Wetland Hydrology

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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."

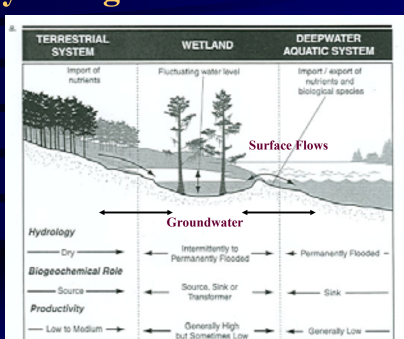
Hydrology is the single most important determinant of the establishment and maintenance of specific wetland types and processes (oxidation and reduction)

Unique Physicochemical Conditions

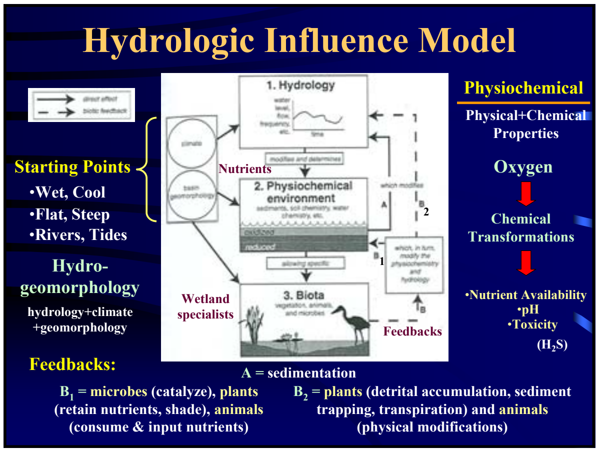
Hydrologic Zones:

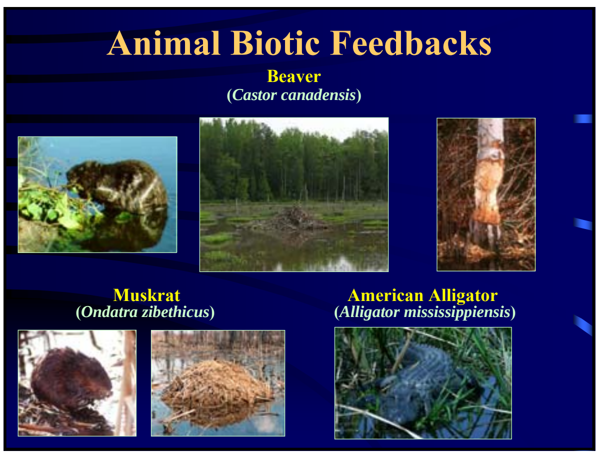
I	Permanently inundated	100%	IV	Seasonally	12.6–25%
II	Semi-permanently	76–99%	V	Irregularly	5–12.5%
III	Regularly	26–75%	VI	Intermittingly	<5%

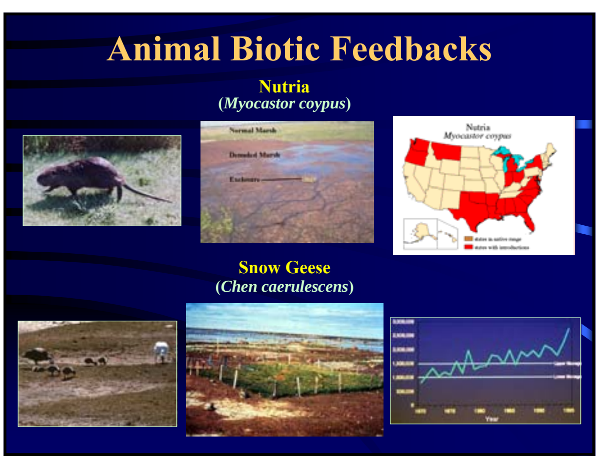
Hydrologic Flows & Processes



Note: Differences between terrestrial, wetland, and deepwater systems.


