NOTE FOR THE READER OR PRESENTER:

- Talking points and additional resources are in the “notes” section of each slide
- **Bold text** highlights the main points and could be read aloud during a presentation, while non-bold text provides additional supporting information
NATURE-BASED SOLUTIONS FOR DISASTER RISK MANAGEMENT

River flood hazards

Photo credit: Flickr/Sergio Tittarini
MANY TERMS FOR “NATURE-BASED SOLUTIONS”
PRESENTATION STRUCTURE

- Context
- The solutions:
  - Floodplains and bypasses
  - Inland wetlands
  - Stream banks and beds
  - Upland forests
- Wrap-up
RIVER FLOODING

- Average 5,900 lives lost annually
- 2.3 billion people have been negatively affected in last 20 yrs.
- Average annual flood losses exceed $23 billion

River flooding is essential:
- Productive and diverse ecosystems
- Food for hundreds of millions of people
Hazard  *  Exposure  *  Vulnerability

Photos/Figure (L-R): Wikipedia/NOAA; Wikipedia/KennyOMG; Wikipedia/Kumarrakajee
INCREASING FLOOD RISK

- **Development, climate change, and aging infrastructure**
- Population in floodplains increased by 114% (1970-2010)
- Economic losses increasing 6.3%/yr

Global Projections of River Flood Risk in a Warmer World

With a 2°C increase, 170% increase in damages and affected population.

Source: Alfieri et al. 2016
STRUCTURAL STRATEGIES

Nature-based Solutions (NBS)

- **Built**
  - Hard, gray, engineered structures built to address development and DRR objectives

- **Hybrid**
  - Combination of ecosystem elements and hard engineering interventions for addressing development and DRR objectives

- **Natural**
  - Creation, protection or restoration of only ecosystem elements for addressing development and DRR objectives

Source: World Bank 2017
Invested ~US$ 53 billion in more than 680 DRM projects globally (FY2012-2018)

Invested ~US$ 1.2 billion in 34 projects targeting river flooding with NBS (FY2012-2018)

Source: World Bank 2018
**ADVANTAGES**

- **Essential role** in preventing floodwaters from damaging assets and harming people
- **Deep industry knowledge**
- **High performance certainty** and control

**CHALLENGES**

- **20% of freshwater fish species** at risk
- Can **increase flood risk** over time
- **Massive investment gap** in flood infrastructure

**EXAMPLES:** Dams, levees/dykes, flood walls, channel modifications
NATURE-BASED SOLUTIONS

- Allow watersheds to **function naturally**, with beneficial flooding
- **Slow and attenuate** floodwaters
- ‘**Hybrid’** solutions **integrate and enhance** the benefits of natural and built solutions

**Examples:** Floodplains, inland wetlands, stream beds and banks, and upland forests
ADVANTAGES OF NATURE-BASED SOLUTIONS

- Provide wide range of **additional co-benefits**, beyond flood risk reduction
- Can be more **cost-effective**
- Can be designed as resilient, flexible, **climate adaptation** measures
- Have capacity to **adapt** and **regenerate**
WORDS OF CAUTION

- Greater **variability and uncertainty**
- Disconnect between **upstream sources** of river flooding and downstream **communities at risk**
- **Data and capacity** limitations
- Challenging to make the **economic case**
- Land requirements and **social equity**
NBS FOR RIVER FLOODING

1. Floodplains and bypasses
2. Inland wetlands
3. Stream beds and banks
4. Upland forests
1. FLOODPLAINS, (BYPASSES AND POLDERS)

- Relatively flat areas between rivers and uplands
- High levels of spatio-temporal variability and species diversity
- Variety of ecosystems
- Hybrid provide added control, but often less diversity
RISK REDUCTION BENEFITS

- Integrated with rivers to slowly convey water and sediment
- Capture large proportion of upstream water
- Successful applications across the globe
ADDITIONAL BENEFITS

- Biodiverse habitat
- Improved water quality
- Groundwater recharge
- Productive agriculture and fisheries
- Carbon sequestration
- Recreation
- Markets exist for some services
CONSIDERATIONS FOR USING FLOODPLAINS

- **Large scale** interventions – up to 10,000s of hectares
- **Land costs** and competition
- Floodplain and water development
- Environmental justice and social equity
- Most effective during **short duration floods**
WHAT DO FLOODPLAINS AND BYPASSES COST?

- Dependent on land prices - often largest cost
- Variable: $10,000 – $700,000/ha
- Operations and maintenance costs are typically low (0.5-1.5%)
CASE STUDY: DANUBE GREEN CORRIDOR

- 2006 floods: US$ 464 million in damages
- Dikes cut off floodplains
- 80% of wetlands lost

Danube Green Corridor

- Restore 224,000 ha of natural floodplain
- Cost: US$ 214 million
- Expected ecosystem services earnings: US$ 100 million/yr

Photo credit: fFlickr/chris lovelock and WWF 2010
2. INLAND WETLANDS

- **Complex, integrated systems** of water, plants, animals, and microorganisms
- Require **specific environmental conditions**
- **Wide variety of wetlands** and flood attenuation potential
- **64–71%** of the world’s natural wetland area **have been lost**

Photo credit: Flickr/Ed Dunens
RISK REDUCTION BENEFITS

- “Act like a sponge”
- A hectare of wetland can store up to 9,400 - 14,000 m$^3$ of floodwater
- Type and location determine function
- Floodplain river-fed wetlands greater potential to reduce floods
ADDITIONAL BENEFITS

- Effectively filter sediments and pollutants
- Hydrologic connectivity and water security
- Wildlife and biodiversity
- Recreation, tourism and education opportunities
- Ecosystem services averaged $26,000 /ha/yr in 2011
CONSIDERATIONS FOR USING INLAND WETLANDS

- Site-specific environmental conditions
- Seasonal and conditional variation in performance
- Potential for moderate flood management benefits
- Justification may require evaluation of additional benefits
WHAT DO INLAND WETLANDS COST?

