The Global Water Cycle - Storage & Fluxes

- Water Vapor over Oceans 10
  - Evaporation over Oceans 430
  - Precipitation over Oceans 390

- New Water Vapor Transport 40
  - Evapotranspiration over Land 75
  - Precipitation over Land 115

- Water Vapor over Land 3
  - Runoff 40
    - Lakes 176
    - Wetlands 11
    - Rivers 2

- Water in Biota 1
  - Soil Moisture 17
  - Glaciers & Snow 24060
    - Permafrost 300

- Oceans 1338000
  - Groundwater 23400

Legend:
- Water Storage in Gt
- Annual Water Flux in Gt/Year

Data Sources:
- Smil, 2008
- Oki & Kanae, 2006
- Dai & Trenberth, 2002
The Proportion of Water Moving Through Different Cycles

Green Water, Blue Water, White Water, Grey Water

Precipitation → Green Water (100%)

Land & Soil → Green Water (65%)

Lakes, Rivers, Groundwater → Blue Water (35%)

Evapotranspiration → White Water (30%)

Rainfed Agriculture

80% of Ag. Land Produces 60% of Food

Irrigated Agriculture

20% of Ag. Land Produces 40% of Food

Domestic & Industrial Water Use

Grey Water
### Projected Global Populations in Each Category by 2050

<table>
<thead>
<tr>
<th>Blue Water</th>
<th>Green Water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green Water Limited</td>
</tr>
<tr>
<td>Blue Water Limited</td>
<td>&lt; 1300 m³/capita/yr</td>
</tr>
<tr>
<td></td>
<td>46%</td>
</tr>
<tr>
<td>Blue Water Sufficient</td>
<td>&gt; 1300 m³/capita/yr</td>
</tr>
<tr>
<td></td>
<td>21%</td>
</tr>
<tr>
<td>Green Water Sufficient</td>
<td>&gt; 1300 m³/capita/yr</td>
</tr>
<tr>
<td></td>
<td>19%</td>
</tr>
</tbody>
</table>

Data Source: Rockstrom et al. 2007, Falkenmark & Rockstrom, 2011

### Example Countries by 2050

<table>
<thead>
<tr>
<th>Blue Water</th>
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<tr>
<td></td>
<td>Green Water Limited</td>
</tr>
<tr>
<td>Blue Water Limited</td>
<td>&lt; 1300 m³/capita/yr</td>
</tr>
<tr>
<td>Jordan, Egypt, India, China</td>
<td></td>
</tr>
<tr>
<td>Blue Water Sufficient</td>
<td>&gt; 1300 m³/capita/yr</td>
</tr>
<tr>
<td>Korea, Japan</td>
<td></td>
</tr>
<tr>
<td>Brazil, Canada</td>
<td></td>
</tr>
</tbody>
</table>

Data Source: Rockstrom et al. 2007, Falkenmark & Rockstrom, 2011
In 2010, 69% of all water was used for agriculture.

Data Source: McKinsey Corp. 2012
WATER DEMANDS FOR AGRICULTURE
MORE IS NEEDED FOR:
- IRRIGATION EXPANSION
- SOIL MOISTURE RECHARGE
- SHIFT in WATER DEMANDING FOOD

MINING - OIL EXTRACTION
MORE IS NEEDED FOR:
- STEAM GENERATION
- EXTRACTION
- PROCESSING

WATER DEMANDS FOR ENVIRONMENTAL SERVICES
MORE IS NEEDED FOR:
- SURVIVAL OF FISH & OTHER AQUATIC BIOTA
- DILUTION OF POLLUTANTS

WATER DEMANDS FOR URBANIZATION
MORE IS NEEDED FOR:
- DOMESTIC WATER USE
- HYDROPOWER EXPANSION
- INDUSTRIAL EXPANSION
- RECREATIONAL DEMANDS

Water Demand Challenges
AGRICULTURAL POLLUTANTS
Reduction in:
- Excess Nutrients
- Sediments
- Antibiotics, Hormones, Trace Metals
- Pathogens

MINING - OIL EXTRACTION
Reduction in:
- Organic Contaminants
- Sediments
- Processing Chemicals

FORESTRY CONTAMINANTS
Reduction in:
- Sediment
- Nutrient after logging & fires

URBANIZATION POLLUTANTS
Reduction in:
- Sediment
- Metals
- Hydrocarbons, Oil,
- Pathogens & Pharmaceuticals

Water Pollution Challenges
Annual total precipitation (cm, GPCP)
Why Integrated Watershed Management?
Advantages of Using a Watershed Approach

**Natural System**
- Natural Unit
  - Ideal for Monitoring
  - Scaling Options
  - Landscape Hierarchy

**Process Studies**
- Mass Balance
  - Input-Output Modelling
  - Enables Cause & Effect Assessment

**Integration**
- Integrates Land Use Effects
  - Links Land Use and Water
  - Facilitates System Analysis

**Complexity**
- Allows Cumulative Effects Analysis
  - Air-Soil-Water Interactions
  - Can Assess Diffuse Sources

**Decision Making**
- Science Based Decision Making
  - Effective for Management
  - Enables Adaptive Management
Difficulties of Using a Watershed Approach

- Long Term Data
  - Long Term Monitoring Needed and is Expensive
  - Needs for an Undisturbed Control Site

- Boundary Issues
  - Political, Census Boundaries do not Match
  - Data is Collected over Different Areas