Hydrologic Influence Model
direct effect
biotic feedback
Starting Points
•Wet, Cool
•Flat, Steep
•Rivers, Tides
Hydro-geomorphology
hydrology+climate +geomorphology
1. Hydrology
climate
basin geomorphology
modifies and determines
Nutrients
2. Physiochemical environment
oxidized
reduced
which modifies
A
B2
B1
allowing specific
3. Biota
Wetland specialists
Feedbacks
Physiochemical
Physical+Chemical Properties
Oxygen
Chemical Transformations
•Nutrient Availability
•pH
•Toxicity
(H2S)
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)

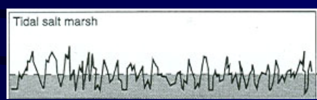

Animal Biotic Feedbacks
Beaver
(Castor canadensis)
Muskrat
(Ondatra zibethicus)
American Alligator
(Alligator mississippiensis)


Animal Biotic Feedbacks
Nutria
(Myocastor coypus)
Snow Geese
(Chen caerulescens)

Wetland Hydroperiod

Seasonal pattern of water level in a wetland.

Hydrologic Signature → Hydrograph



3 Components:

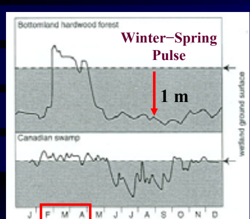
1) Flood duration: (6 COE Zones) Average or total amount of time standing water exists during a flood event.

2) Flood frequency: Average number of times a wetland has standing water per year.

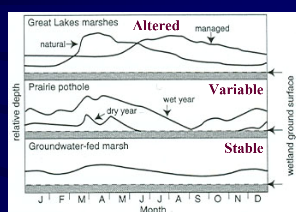
3) Flood depth: Depth of aboveground standing water.

Characteristic Hydrographs

Forested Wetlands



Emergent Wetlands

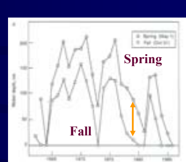


http://waterdata.usgs.gov/nwis/rt

Wetland Hydroperiod

Year-to-Year Fluctuations:

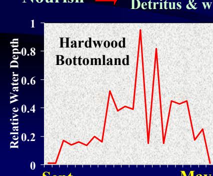
- Climate
- Preceding Water Levels



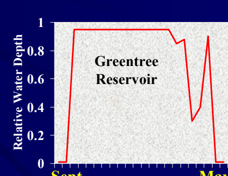
Prairie Pothole

Pulsing Water Levels:

Nourish → Nutrients (influx) Detritus & waste (flushed)



→ Human-induced



Wetland Water Budget

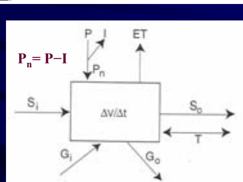
Quantification of all hydrologic inputs and outputs.

$$\frac{\Delta V}{\Delta t} = P_n + S_i + G_i - ET - S_o - G_o \pm T$$

P_n = net precipitation

S_i = surface inflows (sheet, stream flow)

G_i = groundwater inflow



$P_n = P - I$

ET= evapotranspiration

S_o = surface outflows

G_o = groundwater outflows

T = tidal inflow (+) & outflow (−)

I = Interception

ΔV/Δt = Change in volume of water storage per unit time

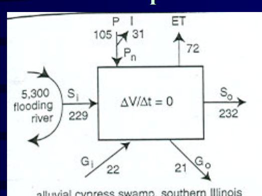
Wetland Water Budget
Example

P = 105 cm/yr

I = 31 cm/yr

S_i = 229 cm/yr

G_i = 22 cm/yr



ET= 72 cm/yr

S_o = 232 cm/yr

G_o = 21 cm/yr

T = 0

1) Calculate net precipitation $P_n = P - I = 105 - 31 = 74 \quad cm/yr$

2) Calculate ΔV/Δt

Does this mean that the water has remained stable?

$$\frac{\Delta V}{\Delta t} = P_n + S_i + G_i - ET - S_o - G_o \pm T = 74 + 229 + 22 - 72 - 232 - 21 = 0 \quad cm/yr$$

What does it mean if ΔV/Δt > 0 or <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!

