area: CWCEP

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

THANK YOU
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 grassroots 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 decision making.

- National Level: good climate scenarios and data for national level assessments and prioritization
- Local level vulnerabilities and realities should inform national level planning and prioritization
- 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

Overview

Center for Water, Climate and Environmental Policy

Dawa Yoezer
Forestry Officer
UWICER

Main Focus Area: CWCEP
- Understanding Ecological Aspects
- Management & Policy aspects of water resources

Partners & Collaborators

- CWCEP, UWICER
- DoFPS
- Watershed Mgmnt. Division, National Parks and Territorial Divisions
- NHCM
- Hydrometrology Services
- Royal University of Bhutan College of Natural Resources, Sherubtse
- NGO’s
- Royal Society for Protection of Nature
- WWF-Bhutan
- National Environment Commission Climate Change Division & Water Resources Coordination Division

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

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

- 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

- Documenting Ecological & Socio-cultural Significance of HAWs

- 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/

- 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 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

Longterm Hydrometeorology studies

• Longterm climate monitoring in the highland valleys of WCNP
• Set up three weather stations

• Citizen Science Project
• Record climate and plant data
**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

**Longterm watershed and stream ecology assessment in the Research Preserve**

- Longterm wildlife, tree biomass and climate and watershed assessment 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

**Longterm Hydrometeorology studies**

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

**Citizen Science Project**

- Record climate and plant data

---

**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

---

**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 (2014-2018)
- 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:**

- Life zone ecology of Bhutan & 2002 – incorporated
- Synoptic and local analysis of relationship between climate and forest in Bhutan Himalaya 2011

---

**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
- Water resources Assessments
  - Water quality - Biotic indicator
    - Scoping
- Policy guidelines

TashiDélek

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

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1130</td>
<td>Rural drinking water supply and quality</td>
<td>Mr. Karma, MoH</td>
</tr>
<tr>
<td>1150</td>
<td>Urban water supply</td>
<td>Ms. Dechen Yangdon, MoWHS</td>
</tr>
<tr>
<td>1210</td>
<td>Water for irrigation</td>
<td>Mr. Kelzang Tenzin Dorji, MoAF</td>
</tr>
<tr>
<td>1225</td>
<td>Water for community and its livelihood</td>
<td>Mr. Kinley Dorji, River Guides of Panghung</td>
</tr>
<tr>
<td>1245</td>
<td>Rainwater harvesting</td>
<td>Mr. Jamyang Phuntscho, Tarayana Foundation</td>
</tr>
<tr>
<td>1300</td>
<td>Q&amp;A Session</td>
<td></td>
</tr>
</tbody>
</table>

Rural Drinking Water Supply & Quality
Presented By

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

- MoSS (1974-1993) PWD
- MoH (2002-...)

Public Health Engineering Division (PHED)

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

**Thank You For Listening**
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 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

Overview Status of WSP

<table>
<thead>
<tr>
<th>Activities</th>
<th>Scheme covered</th>
<th>Participants</th>
<th>Dzongkhag WSP trainer</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSP in Phase II</td>
<td>38</td>
<td>956</td>
<td>12</td>
<td>7 Schools &amp; Monastic Institutions</td>
</tr>
<tr>
<td>WSP in Phase III</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural WSP ToT</td>
<td>81</td>
<td>1864</td>
<td>118</td>
<td></td>
</tr>
<tr>
<td>Rural WSP Scale up</td>
<td>212</td>
<td>3406</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institutional WSP (school &amp; Monastic)</td>
<td>37</td>
<td>1795</td>
<td>2</td>
<td>20 school &amp; 10 monastic institutions</td>
</tr>
<tr>
<td>Total</td>
<td>368</td>
<td>10381</td>
<td>132</td>
<td></td>
</tr>
</tbody>
</table>

Nation Wise RWS MIS status

Dzongkhag wise RWS MIS status

Gewog wise RWS MIS status
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

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.

5. Provision of water quality testing kits.
   - Testing kits for pH, turbidity and residual chlorine were provided.

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:

<table>
<thead>
<tr>
<th>Town</th>
<th>Activities</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsirang</td>
<td>Providing and Laying of Drinking Water Supply Distribution</td>
<td>On-going</td>
</tr>
<tr>
<td></td>
<td>Network for Damphu Town</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rehabilitation of Existing Water Supply Scheme in Damphu Town</td>
<td></td>
</tr>
<tr>
<td>Paro</td>
<td>Providing and Laying Transmission Laying from Bondey WTP to</td>
<td>On-going</td>
</tr>
<tr>
<td></td>
<td>Tshongdue</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Augmentation of Bondey WTP 2ml</td>
<td>On-going</td>
</tr>
<tr>
<td></td>
<td>Distribution Network for Tshongdue</td>
<td>Tender on-going</td>
</tr>
</tbody>
</table>

