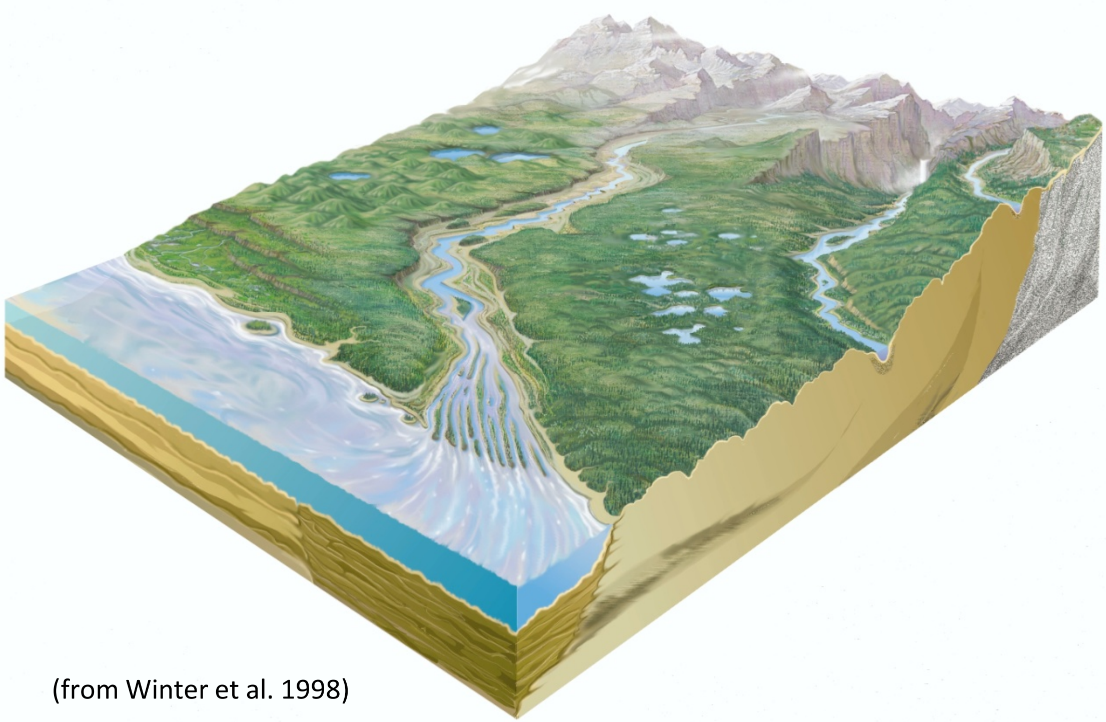
Wetlands Geology and Hydrology



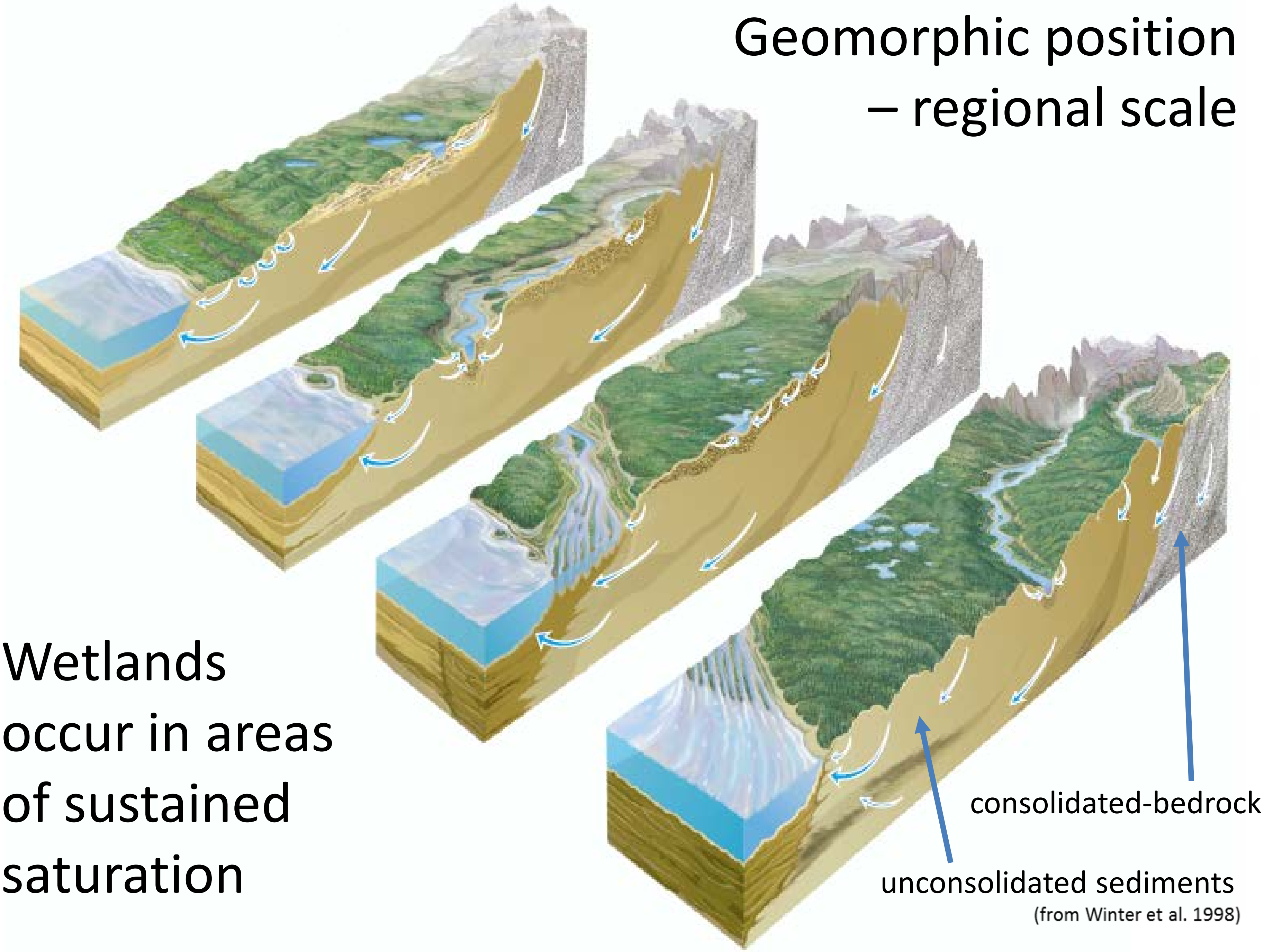
(from Winter et al. 1998)

EARTH 444

BIOLOGY 462

B.G. Warner

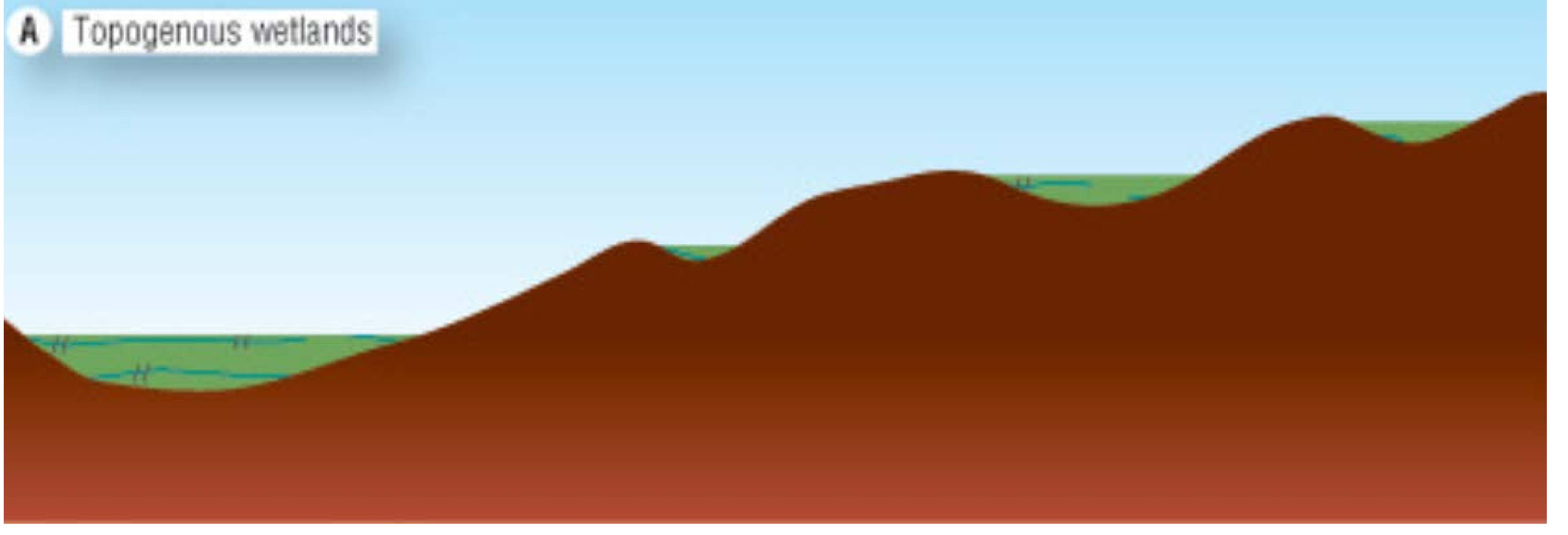
Geomorphic position – regional scale



(from Winter et al. 1998)

