Wetland Hydrology

USACE Definition

“...all hydrologic characteristics of areas that are periodically inundated or have soils saturated to the surface at some time during the growing season.”

Hydrology is the single most important determinant of the establishment and maintenance of specific wetland types and processes (oxidation and reduction).

Hydrologic Zones:

<table>
<thead>
<tr>
<th>Zone</th>
<th>Duration</th>
<th>Hydrologic Zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Permanently inundated</td>
<td>100%</td>
</tr>
<tr>
<td>II</td>
<td>Semi-permanently</td>
<td>76–99%</td>
</tr>
<tr>
<td>III</td>
<td>Regularly</td>
<td>26–75%</td>
</tr>
<tr>
<td>IV</td>
<td>Seasonally</td>
<td>12.6–25%</td>
</tr>
<tr>
<td>V</td>
<td>Irregularly</td>
<td>5–12.5%</td>
</tr>
<tr>
<td>VI</td>
<td>Intermittently</td>
<td>&lt;5%</td>
</tr>
</tbody>
</table>

Unique Physicochemical Conditions

Hydrologic Flows & Processes

Note: Differences between terrestrial, wetland, and deepwater systems.
Hydrologic Influence Model

Starting Points
- Wet, Cool
- Flat, Steep
- Rivers, Tides

Hydro-geomorphology: hydrology + climate + geomorphology

Feedbacks:
A = sedimentation
B1 = microbes (catalyze), plants (retain nutrients, shade), animals (consume & input nutrients)
B2 = plants (detrital accumulation, sediment trapping, transpiration) and animals (physical modifications)

Animal Biotic Feedbacks

Beaver
(Castor canadensis)

Muskrat
(Ondatra zibethicus)

American Alligator
(Alligator mississippiensis)

Nutria
(Myocastor coypus)

Snow Geese
(Chen caerulescens)
Wetland Hydroperiod

Seasonal pattern of water level in a wetland.

Hydrologic Signature → Hydrograph

### 3 Components:
1. **Flood duration**: Average or total amount of time standing water exists during a flood event.
2. **Flood frequency**: Average number of times a wetland has standing water per year.
3. **Flood depth**: Depth of aboveground standing water.

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Characteristic Hydrographs

**Forested Wetlands**

Winter–Spring Pulse

1 m

**Emergent Wetlands**

Variable

Stable

Altered

http://waterdata.usgs.gov/nwis/rt

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Wetland Hydroperiod

Year-to-Year Fluctuations:
- Climate
- Preceding Water Levels

Pulsing Water Levels:

Nourish Nutrients (influx)

Detritus & waste (flushed)

Prairie Pothole

Greentree Reservoir

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Wetland Water Budget

Quantification of all hydrologic inputs and outputs.

\[ \Delta V = P_n + S_i + G_i - \Delta T \]

- \( P_n \): net precipitation
- \( S_i \): surface inflows (sheet, stream flow)
- \( G_i \): groundwater inflow
- \( \Delta T \): tidal inflow (+) & outflow (-)
- \( I \): interception

\[ \Delta V/\Delta t = \text{Change in volume of water storage per unit time} \]

Wetland Water Budget

Example

\[ P = 105 \text{ cm/yr} \]
\[ I = 31 \text{ cm/yr} \]
\[ S_i = 229 \text{ cm/yr} \]
\[ G_i = 22 \text{ cm/yr} \]
\[ ET = 72 \text{ cm/yr} \]
\[ So = 232 \text{ cm/yr} \]
\[ Go = 21 \text{ cm/yr} \]
\[ T = 0 \]

1) Calculate net precipitation
\[ P_n = P - I = 105 - 31 = 74 \text{ cm/yr} \]

2) Calculate \( \Delta V/\Delta t \)

\[ \Delta V = P_n + S_i + G_i - \Delta T = 74 + 229 + 22 - 72 = 232 - 21 = 0 \text{ cm/yr} \]

Does this mean that the water has remained stable?

What does it mean if \( \Delta V/\Delta t > 0 \) or \( \Delta V/\Delta t < 0 \)?

Renewal Rate & Residence Time

Renewal Rate:
- Turnover rate of the water in a wetland
- How rapidly is water replaced in a wetland?
- Drive biochemical processes!

Residence Time:
- Average time that water remains in a wetland
- (Turnover time or detention time)

\[ R = \frac{V}{Q_t} \]

- \( V \): average volume of water in wetland (depth x surface area)
- \( Q_t \): total inflow rate = \( (P_n + S_i + G_i) \)

Residence Time vs. Productivity

As residence time decreases, productivity in wetlands often increases

I.e., turnover increases wetland productivity

Suppose: (in 1 year)

- Area = 10,000 m²
- Depth = 0.35 m
- \( S_i = 7.4 \text{ m}^3/\text{day} \)
- \( G_i = 1.1 \text{ m}^3/\text{day} \)
- \( P_n = 0.06 \text{ m}^3/\text{day} \)

\[ R_t = ?? \]
Hydrologic Pathways

Precipitation

Throughfall (TF)
Water passes through vegetation to wetland

Stemflow (SF)
Water intercepts vegetation & passes to wetland via stem

Interception (I)
Water retained in vegetation
- Total amt of precipitation
- Intensity of precipitation
- Vegetation morphology
- Vegetation strata

\[ P = I + TF + SF \]