Achievements in the 11th FYP

8. Projects under GOI-PTA:

<table>
<thead>
<tr>
<th>Town</th>
<th>Activities</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsirang</td>
<td>Rehabilitation and Augmentation of Existing Water Supply of</td>
<td>completed</td>
</tr>
<tr>
<td></td>
<td>Mongar Town</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction of Compact Water Treatment Plant (1.5 MLD) at</td>
<td>Work awarded</td>
</tr>
<tr>
<td></td>
<td>Kadam, Mongar</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction of Compact Water Treatment Plant (1.0 MLD) at</td>
<td>Work awarded</td>
</tr>
<tr>
<td></td>
<td>Gyelposhing, Mongar</td>
<td></td>
</tr>
</tbody>
</table>

Achievements in the 11th FYP

8. Projects under GOI-PTA:

<table>
<thead>
<tr>
<th>Town</th>
<th>Activities</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>P/ling</td>
<td>Improvement of existing water supply system</td>
<td>completed</td>
</tr>
<tr>
<td></td>
<td>Construction of borewell, laying of pumping main and</td>
<td>Work to be</td>
</tr>
<tr>
<td></td>
<td>reservoir tanks at Ammochu LAP</td>
<td>tendered</td>
</tr>
</tbody>
</table>

Achievements in the 11th FYP

9. Technical Backstopping

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Planning, design and according technical sanction of intake and raw water main for Tingtibi,</td>
</tr>
<tr>
<td></td>
<td>Zhemgang – completed</td>
</tr>
<tr>
<td>2</td>
<td>Planning, design and according technical sanction of distribution network including storage</td>
</tr>
<tr>
<td></td>
<td>reservoir for Zhemgang – completed</td>
</tr>
<tr>
<td>3</td>
<td>Planning and design of distribution network for Ha-ex – completed</td>
</tr>
<tr>
<td>4</td>
<td>Planning, survey, design and according technical sanction for the water supply scheme for</td>
</tr>
<tr>
<td></td>
<td>Royal Academy, Mongar, Paro – completed</td>
</tr>
<tr>
<td>5</td>
<td>Survey, design and estimate for the water supply system (potable and irrigation/gardening) for</td>
</tr>
<tr>
<td></td>
<td>Supreme Court, Thimphu – completed</td>
</tr>
<tr>
<td>6</td>
<td>Planning, design and according technical sanction for the raw water supply for Gola town,</td>
</tr>
<tr>
<td></td>
<td>Sama – completed</td>
</tr>
<tr>
<td>7</td>
<td>Planning, design and according technical sanction for the water supply scheme at Takto (Druk</td>
</tr>
<tr>
<td></td>
<td>Odhinya Foundation) excluding distribution to the peripheral areas (Thangnchu middle and</td>
</tr>
<tr>
<td></td>
<td>town secondary schools, gewog administration offices, etc. – completed</td>
</tr>
</tbody>
</table>
**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
- Urban population with access to adequate (24x7) water supply.
- Urban population using improved drinking water free of fecal contamination (complying with BDWQS).
- Recovery of operation and maintenance cost through reduction of Non-Revenue Water, improve demand management, regulation of tariff etc

---

**Thank you!**

---

**Outline**

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

---

**Water Source**

- Sustainable Use of Water & Energy for Food Security

---

“National Water Symposium”
10-12 May 2017

**Water for Irrigation**

by

Kelzang Tenzin

Engineering Division, DoA

---

National Water Symposium; Technical Presentations
Key issues and challenges

1. Lack of coordination amongst stakeholders.
2. Lack of reliable data.
3. Drying up of water sources.
4. Conflicting water users.
5. Lack of resources for O&M and capacity conservation and conservation of technicians.
6. Poor demand management.
7. Lack of awareness on water source.

Future plans in 12th FYP

- Adequate, safe and sustainable urban water service improved
- 1. Urban population with access to adequate
- 2. Urban population using improved drinking
- 3. Recovery of operation and maintenance cost

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

Organigram of the Agriculture Engineering Division

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

- 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…

Wooden Flume
RRM/PC C/ RCC
HDPE Pipe (Pressurized-Gravity)
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

- 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

- Temporal & Spatial Variation of Rainfall

<table>
<thead>
<tr>
<th>Month</th>
<th>Average Annual Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>700</td>
</tr>
<tr>
<td>Feb</td>
<td>1000</td>
</tr>
<tr>
<td>Mar</td>
<td>1200</td>
</tr>
<tr>
<td>Apr</td>
<td>1500</td>
</tr>
<tr>
<td>May</td>
<td>1800</td>
</tr>
<tr>
<td>Jun</td>
<td>2200</td>
</tr>
<tr>
<td>Jul</td>
<td>2500</td>
</tr>
<tr>
<td>Aug</td>
<td>2800</td>
</tr>
<tr>
<td>Sep</td>
<td>3000</td>
</tr>
<tr>
<td>Oct</td>
<td>3200</td>
</tr>
<tr>
<td>Nov</td>
<td>3500</td>
</tr>
<tr>
<td>Dec</td>
<td>3800</td>
</tr>
</tbody>
</table>