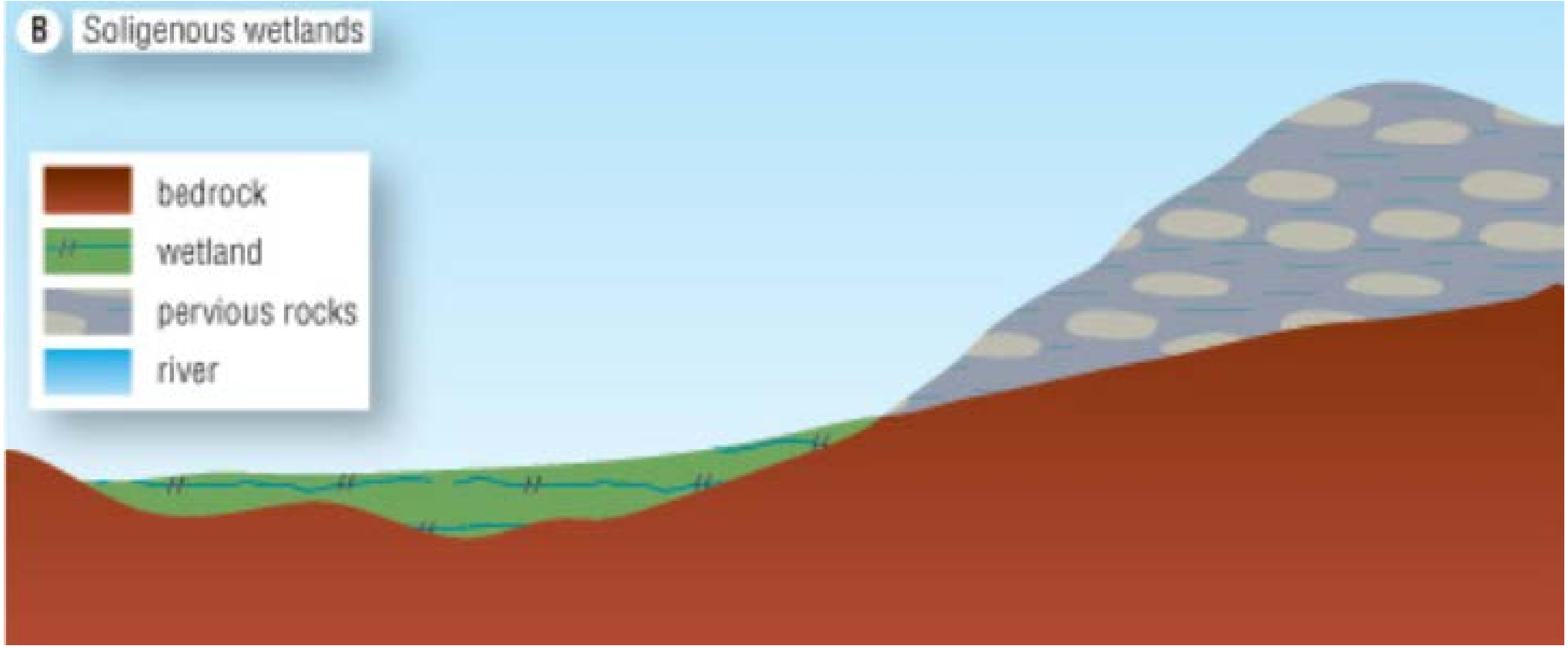
Wetlands occur in areas of sustained saturation

Individual Basin – Local scale



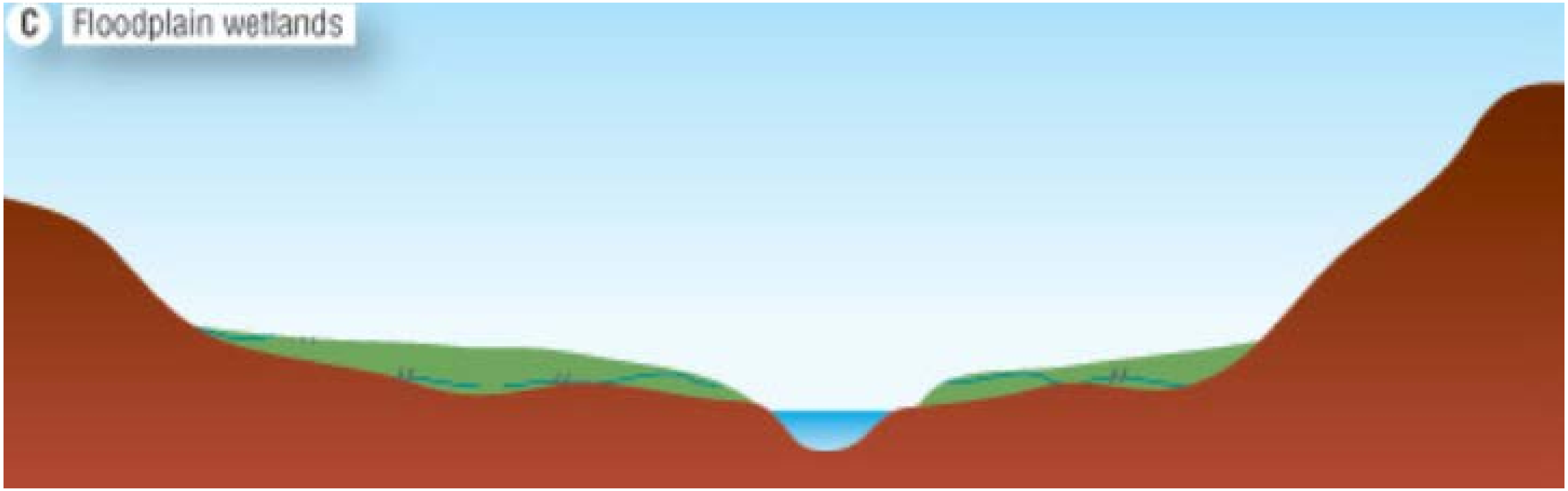
From: Moore 2001

Individual Basin – Local scale



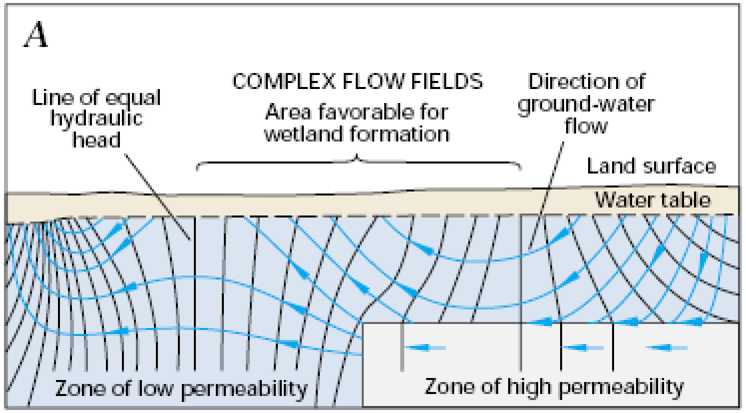
From: Moore 2001

Individual Basin – Local scale

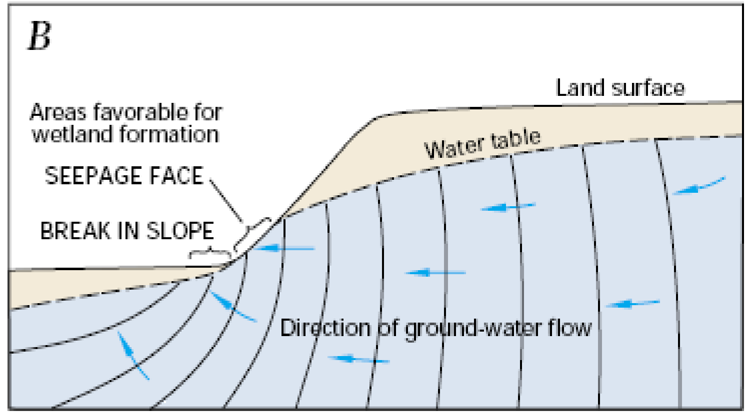


From: Moore 2001

Geomorphology (i.e. hillslope, fluvial, lake hydrology) and local water budgets are key

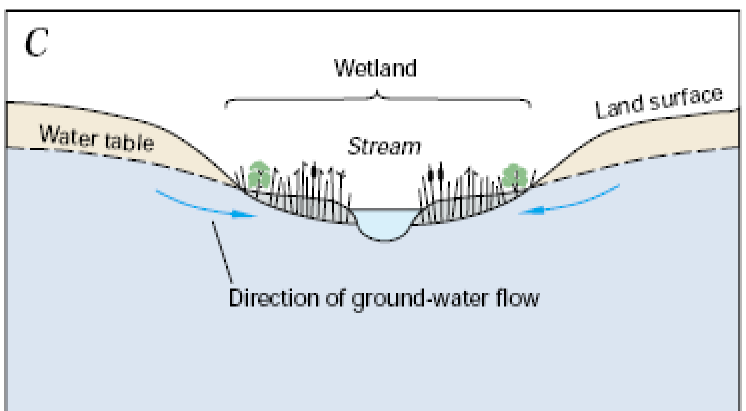


gw discharge where land surface underland by complex gw flow fields

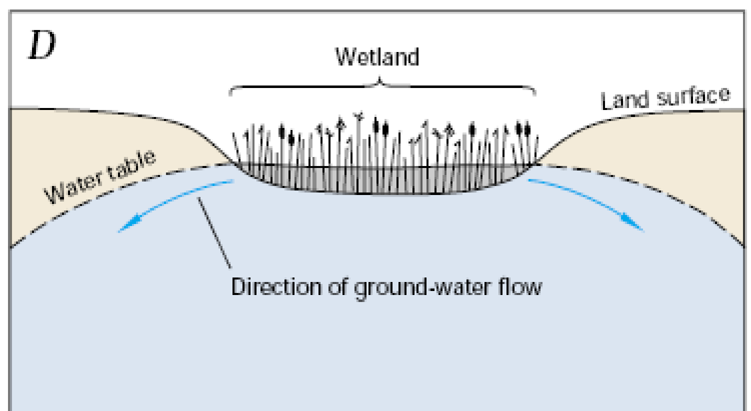


gw discharge by seepage and breaks in slope

"Lakes and wetlands can receive ground-water inflow throughout their entire bed, have outflow throughout their entire bed, or have both inflow and outflow at different localities"