Quantify

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

$$R_t = \frac{V}{Q_t}$$

V = average volume of water in wetland (depth x surface area)

Q_t = total inflow rate = $(P_n + S_i + G_i)_t$

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 = 7.40 m³/day

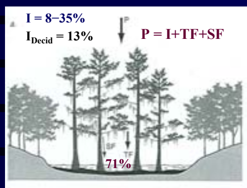
G_i = 1.1 m³/day

P_n = 0.06 m³/day

R_t = ??

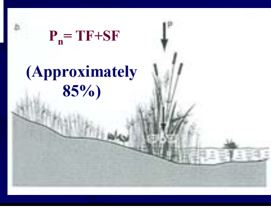
Hydrologic Pathways

Precipitation



Throughfall (TF)
Water passes through vegetation to wetland

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



Interception (I)

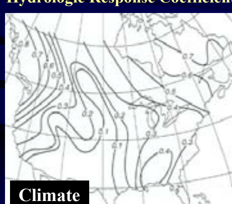
Water retained in vegetation
- Total amt of precipitation
- Intensity of precipitation
- Vegetation morphology
- Vegetation strata

Hydrologic Pathways

Surface Flow: Overland Runoff

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

Hydrologic Response Coefficient



Percent of precipitation that becomes surface runoff

Tennessee ~35%

Rational Runoff Coefficient

Considers Land Use!

p.129

	C	
Urban		
Business District	0.75–0.95	
Residential	0.30–0.50	
Rural		
Sandy Pasture	0.15	
Loamy Cultivated	0.40	0.35
Loamy Woodland	0.30	

$S_i = c(I \times A)$

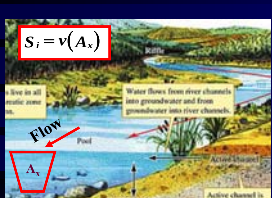
S_i = runoff to wetland (m^3/s)

A = watershed area (km^2)
I = 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

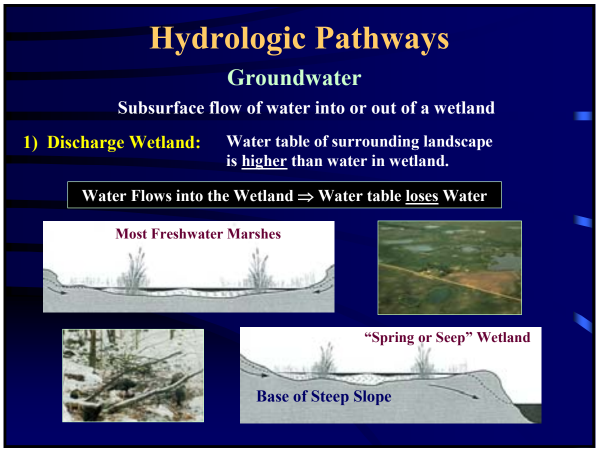
Average duration that a river floodplain experiences bankfull discharge.