- Electricity Supply Grid not Designed for Agriculture or Irrigation Development.
- Distant Source; Lengthy Irrigation Canal (Along Contour Line).
- Fragmented Land Holdings.
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”

Outline

- Our Donors
- Introduction
- Vision
- Objectives
- Our Services
- Conservation Mandates
- Organogram
- Our Strength
- Challenges
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 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 Vision
“TO BE THE PREMIER ECOTOURISM SERVICE PROVIDER IN THE COMMUNITY AND BEYOND”

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

General Manager

Sales & Promotion

Finance

Resource Operation

Our Strength

• We are professionally trained.
• Being under the buffer zone of R M N P.
• 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

Protection of water sources

Construction of reservoir tanks
Climate Resilient Water Harvesting

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Tsangkha</th>
<th>No. of reservoir tanks constructed</th>
<th>No. of Water User Committees formed</th>
<th>No. of climatic water harvesting tanks installed</th>
<th>No. of household beneficiaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Samtse</td>
<td>9</td>
<td>7</td>
<td>12</td>
<td>247</td>
</tr>
<tr>
<td>2.</td>
<td>Mongar</td>
<td>20</td>
<td>9</td>
<td>54</td>
<td>383</td>
</tr>
<tr>
<td>3.</td>
<td>Pemagatshel</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>198</td>
</tr>
<tr>
<td>4.</td>
<td>Turang</td>
<td>3</td>
<td>7</td>
<td>31</td>
<td>268</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>36</td>
<td>31</td>
<td>109</td>
<td>1,096</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Time</th>
<th>Session Title</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>1430</td>
<td>Hydropower development in Bhutan</td>
<td>Mr. Passang, DHPS</td>
</tr>
<tr>
<td>1450</td>
<td>Hydropower energy</td>
<td>Mr. Sonam Dorji, DGPC</td>
</tr>
<tr>
<td>1510</td>
<td>The Economics of Ecosystem and Biodiversity (TEEB) study in Bhutan</td>
<td>Mr. Sangay Wangchuk, UWICER</td>
</tr>
<tr>
<td>1530</td>
<td>Tea Break</td>
<td></td>
</tr>
<tr>
<td>1600</td>
<td>Natural capital valuation in Chumkhar chhu sub-basin</td>
<td>Mrs. Nagdrel Lhamo, WWF-Bhutan</td>
</tr>
<tr>
<td>1620</td>
<td>Bhutan water risk scenarios and opportunities</td>
<td>Mrs. Sonam Choden, WWF-Bhutan</td>
</tr>
<tr>
<td>1640</td>
<td>Issues, challenges and opportunities of water supply system: Mawongpa Solutions</td>
<td>Mr. Sonam Dorji, Mawongpa Water Solutions</td>
</tr>
<tr>
<td>1700</td>
<td>Q&amp;A Session</td>
<td></td>
</tr>
</tbody>
</table>

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
- 22,800 MW (71 sites of >10 MW) techno-economic potential as per PSMP 2003-2022

Integration with Indian Grid

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

Projects under Operation

<table>
<thead>
<tr>
<th>Sl.</th>
<th>Power Plant</th>
<th>IC (MW)</th>
<th>COD</th>
<th>Bilateral Assistance</th>
<th>Financing Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chhukha</td>
<td>336</td>
<td>1986-88</td>
<td>GoI</td>
<td>60% Grant &amp; 40% Loan at 5% interest rate</td>
</tr>
<tr>
<td>2</td>
<td>Kurichhu</td>
<td>60</td>
<td>2001-02</td>
<td>GoI</td>
<td>60% Grant &amp; 40% Loan at 10.75% interest rate</td>
</tr>
<tr>
<td>3</td>
<td>Basochhu-I</td>
<td>24</td>
<td>2001</td>
<td>Austria</td>
<td>38% Grant &amp; 49% interest free Loan and rest by ROGDI</td>
</tr>
<tr>
<td>4</td>
<td>Basochhu-II</td>
<td>40</td>
<td>2005</td>
<td>Austria</td>
<td>Full Loan at 7.786% interest rate</td>
</tr>
<tr>
<td>5</td>
<td>Tala</td>
<td>1,020</td>
<td>2006-07</td>
<td>GoI</td>
<td>60% Grant and 40% Loan at 9% interest rate</td>
</tr>
<tr>
<td>6</td>
<td>Dzongkha</td>
<td>126</td>
<td>2015</td>
<td>DGPC/NPPF/TATA Power</td>
<td>PPP</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sl.</th>
<th>Project</th>
<th>IC (MW)</th>
<th>Implementation Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Punatsangchhu-I</td>
<td>1,200</td>
<td>IG</td>
</tr>
<tr>
<td>2</td>
<td>Mangdechhu</td>
<td>720</td>
<td>IG</td>
</tr>
<tr>
<td>3</td>
<td>Punatsangchhu-II</td>
<td>1,020</td>
<td>IG</td>
</tr>
<tr>
<td>4</td>
<td>Khongchhu</td>
<td>600</td>
<td>JV</td>
</tr>
<tr>
<td>5</td>
<td>Matho</td>
<td>118</td>
<td>PPP (DGPC + )</td>
</tr>
</tbody>
</table>