gw discharge from streams



From precipitation where no inflow from gw, streams, lakes or ocean

(From: Winter et al. *1998)*

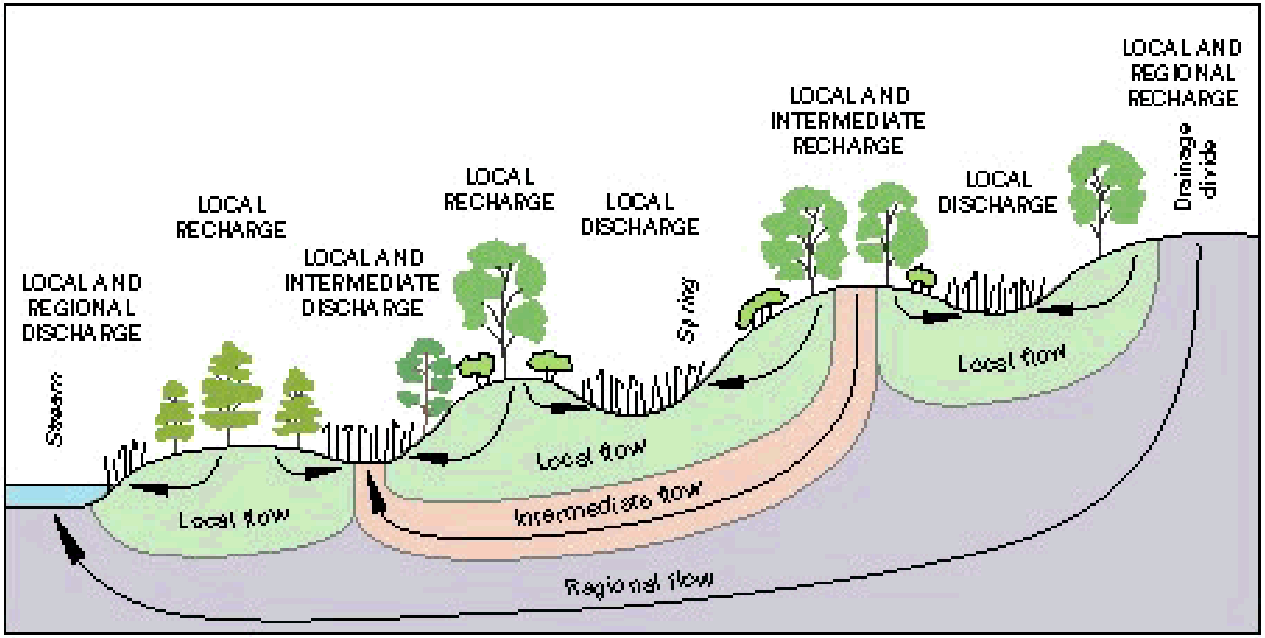
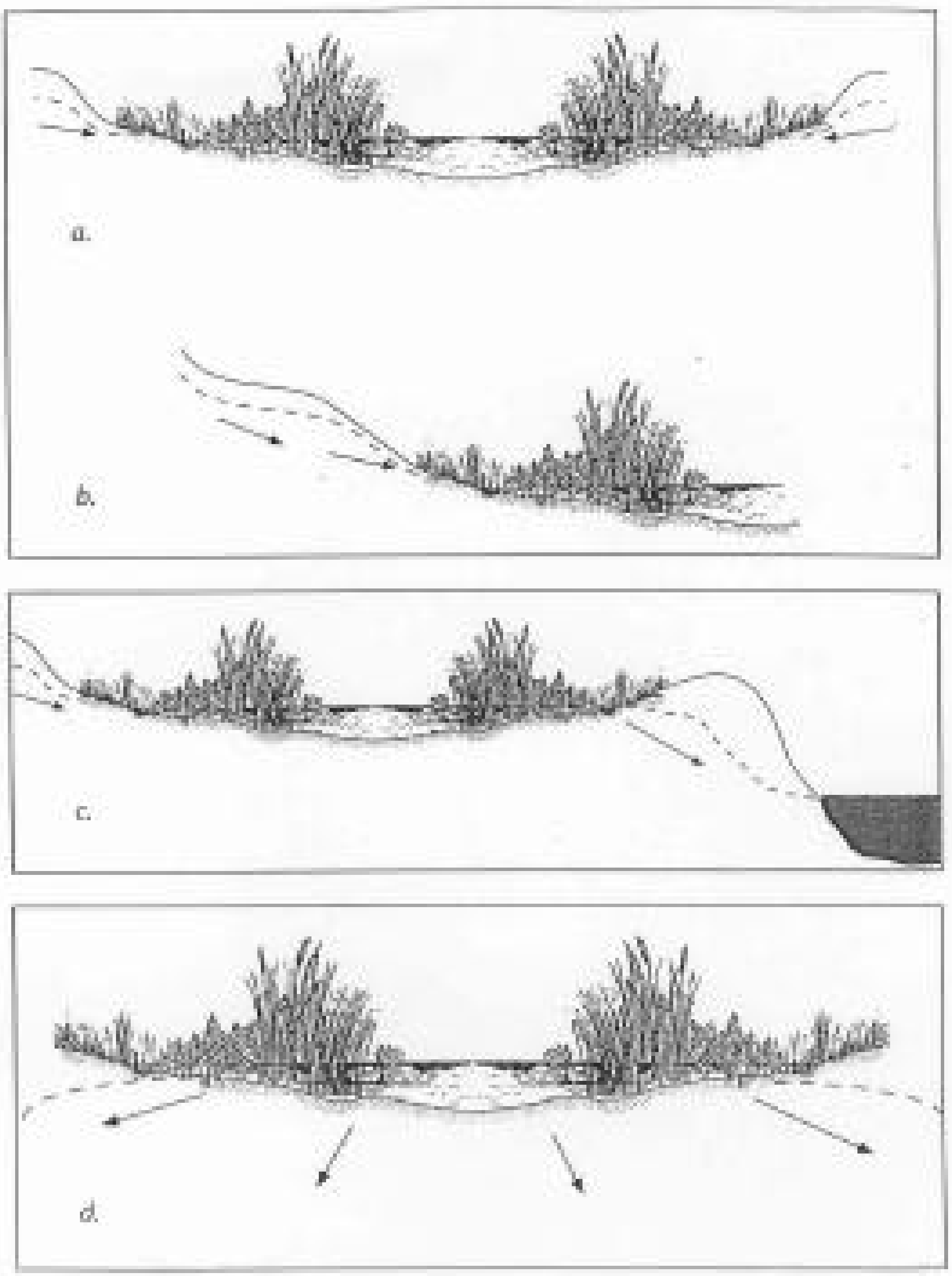


Figure 22. Ground-water flow systems. Local ground-water flow systems are recharged at topographic highs and discharged at immediately adjacent lows. Regional ground-water flow systems are recharged at the major regional topographic highs and discharged at the major regional topographic lows. Intermediate flow systems lie between the other two systems. *(Source: Modified from Winter, 1976.)*