(Approximately 85%)

\[ I = P - (TF + SF) \]

IDecid = 13%

Hydrologic Pathways

Surface Flow: Overland Runoff

Nonchannelized sheet flow usually following rainfall and spring thaw or as tides rise

Hydrologic Response Coefficient

Rational Runoff Coefficient

Consider Land Use

<table>
<thead>
<tr>
<th>Climate</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business District</td>
<td>0.75–0.95</td>
<td>0.15</td>
</tr>
<tr>
<td>Residential</td>
<td>0.30–0.50</td>
<td>0.55–0.75</td>
</tr>
<tr>
<td>Sandy Pasture</td>
<td>0.40</td>
<td>0.30–0.35</td>
</tr>
<tr>
<td>Loamy Cultivated</td>
<td>0.40</td>
<td>0.40–0.50</td>
</tr>
<tr>
<td>Loamy Woodland</td>
<td>0.30</td>
<td>0.35–0.40</td>
</tr>
</tbody>
</table>

\[ C = \frac{A}{S_i} \]

\[ S_i = \text{runoff to wetland (m}^3\text{/s)} \]

\[ A = \text{watershed area (km}^2\text{)} \]

\[ I = \text{rainfall intensity (mm/hr)} \]

Hydrologic Pathways

Surface Flow: Streamflow

Channelized water flow into a wetland

Bankfull Discharge
When water begins to flow over its bank into the floodplain

Recurrence Interval
Average duration that a river floodplain experiences bankfull discharge.

\[ R_b = 1.5 \text{ yrs} \]

Overbank Flow Probability
On average, the chance of bankfull discharge in a year.

\[ P(\text{Bf}) = (1 - \text{Bf})^4 \approx (1.5)^4 = 67% \]
Hydrologic Pathways

Groundwater

Subsurface flow of water into or out of a wetland

1) Discharge Wetland:

Water table of surrounding landscape is **higher** than water in wetland.

Water Flows into the Wetland ⇒ Water table loses Water

Most Freshwater Marshes

“Spring or Seep” Wetland

Base of Steep Slope

2) Recharge Wetland:

Water Flows out of Wetland ⇒ Water table gains Water

Playa wetlands

Darcy’s Law

\[ G = k(s_A) = k(s_{x_A}) \]

- \( G \): flow rate of groundwater
- \( k \): soil permeability
- \( s \): hydraulic gradient = slope of water table
- \( A_x \): groundwater cross-sectional area perpendicular to the direction of flow

pp. 134, 137

Hydrologic Pathways

Evapotranspiration

Combined water loss from evaporation and transpiration

**Evaporation:** Water that vaporizes from water or soil in a wetland.

**Transpiration:** Water loss through vascular plants generally at the stomata of leaves.

- Leaf-surface Area
- Protected Stomata
- Lipped Cuticle

Does wetland vegetation increase or decrease water loss from a wetland?

- Ecological Monographs
- Water Resources Research
Hydrologic Pathways
Estuarine Wetlands

Tides

Gravitational Pull of Moon > Sun on Oceans

Types

A) Frequency
   - Semi-diurnal (two)
   - Diurnal (one)

B) Magnitude
   - Spring (full, new)
   - Neap (1st, 3rd)

Tides Types

A) Frequency

B) Magnitude

Hydrologic Pathways
Estuarine Wetlands
Saltwater Wedge

Salinity is negatively related with distance from the ocean and positively related with depth.

Human Influences
Saltwater Intrusion

Stressors: submergence, saline soils/water, soil anoxia

Hydrologic Pathways

Estuarine Wetlands
Saltwater Wedge

Gradual Transition

Vertical Stratification

Saltwater Wedge

Cross section

Mangrove Wetlands
Species and Latitudinal Zonation

Geography:
- Mangrove <30° N/S
- Emergent Estuarine Wetlands 30°-70° N/S

- Red
- Black
- White
Specific Effects of Hydrology on Wetlands

1) Vegetative Species Composition and Richness
   Results in unique vegetation (zones) related to duration of soil anoxia and may increase or decrease species richness.

2) Primary Productivity
   Depends on nutrient availability and generally is greatest in flowthrough systems with periodic drawdowns.
   Allochthonous (out) + Autochthonous (in) Sources

3) Organic Accumulation and Export
   Accumulation greatest in stagnant, semi-permanently flooded wetlands (sinks) and export greatest in flowthrough with high primary productivity (sources).

4) Nutrient Cycling
   Decomposition maximized when aerobic.
   Nutrient Availability
   Nutrient Transformations

Measuring Hydrology in Wetlands

Staff Gauges

Weather Stations and Rain Gauges

PVC Wells and Water-level Recorders

4" PVC capped at one bottom end

Polyurethane Screen

3/8” holes on opposing sides ca. every 3-4” above and belowground
Measuring Hydrology in Wetlands

PVC Wells and Water-level Recorders

2–4” PVC Converter

36” Depth


$225–500 each