Environmental Water Needs for Groundwater Dependent Ecosystems: A Framework

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Goals

As a component of the Forest Service Groundwater Program, the goals of this effort are to address the need for water by humans while maintaining ecosystem integrity on NFS lands.
What are Groundwater Dependent Ecosystems (GDEs)

- Areas where the groundwater plays a key role in the ecosystem function, and important interactions exist between hydrogeology and ecosystem processes.

The Forest Service Ground Water Policy
- Focus inventory, monitoring, and management efforts on groundwater systems that, if depleted or contaminated, would have an adverse effect on surface resources.
- Manage groundwater cooperatively with the States with regard to the development and/or restoration of aquifers, and groundwater-dependent systems and aquatic ecosystems.
- Manage surface and groundwater as a hydraulically interconnected system.
- Authorize consumptive uses only when such uses are conducted in a manner that adequately protects forest resources over the long run.

Attributes of an Ecosystem’s Dependency on Ground Water
- Flow or Flux - the rate and volume of groundwater supply to a dependent ecosystem.
- Level or Pressure - the depth to the water table for unconfined aquifers, and the potentiometric head of the aquifer and its expression in groundwater discharge areas for confined aquifers.
- Quality - the chemical quality of groundwater including nutrients and contaminants.

The management of groundwater resources in the U.S. has been primarily concerned with the assessment and development of water (for irrigation, urban, industrial, stock and domestic water supply) and the protection or cleanup of groundwater from contamination. Increasingly, the water needs of communities with ever-increasing demands for clean water are in direct conflict with the water needs of natural systems. These demands can alter groundwater flow regimes supporting groundwater-dependent ecosystems that are critical to maintaining desired levels of ecosystem function.

Within the last ten years, Forest Service managers and specialists recognized that the Agency’s focus on surface water was limiting its ability to address watershed-scale issues and respond adequately to water supply and water quality concerns both on and adjacent to Forest Service lands. The Forest Service groundwater policy is specifically designed to protect groundwater-dependent ecosystems so that, wherever possible, ecological processes and biodiversity are maintained, or restored, for the benefit of present and future generations.
What are Groundwater Dependent Ecosystems

Ground Water Dependent Ecosystems

- Discharge Ground Water Systems
  - Lakes
    - Baseflow
    - Hypolentic
  - Streams
    - Baseflow
    - Hyporheic
  - Springs
    - Spring Types (Springer & Stevens 2009)
- Wetlands
  - Fen
    - Fen Ecological Systems (Natureseve)
  - Swamp
    - Swamp Ecological Systems (Natureseve)
  - Marsh
    - Marsh Ecological Systems (Natureseve)
- Subsurface Ground Water Systems
  - Cave/Karst
  - Phreatophytes
  - Aquifers
Phreatophytes
What are Environmental Water Requirements (EWRs)

EWRs describe the quantity, timing, and quality of water flows and levels required to sustain water dependent ecosystems and the human livelihoods and well-being that depend on these ecosystems.
WHY DO WE CARE

- Because of increasing pressure to supply water, minerals, and energy, resource managers are more frequently asking, how much water can be taken from a GDE while still maintaining a low level of risk to the ecosystem.

- GDEs encompass regionally- and nationally-significant ecosystems on NFS lands and are critical to management of some T&E species.

- In watersheds, they support a disproportionately large percentage of the total biodiversity relative to their size.
Framework Methodology: Combined Hydrological/Ecological Approach

Discharge Wetlands/Phreatophytes

- **Hydrological approach**
  - Hydrologic models test sensitivity of water budget parameters to change

- **Ecological approach**
  - Determine current relationships between ecological parameters and water table fluctuations
    
    a) Develop indicator species lists
    b) Determine water table requirements for indicator species
FRAMEWORK FOR ASSESSING ENVIRONMENTAL WATER REQUIREMENTS FOR GROUND WATER DEPENDENT ECOSYSTEMS

Phase 1 - Setting the Context

1.1 Identify Degree of Ground Water Dependency
- spring
- wetland
- phreatophytes

1.2 Threat Analysis
- Identify actives affecting water regime
- Identify other stressors affecting GDE

1.3 Define Study
- Purpose and Scope
- driving mechanism
- required outcomes
- assessment level
- budgets & timing

1.4 Biophysical Setting & Conceptual Model
- climate
- landscape
- hydrogeology
- plants/animals
- ecological system

1.5 Ecological & Management Objectives
- Goal Setting
- ecological significance
- ecosystem services
- human uses
- forest plan
- permits