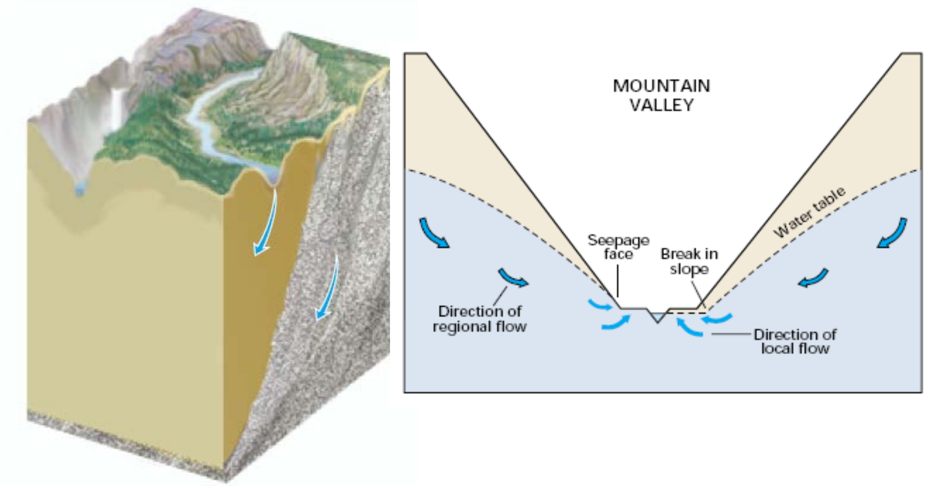


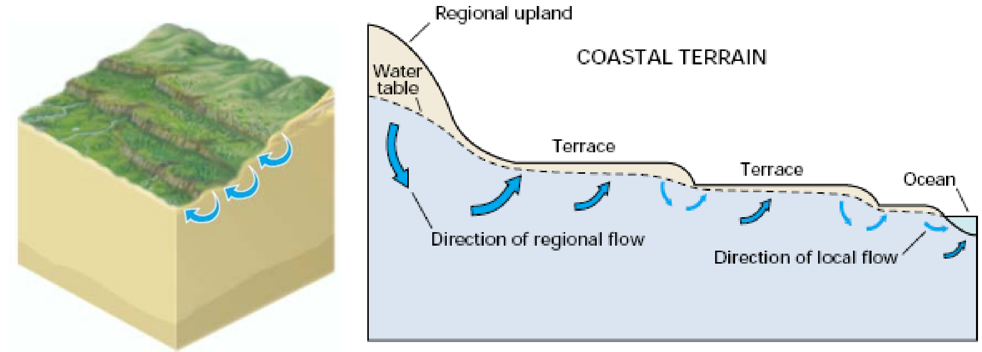
Discharge wetland

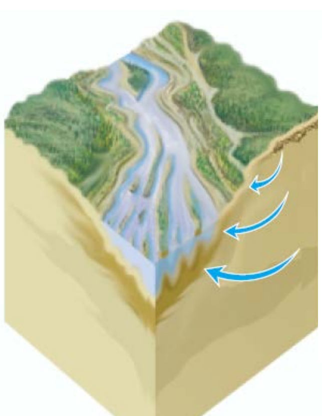
Seepage wetland

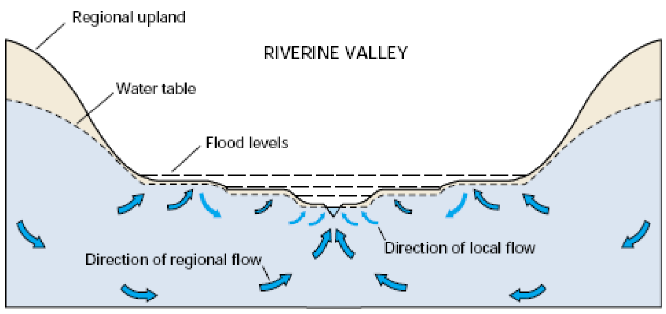
Floodplain wetland

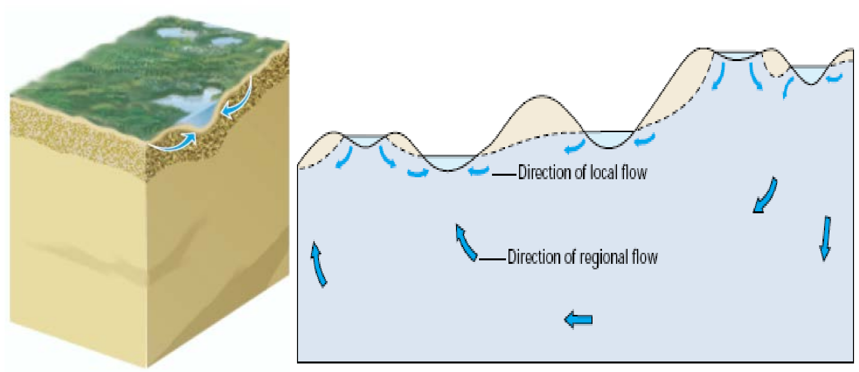
Recharge wetland











Other gw terrain: karst

Other non-gw terrain: sea coasts

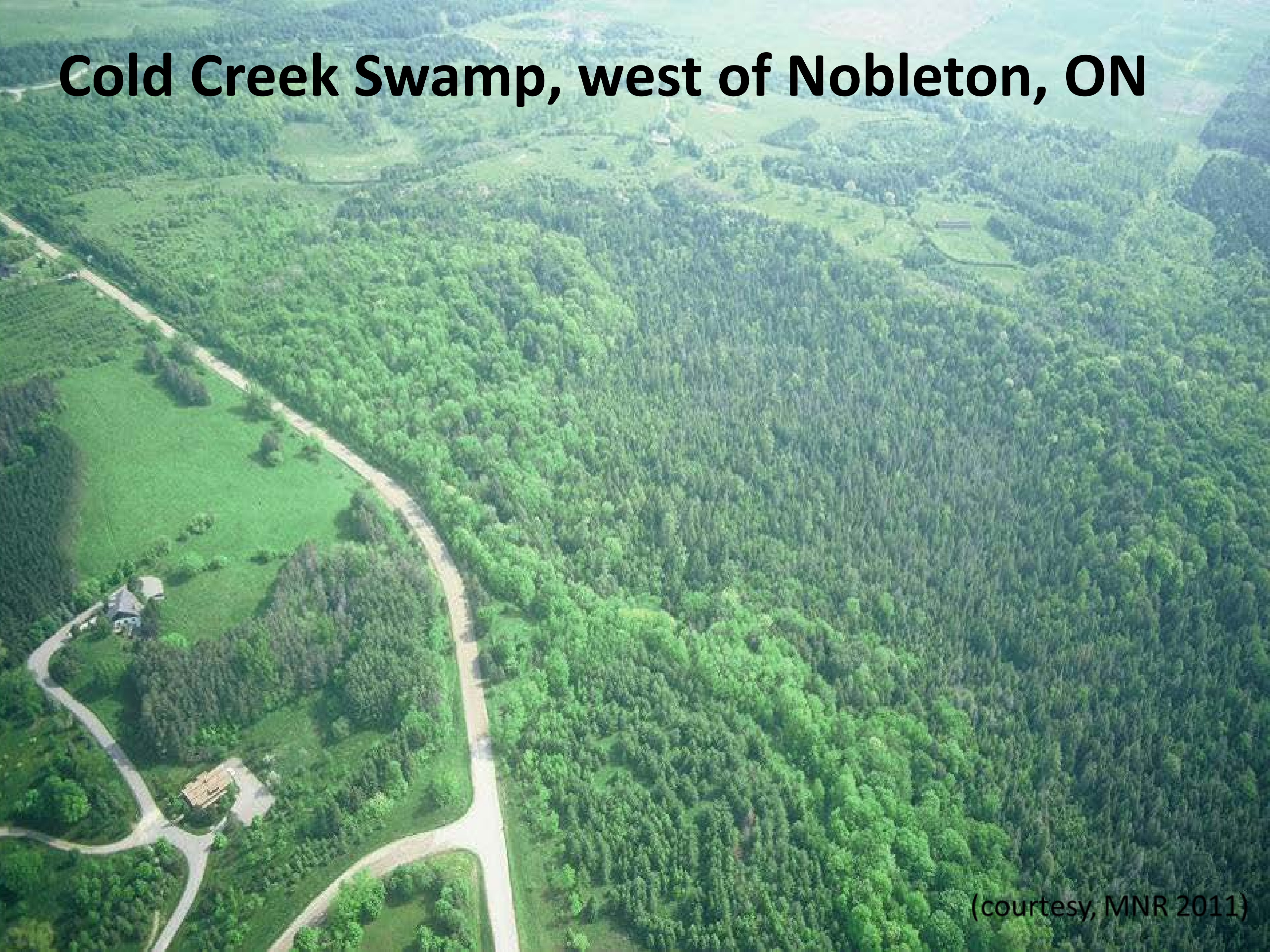
Permafrost: ice-dominated processes

(From: Winter et al. *1998)*

New Scotland wetlands, west of King City, ON – Kettle wetlands on Oakridges Moraine

(courtesy, MNR 2011)

Cold Creek Swamp, west of Nobleton, ON



(courtesy, MNR 2011)


Bond Lake peatland, near Richmond Hill -
Oak Ridges Moraine
(courtesy, MNR 2011)

Barrier Beach Bar on north shore of Lake Ontario with marsh

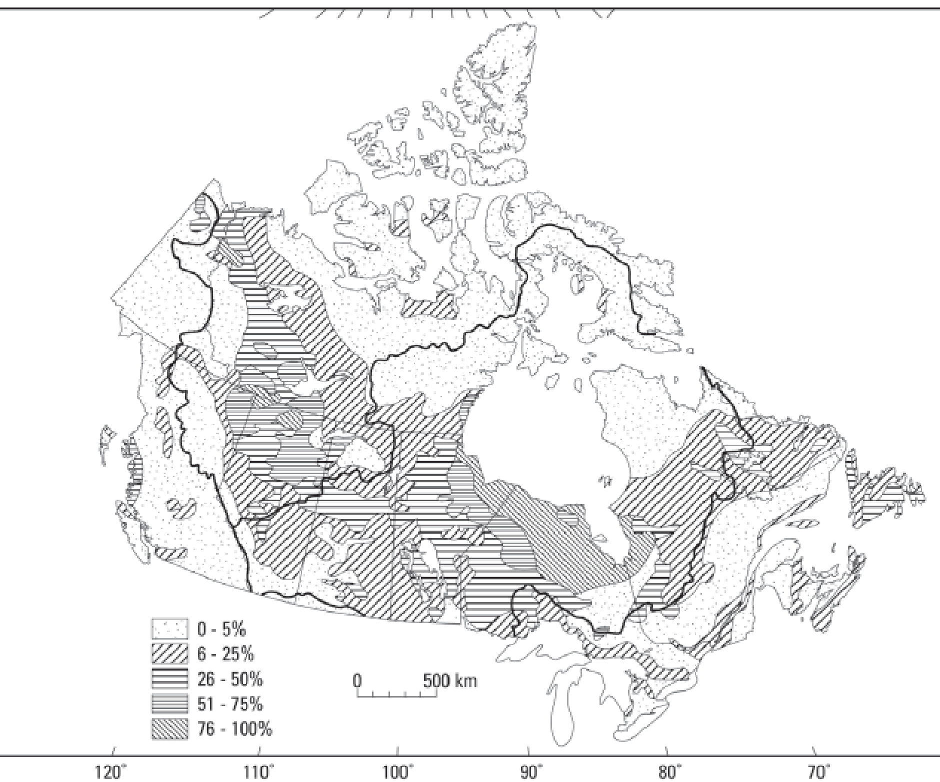
(courtesy, MNR 2011)