- Smaller spatial scale than floodplain or re-meandering
- High costs per area (US$ $≈33,000/ha)
- Highly dependent on land acquisition costs
- Low operation and maintenance costs ($410/ha/yr)
CASE STUDY: BEDDAGANA WETLAND PARK, SRI LANKA

- 2010 Flood: 36,000 families homeless, US$ 50-100 million damages
- Wetlands capture 39% of the flood waters during storms
- Degraded at 1.2% (23 ha)/yr
- Without wetlands 1% lost of GDP/yr

Wetland Management Strategy

- Restore and protect the 18 ha Beddagana Wetland Park
- Cost: US$ 1.2 million
- Recreational income potential US$ $13.6 million/yr (10x investment!)
3. STREAM BEDS AND BANKS

- Vegetated banks along meandering streams slow floodwaters
- The majority of large rivers have been modified
- Modifications fight against natural processes

**Interventions**: Re-meandering, setting back levees, de-armoring and revegetating banks.
RISK REDUCTION BENEFITS

- Re-meandering the River Skjern extended stream length 36%
- Mississippi River levee set backs could reduce expected annual damages by 55%
- Restoring streambed delayed flood wave by two hours
ADDITIONAL BENEFITS

- Improved riparian biodiversity
- More diverse fish habitat
- Decreased water temperature
- Erosion control
- Recreation and aesthetic value

Natural river banks in Belgium evaluated at **US$ 27,000/km – 60,000/km** per year
CONSIDERATIONS FOR RESTORING STREAM BEDS AND BANKS

- **Reference state** and objectives
- Requires solid understanding of current and future hydrologic regimes
- **Dynamic river systems** versus anthropogenic constraints
WHAT DOES IT COST TO RESTORE STREAM BEDS AND BANKS?

- High construction costs
- Lower land acquisition and compensation costs
- Bank stabilization: $29,000 to $137,000/km
- Channel rehabilitation: $25,000 to $85,000/km
CASE STUDY: ROOM FOR THE RIVER, THE NETHERLANDS

- **55% of housing** in flood-prone areas
- Higher dykes no longer sufficient due to **climate change**

Room for the River - Nijmegen
- **US$ 460 million** to push dyke 350 m inland
- **Local participation** and compensation
- New island and **river park**
4. UPLAND FORESTS

- Upstream watershed characteristics influence downstream river floods
- Upstream forests slow and retain runoff
- Land use changes increase flood runoff
RISK REDUCTION BENEFITS

- **82% of studies** reported a decrease in peak flow after restoration.
- Reforesting areas over 25-40% of a UK catchment could **decrease the flood maximum by 20%**.

- Most risk reduction evidence from North American and European **temperate forests**.
- Most effective during **moderate floods of short duration**.
ADDITIONAL BENEFITS

- Water and air purification
- Carbon storage
- Soil production, reduced erosion and sedimentation
- Timber, food, and fuel
- Habitat creation
- Recreation

Photo credit: Flickr/Mathias Appel
CONSIDERATIONS FOR UPLAND FOREST RESTORATION

- Not all forests are created equal
- Some studies demonstrate negligible flood impacts
- Problems of scale and cost
- Importance of data and monitoring
WHAT DOES FOREST RESTORATION COST?

- Lower per hectare cost than other NBS: US$ 3,450/ha (tropical), 2,390/ha (other)
- Significant compensation and transaction costs in catchments with large private landownership
- High aggregate costs
CASE STUDY: UPLAND FOREST RESTORATION AS PART OF INTEGRATED FLOOD MANAGEMENT FOR DAR ES SALAAM

- 7 disastrous floods since 1995
- Avg of 14 people die annually
- Main cause of cholera outbreaks
- Charcoal use severely degraded upland forests

- Suite of NBS, including forest restoration, outperformed other strategies
- Pays for itself in less than 10 years
- Net benefits of US$80 million over 20 years
KEY CONSIDERATIONS FOR INTEGRATING NBS INTO RIVER FLOOD MANAGEMENT

- Natural versus current conditions
- Watershed risks and additional benefits
- Integration with built infrastructure
- Spatial footprint and land cost
THANK YOU

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$26 billion in loses (1998 floods) due to deforestation and steep cultivation

NFCP meant to reduce flood risk, but no flood metrics formulated

3.3 times less forest loss

0.84 million increase in forest employment

However, questionable net benefits
CASE STUDY: YOLO BYPASS, USA

- **Multi-purpose** advantages of hybrid infrastructure
- Conveys **80% flood flow**
- **200 bird species**, and highest salmon population in CA
- 2/3 are in private **agriculture**
- **Multi-billion dollar** investment