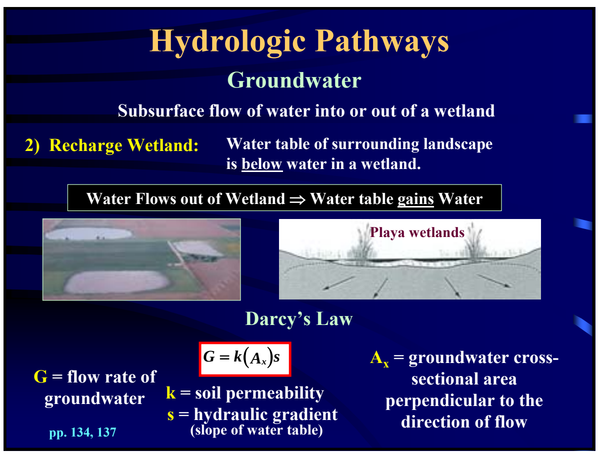
$\bar{x}_{RI} = 1.5$ yrs

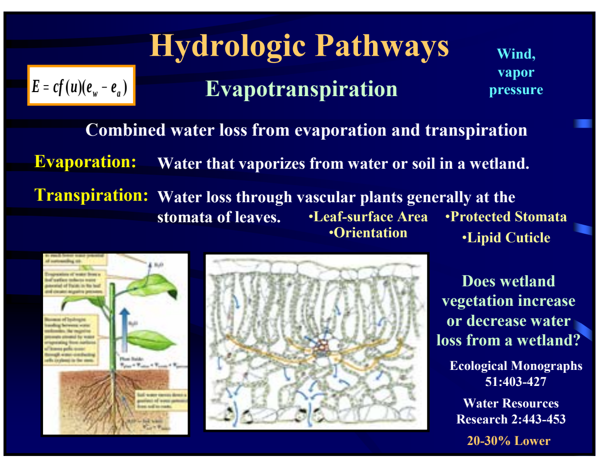
Overbank Flow Probability

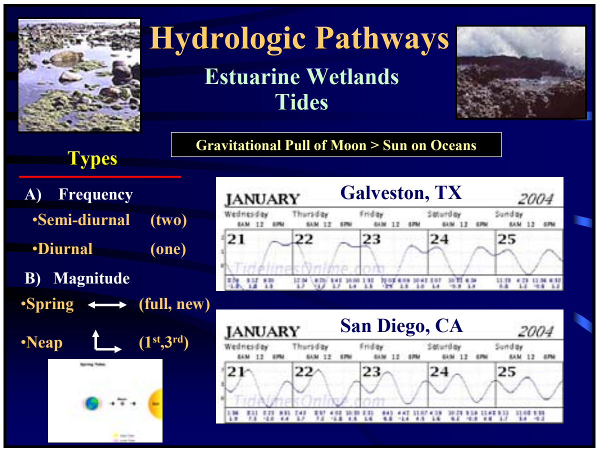
On average, the chance of bankfull discharge in a year.

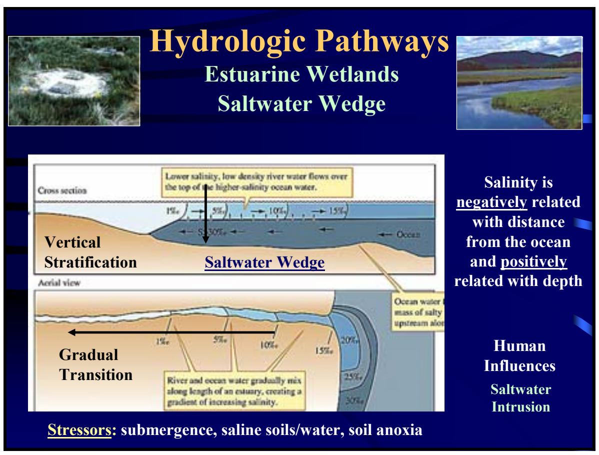
$P(\bar{x}_{RI}) = (\bar{x}_{RI})^{-1}$ $= (1.5)^{-1} = 67\%$

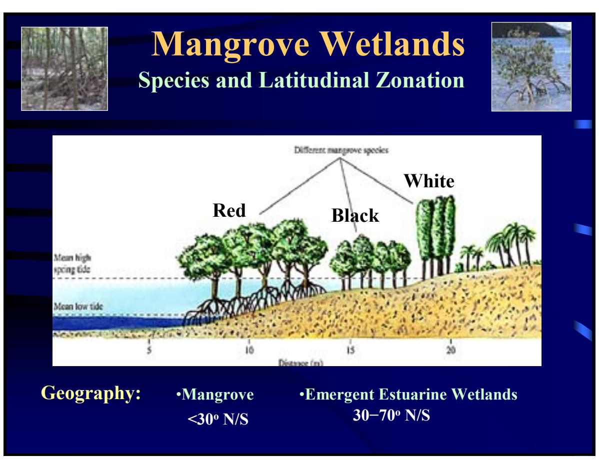

Hydrologic Pathways
Groundwater
Subsurface flow of water into or out of a wetland
1) Discharge Wetland:
Water table of surrounding landscape is higher than water in wetland.
Water Flows into the Wetland ⇒ Water table loses Water
Most Freshwater Marshes
"Spring or Seep" Wetland
Base of Steep Slope