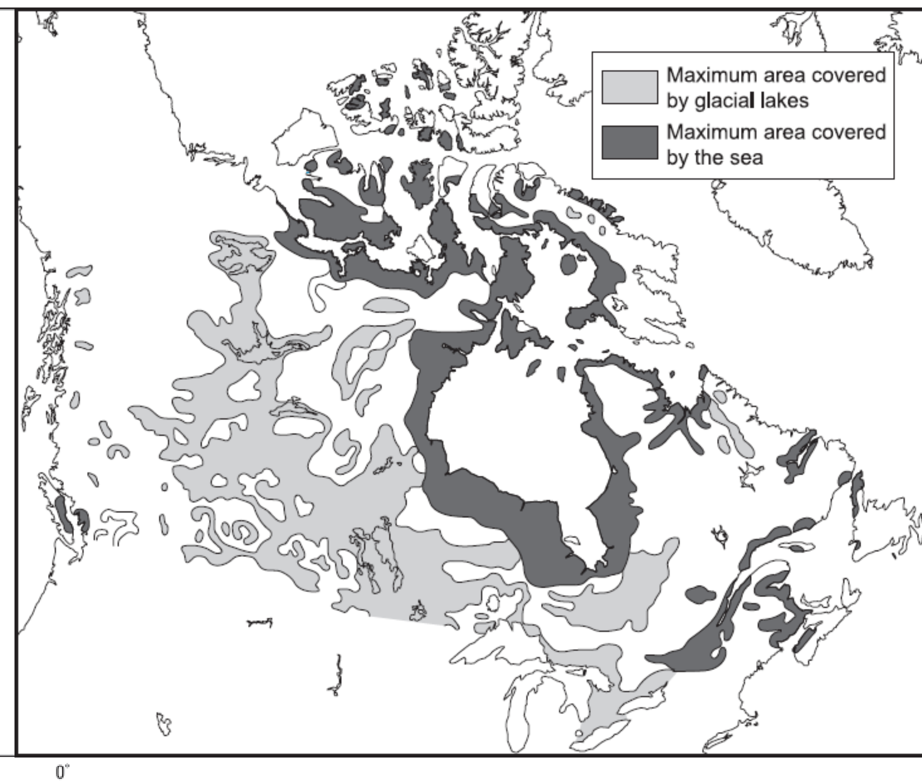
North Goodwood Wetland, near Carleton Place, ON – Altered by beavers and road construction

(courtesy, MNR 2011)

Wetland geology and soils-Continental scale

- Landscape geomorphology influences how and where water moves





From: Warner (2004)

Table 1. An example of a geological classification of natural wetlands in the Great Lakes region

Basin type	Predominant Wetland Type
I. Basins of glacial origin	
Large basins	Mineral wetland
Kettles	Mineral wetland and peatland
Depressions and drainage impedients	Mineral wetland and peatland
II. Basins formed by river action	
Floodplain wetlands	Mineral wetland and peatland
Oxbows	Mineral wetland and peatland
III. Basins formed by shoreline processes	
	Mineral wetland
IV. Basins formed by isostatic uplift	
	Mineral wetland
V. Wind-formed basins	
	Mineral wetland
VI. Basins of biotic origin	
Beaver dams	Mineral wetland and peatland

(Taken from Warner 2004)

Energy is the driving force

- Wetlands occur mostly in areas of low energy; thus flows are slow
- Direction and rate of water movement into and out of wetlands is dependant on energy
- Moves from zones of high to zones of low energy; mostly driven by gravity;

Hydrology

- Infiltration: movement of water into the ground; complicated by soil physics; organic matter leads to greater infiltration
- Overland flow (or not): precip. exceeds maximum infiltration rate
- Evapotranspiration: evaporation-movement from water body to atmosphere; transpiration-movement from plant tissue to atmosphere
- Groundwater flow: subsurface movement of water in vadose zone (unsaturated zone) and below water table (saturated zone)

Key Hydrologic Characteristics

- Water levels in wetlands or water table
- Wetland hydroperiod or hydropattern
- Wetland water residence time

Wetland Water Table

- Above the surface
  - same as elevation of the SW in wetlands (water table outcrops)

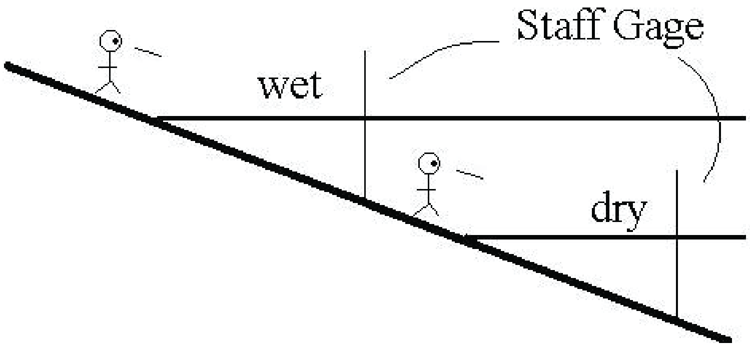
- Below the surface
  - interface between complete saturation of pore space
  - interface in porous media where pore pressure = atmospheric pressure

How to measure the water table

- Measure on surface if exposed
- Dig a hole
- Use water well (screened PVC tube with GW beeper tape)
- Usually expressed as m a.s.l. or m above datum and plotted on hydrograph

Wetland Water Table – Above Surface

- Staff gauge
  - Manual readings
  - Digital instruments
- Multiple staff gauges
  - Recognize seasonal changes



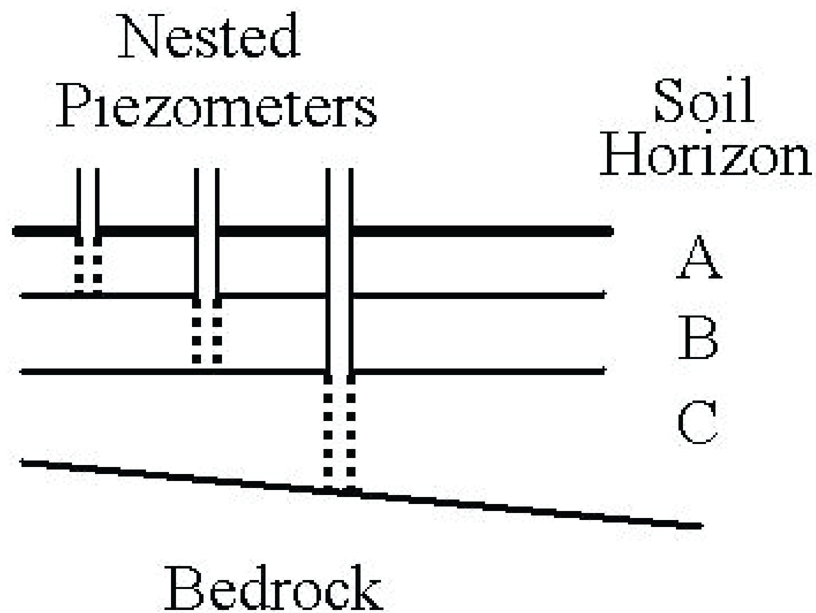
(from USEPA Rpt, 2008: EPA-822-R-08-024)

Dry season –
Creditview wetland, Mississauga, Ontario

(from: creditviewwetland.org)

Wetland Water Table – Below Surface

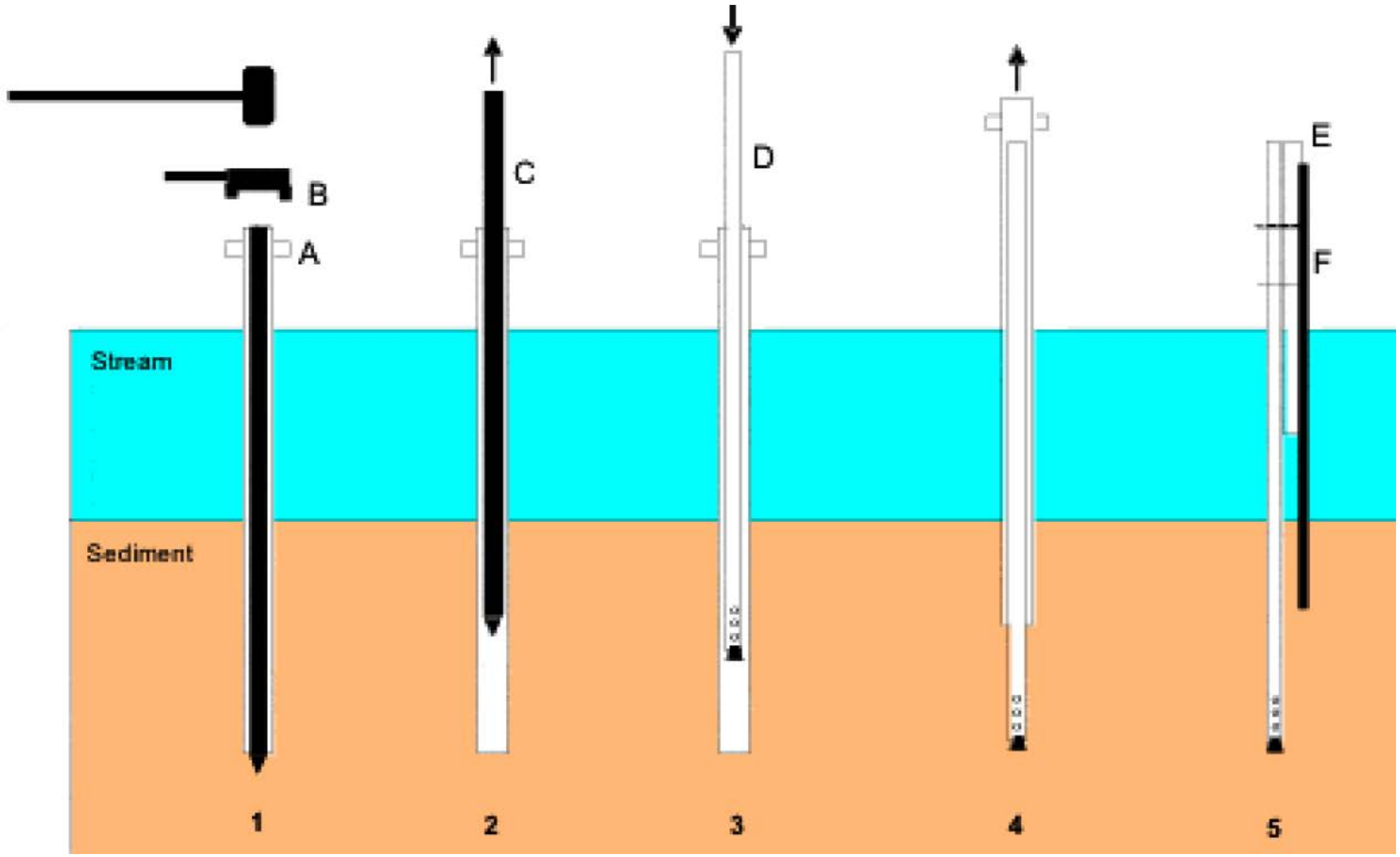
- Water well
- Piezometer nest



(from USEPA Rpt, 2008: EPA-822-R-08-024)