Projects under development

<table>
<thead>
<tr>
<th>Sl.</th>
<th>Project</th>
<th>IC (MW)</th>
<th>Implementation Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Dzongkha</td>
<td>126</td>
<td>PPP</td>
</tr>
</tbody>
</table>

Integration with Indian Grid (NTGMP)

Huge Potential
11th FYP activities

1. Under Reconnaissance Studies – 7 projects
2. Under PFS – 9 projects
4. Under construction – 3,658MW (>15%: 5 projects) to be commissioned from 2018-2022

Planning & investigation
1. RSR
2. PFS
3. DPR

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.

Commission 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 ($3.2bn/$18.8bn) and about 14.30% ($3.9bn/$27.0bn) to GDP, 40% of trade ($1.9bn/$15.25 bn)

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

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

2. Lean season deficit
   - Firm power of 35 MW (production from 5 projects during lean months)
   - Peak demand touched 363.50 MW
   - Affords to enhance lean season availability
   - Currently imports from India during lean months

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

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)

Tashi Delek!
**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 the hydropower sector for accelerated development of the hydropower sector in Bhutan;

**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.

**Contents**

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

**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.

**Plants under Operation**

- 336 MW Chukha Hydropower Plant
- 1020 MW Tala Hydropower Plant
- 24+40 MW Basochhu Hydropower Plant
- 60 MW Kurichhu Hydropower Plant
Chukha Hydropower Plant
- Conceived in the early 1970s (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, 1988 and by August 22, 1988 all the other three Units were commissioned.

- **Features:**
  - Installed Capacity: 336 MW (84 x 4 Units)
  - Project Cost: Nu. 2,465 million
  - 40 m high dam, 2 intake gates, 6.5 km HRT
  - Underground Powerhouse
  - Diverted Tichhalunchhu to reservoir (right) & Chukha to Surge Shaft to gain additional 67 GWh during the mean seasons.

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 Wanglaphashong
  - Project Cost: Nu. 3,261 million
  - Upper Stage: 2.5 km HRT, 1.4 km penstock, 21 MW + 2 Units, with annual generation of 106 GWh.
  - Lower Stage: Water available through a pondage scheme from upper stage delivered on 2.51 km penstock; Surface PH (2 x 20 MW); Mean annual generation: 146 GWh.

Kurichhu Hydropower Plant
- 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.

- **Features:**
  - 60 MW (15 x 4), at Ghyogphashang, Mongar in the East
  - Rest 3 units were commissioned by May 2002.
  - Project Completion Cost: Nu. 5,600 million
  - Has 55 m concrete gravity dam, 292.3 m crest length
  - Mean annual generation: 400 GWh
  - Has Fish Ladder for migration of fish.

Subsidiary Companies
- BHEC - Engineering Section
  - 30% Government Stake (Government of Bhutan & Austrian Federal Ministry of Finance 30% & ADB 40%)
  - Operations commenced since October 2004 – more & complexing of works is underway.
  - Project Establishment Cost: Nu. 1.17 billion
- TKB – Fully BHEC owned subsidiary company since April 2006
  - Managing 350 MW Kurichhu Hydropower Project in Trongsa under construction.
  - Estimated Project Cost: Nu. 10 billion
- NDB – Fully BHEC owned subsidiary company since April 2006
  - Managing 336 MW Chukha Hydropower Project in Wangdiphodrang under construction.
  - Estimated Project Cost: Nu. 10 billion
- ADB is the lead financier USD 12.61 billion
- Currently: Completed infrastructure works, main works under progress (CHP, PH etc.)
- Commission is expected during 2017
- Commission is expected during 2017

Druk Green Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Capacity (MW)</th>
<th>Cost (Nu.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorjling DPR completed</td>
<td>1,715</td>
<td></td>
</tr>
<tr>
<td>Nyeru Amari (1+2) DFR</td>
<td>443</td>
<td></td>
</tr>
<tr>
<td>Druk Bindu DFR</td>
<td>18 + 8</td>
<td></td>
</tr>
<tr>
<td>Gamri (1+2) PFR</td>
<td>45 + 85</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,717</strong></td>
<td></td>
</tr>
</tbody>
</table>
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!