- Extrapolation
  - Every Watershed is Different-Makes Extrapolation Challenging
  - Processes Change over Time & Space

- Scale Issues
  - Non-Linear Processes make Up-Scaling & Down-Scaling Difficult
  - Accuracy Changes Between Scales

- External Factors
  - Air-Pollution Climate Change Transportation do not Recognise Watershed Boundaries
How to Cope with Climate Extremes and Land Use Intensification and its Impact on Water
<table>
<thead>
<tr>
<th>Impact Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flood Impacts</strong></td>
</tr>
<tr>
<td>Flood impacts occur in individual watersheds</td>
</tr>
<tr>
<td>Floodplains are the main impacted areas</td>
</tr>
<tr>
<td>The source of the flood water usually is long distance away from the flood impact</td>
</tr>
<tr>
<td>The impact is over relatively short time periods (Days-Weeks)</td>
</tr>
<tr>
<td><strong>Droughts Impacts</strong></td>
</tr>
<tr>
<td>Droughts cover very large areas</td>
</tr>
<tr>
<td>The impact can be over large watersheds</td>
</tr>
<tr>
<td>The impact is regional and not specific to floodplains</td>
</tr>
<tr>
<td>The impact is over longer periods (Months-Years)</td>
</tr>
</tbody>
</table>
Mining Impacts on Water

**Type**
- Strip
- Pit
- Underground
- Placer
- Gravel Extraction

**Activities**
- Overburden Storage
- Surface & subsurface alterations
- Mine Tailings
- In Situ Leaching
- Stream Diversion
- In stream washing and sorting

**Impacts**
- Changes in surface hydrology
- Changes in groundwater hydrology
- Water Temperature
- Sediments
- Acid mine drainage
- Alteration in stream morphology and habitat
- Metals

**Issues**
- Hydrology - Water Quality - Aquatic Biota
Rainfall Redistribution by Land Use

Note: Change in Surface Runoff as a result of land use changes (in Red)
Water Governance Issues

Key User Sector Institutions Dealing with Water:
- Health
- Agriculture
- Industry
- Hydro-Power
- Fisheries
- Cities & Municipalities
- Recreation
- Transportation

Institutions that are Responsible for Water Monitoring:
- Ministries of Environments
- Mines, Energy or Geological Surveys
- Ministries of Health
- Utilities & Engineering Dep.

Institutions Responsible for Setting Guidelines, Standards, and Regulations:
- World Health Organization
- Food & Health Administrations
- Ministries of Health
- Utilities & Engineering Dep.
Water Access & Equity Issues

Access to Resource
Ownership of source
Responsibility to assure quality
Drinking water
Sanitation and Health
Responsibility to assure availability
Ecological Service
Animal Care and Fish
Gender and Social Equity
Commercial Equity
Nature and Rights
Irrigation
Risk Floods & Droughts
Economic Equity (cost & price)
Why We Need for Water Conservation

Why do we need water conservation efforts?
- More needs to maintain Ecological Services
- Limited supplies, uneven distribution
- Escalating costs for treatment
- Demands exceeding supplies
- High risk & uncertainty due to climate change

Where are the greatest savings to be made?
- Agricultural Water Use: Improved irrigation efficiency, match water demanding crops with climate
- Powerplant Operations: Improve use efficiency and water release, re-use for heat exchange
- Recreational Water Use: Use of water saving technologies, treat and recycle water
- Household Water Use
- Industrial Water Use: Low water use facilities, greywater use for gardens, dual water system
- Recreational Water Use: Water re-use and recycling
In Need of a Multi-Barrier Approach

Protective Measures:

1. Source Control - Reduce Input
2. Budget Accounting (N & P)
3. Large Riparian Buffer Zones
4. Wetland Preservation & Use
5. Beneficial Management Practices
6. Water Absorption & Infiltration
7. Limit Stocking Densities
8. Septic System Density
9. Tertiary Waste Water Treatment
10. Soil Erosion Control
11. Detention Ponds
12. Improved Manure Management
### Changing Course

<table>
<thead>
<tr>
<th>Traditional Approach</th>
<th>Innovative Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Revolution (low Carbon Input)</td>
<td>Increase Soil Carbon</td>
</tr>
<tr>
<td>Intensive Land Use (Soil Compaction)</td>
<td>Minimize Soil Compaction</td>
</tr>
<tr>
<td>Minimizing Buffer Zones</td>
<td>Maximizing Buffer Zones</td>
</tr>
<tr>
<td>Draining Wetlands</td>
<td>Creating Wetlands</td>
</tr>
<tr>
<td>Excessive Drainage</td>
<td>Detaining Drainage Water</td>
</tr>
<tr>
<td>End of Pipe Treatment</td>
<td>Source Control</td>
</tr>
<tr>
<td>Point Source Pollution</td>
<td>Non-Point Source Pollution</td>
</tr>
<tr>
<td>Expanding Water Supplies</td>
<td>Controlling Demand (Water Smart)</td>
</tr>
<tr>
<td>Dealing with Single Pollutants</td>
<td>Cumulative Effects</td>
</tr>
<tr>
<td>Water Use for Human Activities</td>
<td>Water for Environmental Services</td>
</tr>
<tr>
<td>Flood Irrigation</td>
<td>Innovative Irrigation</td>
</tr>
<tr>
<td>Managing Blue Water</td>
<td>Managing Green Water</td>
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