FRAGILE

Installation of piezometer



From: http://www.connectedwater.gov.au/framework/hydrometric_piezometer.php

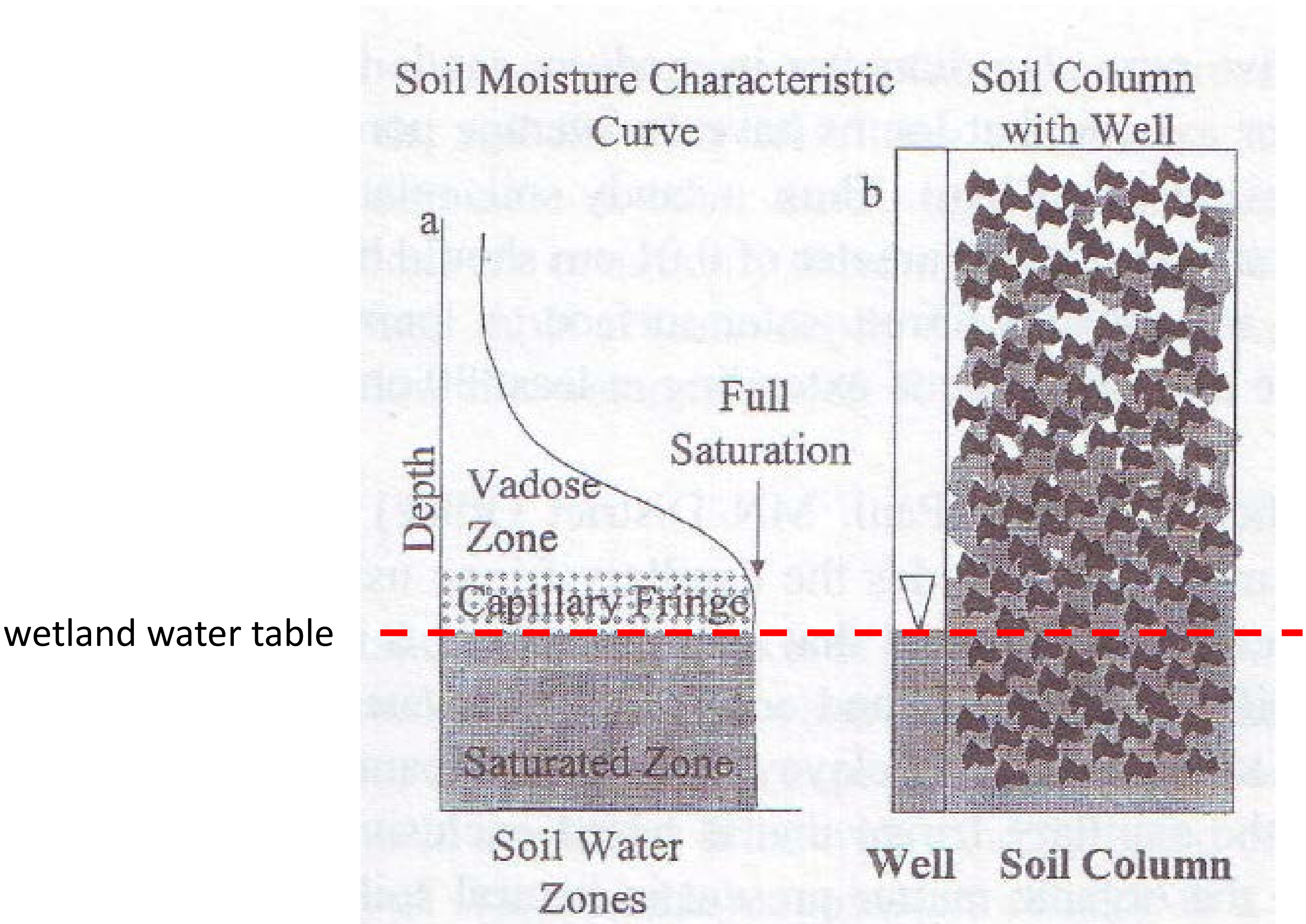
groundwater beeper tape

peristaltic pump

(from www.solinst.com)

Capillary Fringe

- Zone immediately above water table in which water is drawn upward by capillary action (i.e. forces of adhesion and surface tension which pull water upwards against gravity into soil pores)



(Taken from Richardson & Vepraskas 2001)

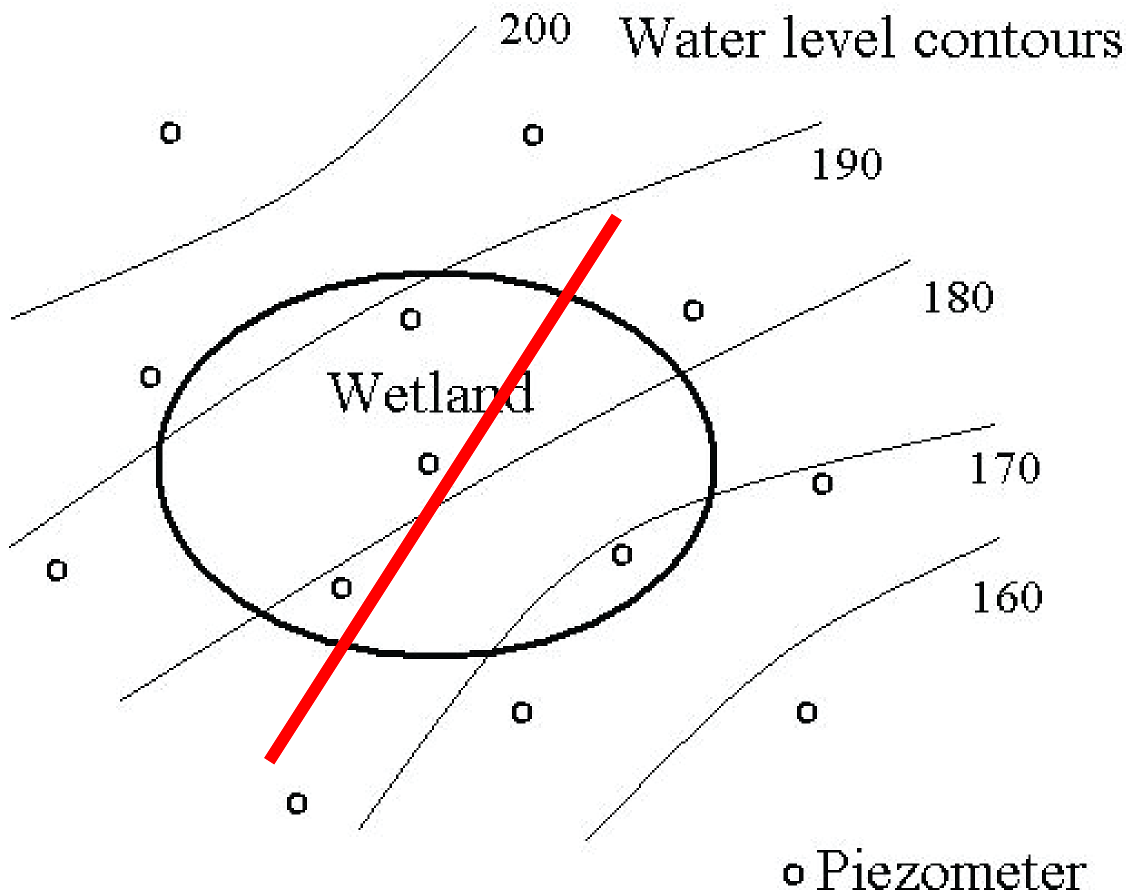
Estimates of Capillary Fringe

(from: Mausbach, M.J. 1992. Soil survey interpretation for wet soils. P. 172-178. In Eighth Internationsl Soil Correlation meeting.)

Soil Texture	Capillary Fringe (cm)	Capillary Fringe (in)
Soil sand	1-7	0.4-2.8
Sand	1-9	0.4-3.5
Fine sand	3-10	1.2-3.9
Very fine sand	4-12	1.6-4.7
Loamy course sand	5-14	2.0-5.5
Loamy sand	6-14	2.4-5.5
Loamy fine sand	8-18	3.1-7.1
Coarse sandy loam	8-18	3.1-7.1
Loamy very fine sand	10-20	3.9-7.9
Sandy loam	10-20	3.9-7.9
Fine sandy loam	14-24	5.5-9.4
Very fine sandy loam	16-26	6.3-10.2
Loam	20-30	7.9-11.8
Sandy clay loam	20-30	7.9-11.8
Sandy clay	20-30	7.9-11.8
Clay loam	25-35	9.8-13.8
Silt loam	25-40	9.8-15.7
Clay	25-40	9.8-15.7
Silt	35-50	13.8-19.7
Silty clay loam	35-55	13.8-21.7
Silty clay	40-60	15.7-23.6

These values were determined in laboratory conditions. Field values will tend to be at the smaller side of the range.