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 audiences;
  - Video and Radio broadcasts in BBS;

Themes
- River Catchment Protection;
- Plantations;
- Waste Management;
- Hydropower and Revenue Generation;
- Plantations/collaboration;

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!
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

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

Themes
- River Catchment Protection;
- Plantations;
- Waste Management;
- Hydropower and Revenue Generation;
- Plantations/collaboration;

The Economics of Ecosystems and Biodiversity
[TEEB – Bhutan]

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 CBD meeting in Poznan, Germany, where Environment Ministers from eight developed countries (CBD) and five developing countries (Brazil, China, India, Mexico and South Africa) called for a study to analyze the global economic benefits of biodiversity, costs of biodiversity loss, and costs of taking 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.

www.uwice.gov.bt

Thank you LA
An initial estimate of the value of ecosystem services in Bhutan

Ma Kubisewski (1), Robert Costaana (1), Jharn Deja (2), Philip Thoren (3), Renato Fisherina (3)


Abstract

A country study was conducted for Bhutan to determine the valuation of ecosystem services using a benefit transfer methodology. The study was based on a review of existing literature and primary data collection. The study estimated the total ecosystem service value in Bhutan to be approximately USD 105 million (385 million Bhutanese Rupees), highlighting the importance of the good management practices for maintaining the sustainability of these services. The study found that the total value of ecosystem services in Bhutan is high, with the majority of the benefits accruing to people under the poverty line, 7% of the national GDP, and 1% of the local level. Based on this, the project aim of improving GDP and local level in Bhutan's natural assets and biodiversity will be achieved.

The Economics of Ecosystems and Biodiversity

WORKSHOP REPORT

11 - 13 March, 2014

TEEB- Bhutan

- Assess changes in ES under different hydropower diversification scenarios

- Inform:
  1. Sustainable Hydropower Development Policy 2008

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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BAU</td>
<td>340,000</td>
<td>335,000</td>
<td>330,000</td>
<td>325,000</td>
<td>320,000</td>
<td>2000</td>
<td>2004</td>
<td>2008</td>
<td>2012</td>
<td>2016</td>
<td>2020</td>
</tr>
<tr>
<td>Punatsangchhu Hydro + ER</td>
<td>3.5 M</td>
<td>3.75 M</td>
<td>2.5 M</td>
<td>1.25 M</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Punatsangchhu BAU</td>
<td>3.5 M</td>
<td>3.75 M</td>
<td>2.5 M</td>
<td>1.25 M</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[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
The SDR (Sediment Delivery Ratio) Model

Understanding where the sediments are produced and delivered allows managers 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 output from the sediment model includes 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.

Significance of modeling Sediment/Erosion

Growing evidence of land degradation in Bhutan.
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 show higher sedimentation.
3. Demonstrate the kind of study and results that can be expected from an InVEST model for use in conservation-related activities in priority areas.
4. Develop capacity in the government as well as in WWF on ecosystem service valuation.

Study Area: Chamkhar Chhu Sub Basin

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

<table>
<thead>
<tr>
<th>Project</th>
<th>Installed Capacity (MW)</th>
<th>Annual Energy (GWh)</th>
<th>Tariff (N/kg)</th>
<th>Annual Revenue (N/MM)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamkhar Chhu A</td>
<td>179</td>
<td>5941</td>
<td>4.79</td>
<td>23,518.18</td>
<td>23%</td>
</tr>
<tr>
<td>Chamkhar Chhu B</td>
<td>518</td>
<td>24,264</td>
<td>3.87</td>
<td>9,386.48</td>
<td>79%</td>
</tr>
<tr>
<td>Chamkhar Chhu C</td>
<td>42.8</td>
<td>1,217.8</td>
<td>4.87</td>
<td>22,698.6</td>
<td>Installed 22%</td>
</tr>
<tr>
<td>Chamkhar Chhu D</td>
<td>364</td>
<td>1,894.7</td>
<td>4.43</td>
<td>8,347.37</td>
<td>Installed 21%</td>
</tr>
<tr>
<td>Chamkhar Chhu E</td>
<td>425</td>
<td>4,973.3</td>
<td>4.43</td>
<td>8,347.37</td>
<td>Installed 25%</td>
</tr>
<tr>
<td>Gesarling</td>
<td>320</td>
<td>2,305.5</td>
<td>4.43</td>
<td>10,106.5</td>
<td>69%</td>
</tr>
<tr>
<td>Guarchhu</td>
<td>261</td>
<td>1,085.8</td>
<td>4.43</td>
<td>4,816.3</td>
<td>Installed 96%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>46,808.3</td>
<td></td>
</tr>
</tbody>
</table>

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

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 upstream such as watershed management, sustainable land use practices etc.

Tools & Data

<table>
<thead>
<tr>
<th>Data Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>LULC</td>
<td>LCMP, 2010</td>
</tr>
<tr>
<td>DEM</td>
<td>30 meter ASTER</td>
</tr>
<tr>
<td>Erosivity &amp; Erodibility</td>
<td>Biophysical parameters</td>
</tr>
<tr>
<td>Rainfall</td>
<td>Emanuel-Hersch method</td>
</tr>
<tr>
<td>Stream flow</td>
<td>Natural Land use map</td>
</tr>
<tr>
<td>Hydrology</td>
<td>Natural Land use map</td>
</tr>
<tr>
<td>Ecosystem types</td>
<td>Natural Land use map</td>
</tr>
<tr>
<td>Environmental</td>
<td>Natural Land use map</td>
</tr>
<tr>
<td>Biophysical</td>
<td>Natural Land use map</td>
</tr>
</tbody>
</table>

National Water Symposium; Technical Presentations
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 show 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 government as well as in WWF on ecosystem service valuation.