Determine Eco-Hydrological Relationships

3.1 Form & Degree of...
Determine Eco-Hydrological Relationships

2.1 Form & Degree of Dependence
Establish relationship between GDE and ground water
- obligate
- seasonal
- water balance
- plant/animal requirements

2.2 Response Function
Develop environmental response function

Estimate / Refine EWR

2.3 Water Requirements
Derive EWR
- environmental flow
- water table depth
- water quality
- flux

2.4 Monitoring & Evaluation
Phase 1 - Setting the Context

- Threat Analysis
- Define Study Purpose and Scope
- Identify Biophysical Setting and Develop a Conceptual Model
- Determine Ecological and Management Objectives
Example: Biophysical Conceptual Model for Fens

B. Areas of stratigraphic change

- Glacial till
- Sand and gravel
- Glacial till
- Sand and gravel
- Glacial till

Fen
### Example: Ecological and Management Objectives

<table>
<thead>
<tr>
<th>Management Goal</th>
<th>GDE Use</th>
<th>Indicator of GDE Function</th>
<th>Indicator of GDE Economic Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biodiversity conservation</strong></td>
<td>Ecosystem protection</td>
<td>Biotic potential (area with water 0-40 cm below surface)</td>
<td>Willingness to pay for biodiversity conservation</td>
</tr>
<tr>
<td><strong>Income generation</strong></td>
<td>Grazing</td>
<td>Biomass production, water availability</td>
<td>Net value added</td>
</tr>
<tr>
<td><strong>Reduction of ( \text{CO}_2 ) emissions</strong></td>
<td>( \text{CO}_2 ) sequestration</td>
<td>( \text{CO}_2 ) emission (tons/acre/year)</td>
<td>( \text{CO}_2 ) emission mitigation costs</td>
</tr>
</tbody>
</table>
Phase 2 - Identifying Processes

- Determine Eco-Hydrological Relationships
  - Establish Form and Degree of gw Dependence
  - Develop Environmental Response Function
- Estimate and refine EWR
  - Derive EWR
  - Monitoring and Evaluation
Example: Form and Degree of Groundwater Dependence for a Peatland

- Sustained groundwater discharge
- Water table close to land surface
- Net primary production $\geq$ Decomposition
- Peat accretion or maintenance
- Plant & animal communities adapted to:
  - saturated soils
  - anoxic conditions
  - low nutrient availability
Example: Fen Water Balance Components

- ET or surface seepage of ground water
- Percolation
- Stream
- Water table
- Lateral ground water flow to the wetland
- Ground water flow to stream
- Shallow ground water moving to deeper aquifer
- Deeper ground water moving up into wetland
- Lateral flow out of the wetland
Example: Piezometer Network

Water table wells

Nested mini-piezometers

Kellogg et al. 2008
Example: Water Table Requirements for Vascular Indicator Plants

<table>
<thead>
<tr>
<th>Species</th>
<th>Water Table (cm)</th>
</tr>
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<tbody>
<tr>
<td>Drosera rotundifolia</td>
<td>-5 to 0</td>
</tr>
<tr>
<td>Menyanthes trifoliata</td>
<td>-5 to 0</td>
</tr>
<tr>
<td>Carex capitata</td>
<td>5 to 10</td>
</tr>
<tr>
<td>Carex limosa</td>
<td>10 to 15</td>
</tr>
<tr>
<td>Utricularia intermedia</td>
<td>10 to 15</td>
</tr>
<tr>
<td>Eriophorum gracile</td>
<td>20 to 25</td>
</tr>
<tr>
<td>Carex echinata ssp. Echinate</td>
<td>30 to 35</td>
</tr>
</tbody>
</table>

Data Range

Source: The Nature Conservancy, Oregon
Example: Water Table Requirements for Bryophyte Indicator Species

- **Hamatocaulis vernicosus**
- **Tomentypnum nitens** (acidic peatland)
- **Helodium blandowii**
- **Calliergon stramineum**

Source: The Nature Conservancy, Oregon
Example: Environmental Response Function for a Discharge Wetland

Environmental Response Function

Optimal water regime for GDE function

Water regime too dry for wetland to function.

Inundation forces wetland toward new wetland type.
Example: Environmental Water-Level Requirements for a Wet Grassland

![Diagram showing water table depth over the months with different color zones indicating ideal hydrologic regime, limited impact, and GDE affected areas.]

Pilot Project
Study Area:

Fremont-Winema National Forest, Oregon
Next Steps

- Test Framework methodology and revise if necessary.
- Develop strategies for protecting GDEs while also providing water for land users.
Questions