Mapping wetland water levels



(from USEPA Rpt, 2008: EPA-822-R-08-024)

HINT: At least one transect through the wetland depending on size; more for bigger wetlands

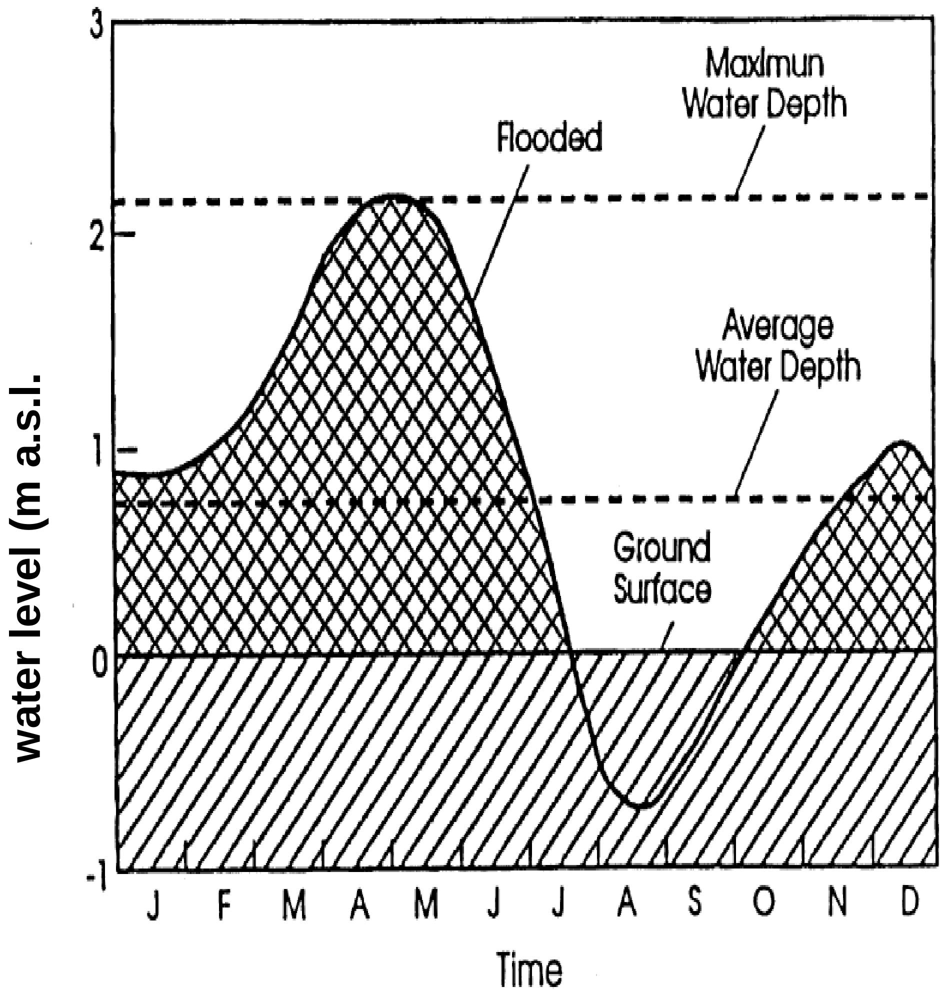
Wetland Hydroperiod or Hydropattern

- Measure of extent wetland remains saturated
- plot of water table over time = hydroperiod or hydropattern
- the seasonal pattern of the water table
- biota dependent on hydroperiod/pattern
  - water-inhabiting biota
  - soil surface inhabiting biota
  - soil inhabiting biota: plants and oxygen content

Hydrograph

- *Stage* = period of time that shows the range of variation in hydrologic variability as reflected by elevation of water table; usually 12 months
- Water level elevation versus time; plotted as *hydrograph*

Wetland Hydroperiod



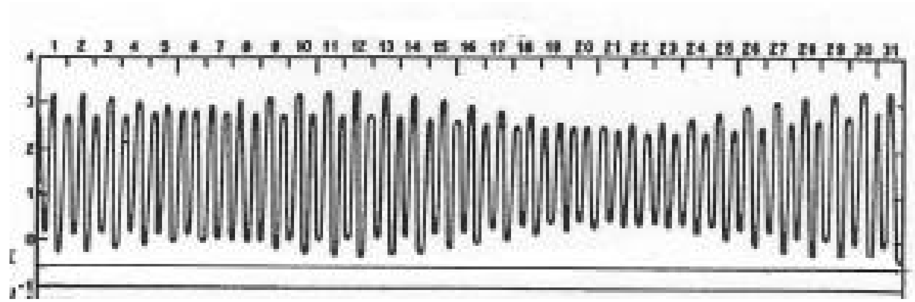
- Seasonal pattern of water level
- Hydrological signature of wetland
- Can be #days/year or % time water table is at a certain position (ie. above surface)
- eg.: Hydroperiod = 220/365 = 60%

hydrograph

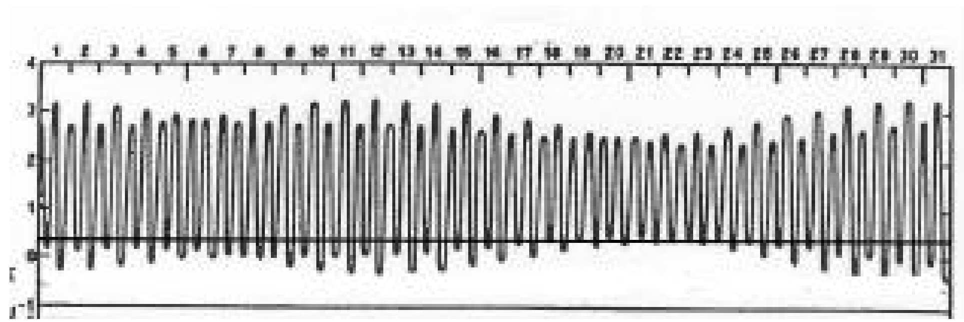
(Taken from Kadlec 1988)