Study Area: Chamkharchhu Sub Basin

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

- 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 upstream 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

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 remediation 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 the river (Conservation).

Top 3 sediment exporting land-cover types.

<table>
<thead>
<tr>
<th>Land Cover (Code)</th>
<th>Total annual sediment export (tonnes)</th>
<th>% of Total annual sediment export</th>
<th>Area (ha)</th>
<th>% of High sediment export area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Shrub (SS)</td>
<td>612,273.80</td>
<td>69.14</td>
<td>60,226</td>
<td>100</td>
</tr>
<tr>
<td>2. Meadows (GP)</td>
<td>76,687.60</td>
<td>8.76</td>
<td>161,918</td>
<td>20.90</td>
</tr>
<tr>
<td>3. Agriculture</td>
<td>55,054.10</td>
<td>6.27</td>
<td>108,398</td>
<td>13.66</td>
</tr>
</tbody>
</table>

Area of Interest (AOI)

<table>
<thead>
<tr>
<th>Sediment export for Whole basin</th>
<th>Baseline scenario</th>
<th>Restoration scenario</th>
<th>Degradation scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount (tonnes per year)</td>
<td>631,339.62</td>
<td>101,324.58</td>
<td>-530,015.04</td>
</tr>
<tr>
<td>% of Total annual sediment export</td>
<td>80%</td>
<td>10%</td>
<td>90%</td>
</tr>
<tr>
<td>Absolute change (tonnes per year)</td>
<td>-530,015.04</td>
<td>447.36</td>
<td>2,828,254.70</td>
</tr>
<tr>
<td>Percent change (%)</td>
<td>-83.95</td>
<td>0.52</td>
<td>447.36</td>
</tr>
<tr>
<td>Sediment export for Dam basin</td>
<td>300,249.44</td>
<td>78,543.48</td>
<td>-221,705.96</td>
</tr>
<tr>
<td>Amount (tonnes per year)</td>
<td>300,249.44</td>
<td>78,543.48</td>
<td>-221,705.96</td>
</tr>
<tr>
<td>% of Total annual sediment export</td>
<td>80%</td>
<td>10%</td>
<td>90%</td>
</tr>
<tr>
<td>Absolute change (tonnes per year)</td>
<td>-221,705.96</td>
<td>444.51</td>
<td>1,334,936.50</td>
</tr>
<tr>
<td>Percent change (%)</td>
<td>-73.84</td>
<td>0.47</td>
<td>444.51</td>
</tr>
</tbody>
</table>

For Kurjey basin

<table>
<thead>
<tr>
<th>Sediment export for Whole basin</th>
<th>Baseline scenario</th>
<th>Restoration scenario</th>
<th>Degradation scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount (tonnes per year)</td>
<td>113,072.47</td>
<td>33,211.40</td>
<td>-79,861.07</td>
</tr>
<tr>
<td>% of Total annual sediment export</td>
<td>10%</td>
<td>8%</td>
<td>92%</td>
</tr>
<tr>
<td>Absolute change (tonnes per year)</td>
<td>-79,861.07</td>
<td>7.27</td>
<td>90,915.57</td>
</tr>
<tr>
<td>Percent change (%)</td>
<td>-70.63</td>
<td>0.81</td>
<td>7.27</td>
</tr>
</tbody>
</table>

Sediment retention index for Whole basin

<table>
<thead>
<tr>
<th>sediment retention index</th>
<th>Baseline scenario</th>
<th>Restoration scenario</th>
<th>Degradation scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount (tonnes per year)</td>
<td>82,938,210.75</td>
<td>83,471,226.04</td>
<td>533,066.19</td>
</tr>
<tr>
<td>% of Total annual sediment export</td>
<td>100%</td>
<td>99%</td>
<td>0.64</td>
</tr>
<tr>
<td>Absolute change (tonnes per year)</td>
<td>-533,066.19</td>
<td>3,459,594.36</td>
<td>80,113,007.17</td>
</tr>
<tr>
<td>Percent change (%)</td>
<td>-83.95</td>
<td>447.36</td>
<td>80,113,007.17</td>
</tr>
</tbody>
</table>

For Dam basin

<table>
<thead>
<tr>
<th>Sediment retention index</th>
<th>Baseline scenario</th>
<th>Restoration scenario</th>
<th>Degradation scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount (tonnes per year)</td>
<td>47,774,413.49</td>
<td>47,999,218.32</td>
<td>-224,804.83</td>
</tr>
<tr>
<td>% of Total annual sediment export</td>
<td>100%</td>
<td>99%</td>
<td>0.47</td>
</tr>
<tr>
<td>Absolute change (tonnes per year)</td>
<td>-224,804.83</td>
<td>444.51</td>
<td>1,331,837.65</td>
</tr>
<tr>
<td>Percent change (%)</td>
<td>-47.02</td>
<td>0.47</td>
<td>1,331,837.65</td>
</tr>
</tbody>
</table>