Hydrologic Pathways
Groundwater
Subsurface flow of water into or out of a wetland
2) Recharge Wetland:
Water table of surrounding landscape is below water in a wetland.
Water Flows out of Wetland ⇒ Water table gains Water
Playa wetlands
Darcy's Law
$G = k(A_x)s$
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
$E = cf(u)(e_w - e_a)$
Evapotranspiration
Wind, vapor pressure
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
•Orientation
•Protected Stomata
•Lipid Cuticle
Does wetland vegetation increase or decrease water loss from a wetland?
Ecological Monographs 51:403-427
Water Resources Research 2:443-453
20-30% Lower


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)
JANUARY Galveston, TX 2004
21 22 23 24 25
JANUARY San Diego, CA 2004
21 22 23 24 25


Hydrologic Pathways
Estuarine Wetlands
Saltwater Wedge
Cross section
Lower salinity, low density river water flows over the top of the higher-salinity ocean water.
Vertical Stratification
Saltwater Wedge
Aerial view
Gradual Transition
River and ocean water gradually mix along length of an estuary, creating a gradient of increasing salinity.
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


Mangrove Wetlands
Species and Latitudinal Zonation
Different mangrove species
Red
Black
White
Mean high spring tide
Mean low tide
Distance (m)
Geography:
•Mangrove
<30° N/S
•Emergent Estuarine Wetlands
30–70° N/S

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.

Flowthrough & dynamic hydrology w/ spatial heterogeneity → "pulses"

2) Primary Productivity

Depends on nutrient availability and generally is greatest in flowthrough systems with periodic drawdowns.

Allochthonous (out) + Autochthnous (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).

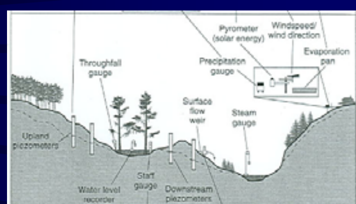
Decomposition maximized when aerobic.

4) Nutrient Cycling

- Nutrient Availability — When primary productivity & decomp high
- Nutrient Transformations — Oxidized to reduced, solubility & pH

Measuring Hydrology in Wetlands

Staff Gauges



Weather Stations and Rain Gauges

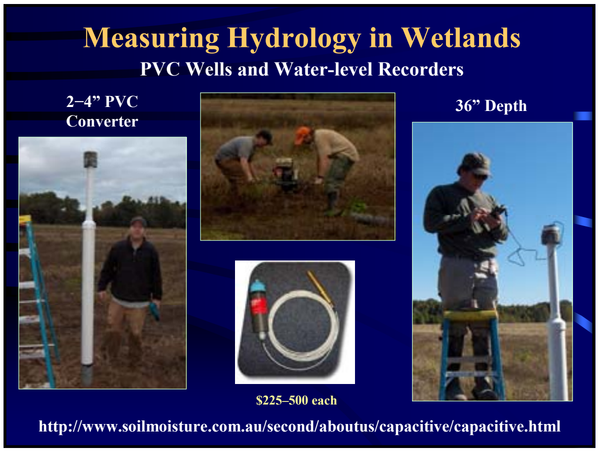
Measuring Hydrology in Wetlands

PVC Wells and Water-level Recorders

4" PVC capped at one bottom end

3/8" holes on opposing sides ca. every 3-4" above and belowground

Polyurethane Screen


Measuring Hydrology in Wetlands
PVC Wells and Water-level Recorders
2–4" PVC
Converter
36" Depth
$225–500 each
http://www.soilmoisture.com.au/second/aboutus/capacitive/capacitive.html