For Kurjey basin

<table>
<thead>
<tr>
<th>Sediment retention index</th>
<th>Baseline scenario</th>
<th>Restoration scenario</th>
<th>Degradation scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount (tonnes per year)</td>
<td>1,965,517.29</td>
<td>1,856,103.68</td>
<td>-109,413.61</td>
</tr>
<tr>
<td>% of Total annual sediment export</td>
<td>100%</td>
<td>99.99</td>
<td>0.01</td>
</tr>
<tr>
<td>Absolute change (tonnes per year)</td>
<td>-109,413.61</td>
<td>4.63</td>
<td>90,915.57</td>
</tr>
<tr>
<td>Percent change (%)</td>
<td>-5.57</td>
<td>0.46</td>
<td>90,915.57</td>
</tr>
</tbody>
</table>
Discussion

- The InVEST SDR modeling results for Chamkhar Chhu basin appear to indicate that the sediment production processes in the Chamkhar Chhu 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 especially 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).

WWF has over 5 million supporters

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

WWF was founded in 1961

WWF is in over 100 countries, on 6 continents

WWF is in over 100 countries, on 6 continents

WWF is in over 100 countries, on 6 continents
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.

Who’s been on the journey

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

- Department of Water, Ministry of Works and Human Settlement
- Department of Agriculture, Ministry of Agriculture and Forests
- Department of Forests and Park Services, Ministry of Agriculture and Forests
- Department of Cottage and Small Industries, Ministry of Economic Affairs
- Department of Hydropower, Ministry of Energy
- Department of Disaster Management, Ministry of Home and Cultural Affairs
- Department of Public Health, Ministry of Health
- Income Tax Assessment and Verification
- National Environment Commission
- United Nations Development Programme
- National Environment Commission
- Bhutan Foundation
- Royal Society for Protection of Nature
- Asian Development Bank and Integrated River Basin Management team leader
- United Nations Environment Programme
- National Environment Commission
- Bhutan Foundation
- Royal Society for Protection of Nature
- Asian Development Bank and Integrated River Basin Management team leader

The process in Bhutan

- 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

Range of Risks Arising from the Threats

- Flash Floods
- Landslides
- GLOFS
- Water Shortages
- Sedimentation
- Loss of Biodiversity
- Drying Streams / Dry Season Low Flows
- Water Quality Challenges / Pollution

Threats to Bhutan’s Water Resources

- Climate Change
- Inadequate Watershed Management
- Hydropower Expansion
- Agricultural Intensification
- Urbanization and Industrialization
- Institutional Capacity Challenges
- Linear Infrastructure Development
- Carbon (with availability of future LC scenarios)

Three plausible Scenarios

- Hydro Bhutan
  - Centralised growth
  - Hydropower driving economy
  - 20GW by 2035
  - Increases in storage dams
  - Environmental impacts rise
  - Cumulative impact
  - Assessments key
  - Distribute micro hydro
- Brand Bhutan
  - Decentralised growth
  - Agriculture and tourism driving the economy
  - Happy natural brand leveraged for community report
  - Natural and ecosystem levy
  - Watershed impact grow
- Green Bhutan
  - Growth in hubs
  - Industry driving growth
  - Industrial parts and surrounding settlements drow water
  - Water quality impacts grow
  - Industry is green and low carbon

15 Asian Development Bank and Integrated River Basin Management team leader
**HYDRO BHUTAN**

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015 - 2020</td>
<td>7 GW complete</td>
</tr>
<tr>
<td></td>
<td>Mainly Run of River</td>
</tr>
<tr>
<td></td>
<td>No Multipurpose</td>
</tr>
<tr>
<td></td>
<td>Built across many basins</td>
</tr>
<tr>
<td></td>
<td>India = primary investment + offtake</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020 - 2025</td>
<td>Implementation of CIA, basin and spatial optimization</td>
</tr>
<tr>
<td></td>
<td>Conversations emerge about local benefit sharing</td>
</tr>
<tr>
<td></td>
<td>Environmental and social consequences</td>
</tr>
<tr>
<td></td>
<td>Move towards redistributive model</td>
</tr>
</tbody>
</table>

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

**Future trade-offs**

- 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

**Future trade-offs ( cont.)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015 - 2020</td>
<td>Tourism grows, moves to decentralized model</td>
</tr>
<tr>
<td></td>
<td>People leave land</td>
</tr>
<tr>
<td></td>
<td>Govt. places emphasis on creating opportunity in Ag.</td>
</tr>
<tr>
<td>2020 - 2025</td>
<td>Linear infra grows to support tourism</td>
</tr>
<tr>
<td></td>
<td>Forest cover and watershed impacts (sediment for hydro)</td>
</tr>
<tr>
<td></td>
<td>Shift to market-based ag + niche products</td>
</tr>
<tr>
<td></td>
<td>Ag subsidies + irrigation investment</td>
</tr>
<tr>
<td></td>
<td>Hydro as support; circumspect growth</td>
</tr>
</tbody>
</table>

**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

---

**BRAND BHUTAN**

**Assumptions:**
- Decentralization
- Growth in tourism
- Retain emphasis on high value tourism
- Commitment to food self-sufficiency

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015 - 2020</td>
<td>Tourism grows, moves to decentralized model</td>
</tr>
<tr>
<td></td>
<td>People leave land</td>
</tr>
<tr>
<td></td>
<td>Govt. places emphasis on creating opportunity in Ag.</td>
</tr>
<tr>
<td>2020 - 2025</td>
<td>Linear infra grows to support tourism</td>
</tr>
<tr>
<td></td>
<td>Forest cover and watershed impacts (sediment for hydro)</td>
</tr>
<tr>
<td></td>
<td>Shift to market-based ag + niche products</td>
</tr>
<tr>
<td></td>
<td>Ag subsidies + irrigation investment</td>
</tr>
<tr>
<td></td>
<td>Hydro as support; circumspect growth</td>
</tr>
</tbody>
</table>

**Future trade-offs**

- 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

**Future trade-offs ( cont.)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015 - 2020</td>
<td>Tourism grows, moves to decentralized model</td>
</tr>
<tr>
<td></td>
<td>People leave land</td>
</tr>
<tr>
<td></td>
<td>Govt. places emphasis on creating opportunity in Ag.</td>
</tr>
<tr>
<td>2020 - 2025</td>
<td>Linear infra grows to support tourism</td>
</tr>
<tr>
<td></td>
<td>Forest cover and watershed impacts (sediment for hydro)</td>
</tr>
<tr>
<td></td>
<td>Shift to market-based ag + niche products</td>
</tr>
<tr>
<td></td>
<td>Ag subsidies + irrigation investment</td>
</tr>
<tr>
<td></td>
<td>Hydro as support; circumspect growth</td>
</tr>
</tbody>
</table>

**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

---

**GREEN BHUTAN**

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015 - 2020</td>
<td>Shift from cottage industries to value-addition, processing</td>
</tr>
<tr>
<td></td>
<td>Growth in agro-based industries + minerals beneficiation</td>
</tr>
<tr>
<td></td>
<td>Industrial sector drives job growth</td>
</tr>
<tr>
<td>2020 - 2025</td>
<td>Urban demand for processed goods</td>
</tr>
<tr>
<td></td>
<td>Hydro plays supporting role</td>
</tr>
<tr>
<td></td>
<td>Shift towards Green Economy (transformational low carbon economy)</td>
</tr>
<tr>
<td></td>
<td>Export-orientation; competitive adv.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>2025 - 2035</td>
<td>Impacts on water quality</td>
</tr>
<tr>
<td></td>
<td>Strong regulation of water quality; need for better siting</td>
</tr>
<tr>
<td></td>
<td>Investment in water technology + infra</td>
</tr>
<tr>
<td></td>
<td>F&amp;B partnerships</td>
</tr>
<tr>
<td></td>
<td>Industrial brand</td>
</tr>
<tr>
<td></td>
<td>Equity tensions</td>
</tr>
<tr>
<td></td>
<td>Disaster Mgmt = flood zoning</td>
</tr>
</tbody>
</table>

**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

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.

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.

Reports available on WWF Bhutan and NEC website
http://www.wwfbhutan.org.bt/news_stories.cfm?2278150/WATER%2Din%2DBhutans%2Deconomy

Mawongpa Water Solutions, Machineries & Equipment

Prefabricated water tanks and other water infrastructures.

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

- Multi layer food grade anti algae.
- UV stabilized.
- Stretch resistant.
- 3 layers of PVC fabric.
- Tested up to 2kg/cm².
- Liner will not affect taste and odor.

Accessories

Roof platform

Safety cage

manhole

Ladder
INTRODUCTION

2009-2010 Treatment plants.

Electro-mechanical Storage 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
  • Multi layer food grade anti algae.
  • UV stabilized.
  • Stretch resistant.
  • 3 layers of PVC fabric.
  • Tested up to 2kg/cm².
  • Liner will not affect taste and odor.

Accessories
  • Roof platform
  • Safety cage
  • Ladder
  • manhole

Other applications.

Nozzles
  • Turbine Vent

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.
Tashi Delek
Sonam Dorji
301, building No.7, Olakha, Thimphu; Bhutan
Mobile: 17115539
sdorji25@gmail.com
Acknowledgement

The National Water Symposium was organized with the generous support of USAID through the WWF Conservation and Adaptation in Asia’s High Mountain Landscapes and Communities Project and WWF Living Himalayas Initiatives. The organizers are very grateful to these donors for their financial support.

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.

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.