Tidal Wetlands

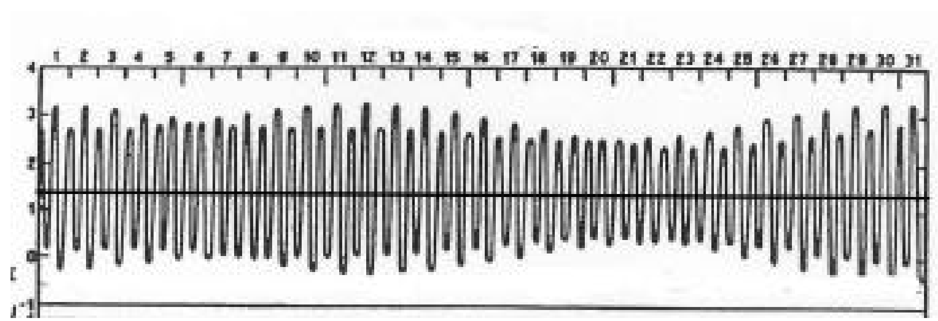
Permanently inundated



Irregularly Exposed



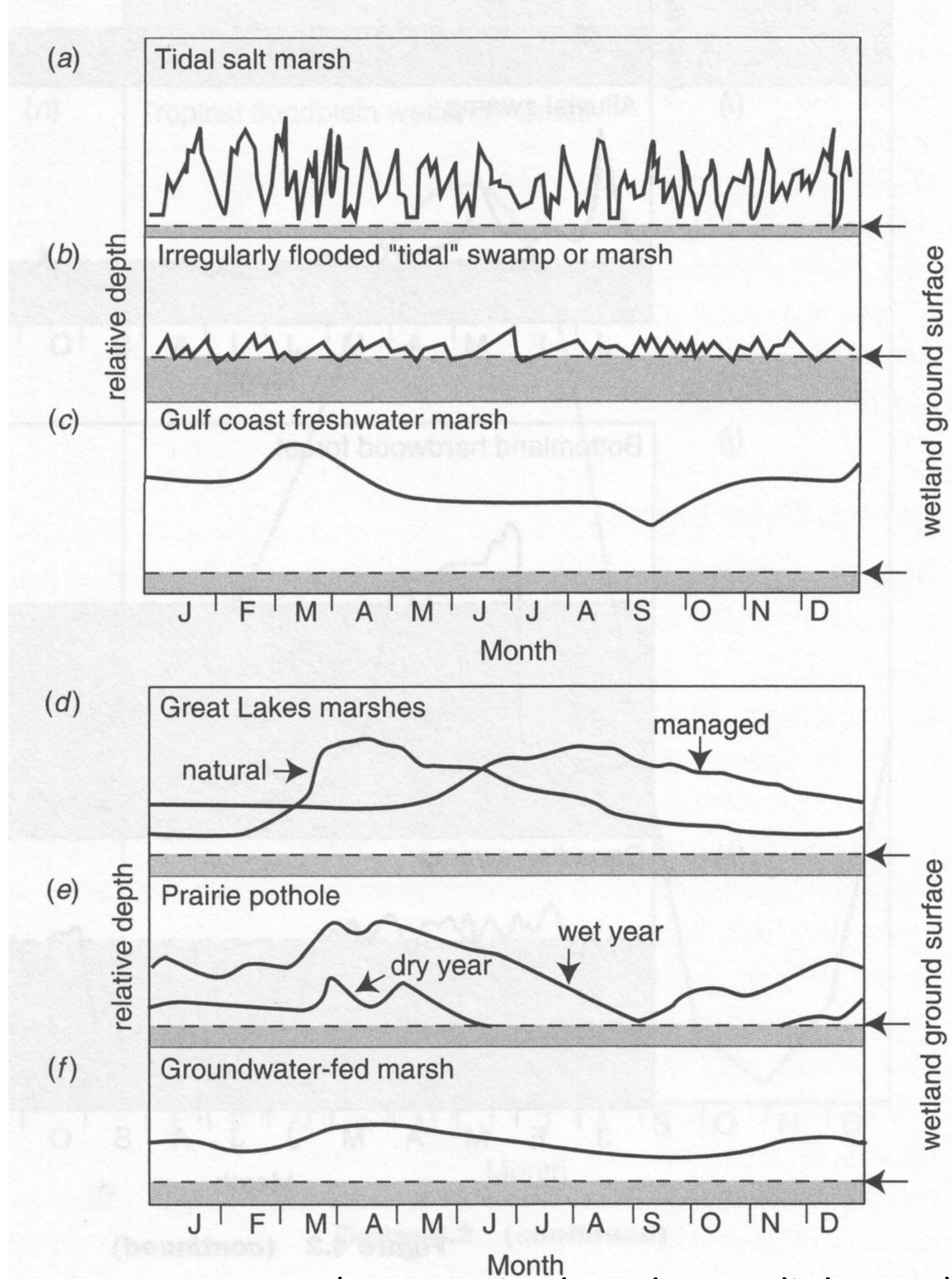
Regularly Exposed



Permanently inundated – occasionally dry

Intermittently inundated

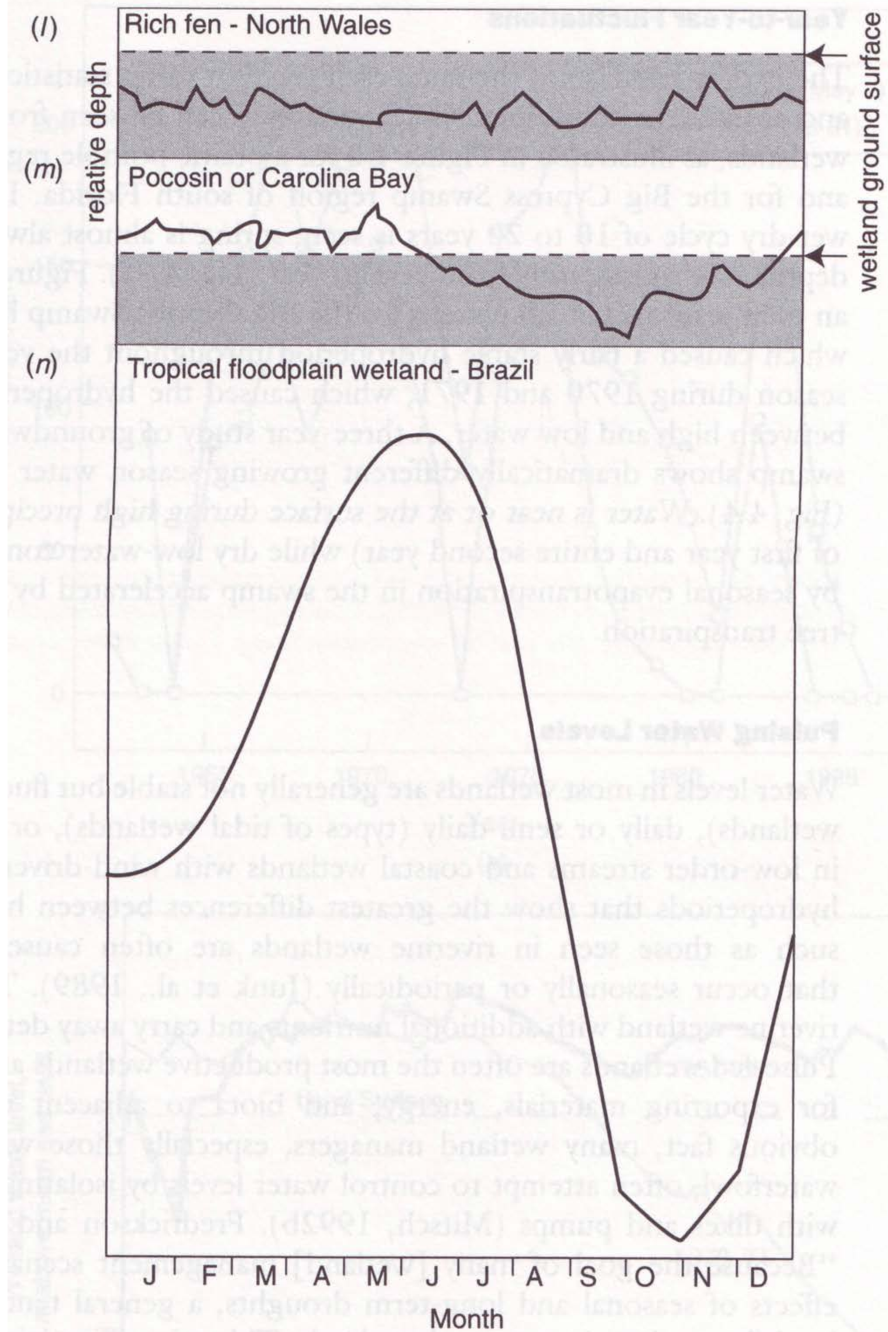
Permanently inundated



(From: Mitsch and Gosselink 2007)

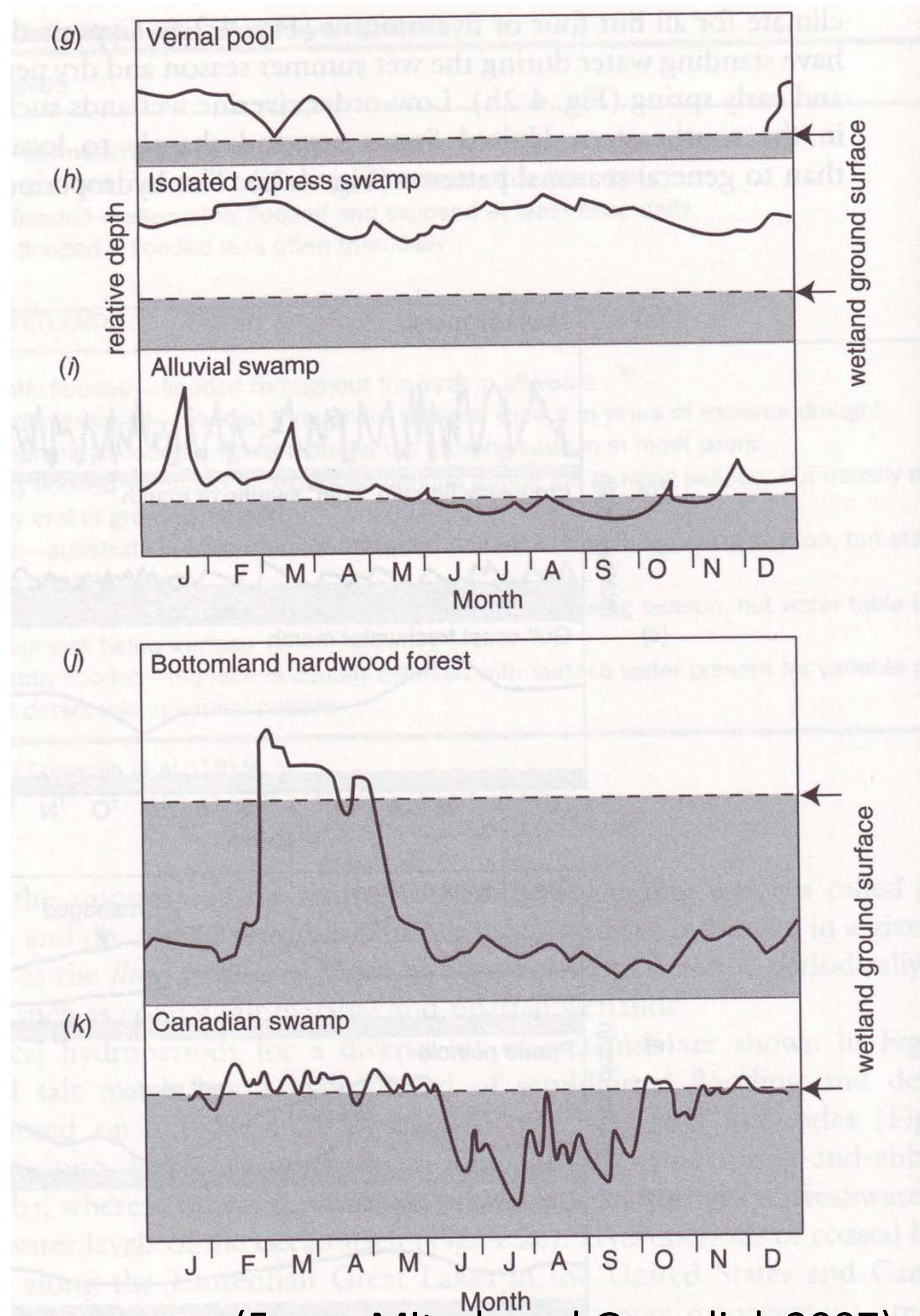
Permanently saturated

Seasonally inundated



(From: Mitsch and Gosselink 2007)

Seasonally inundated



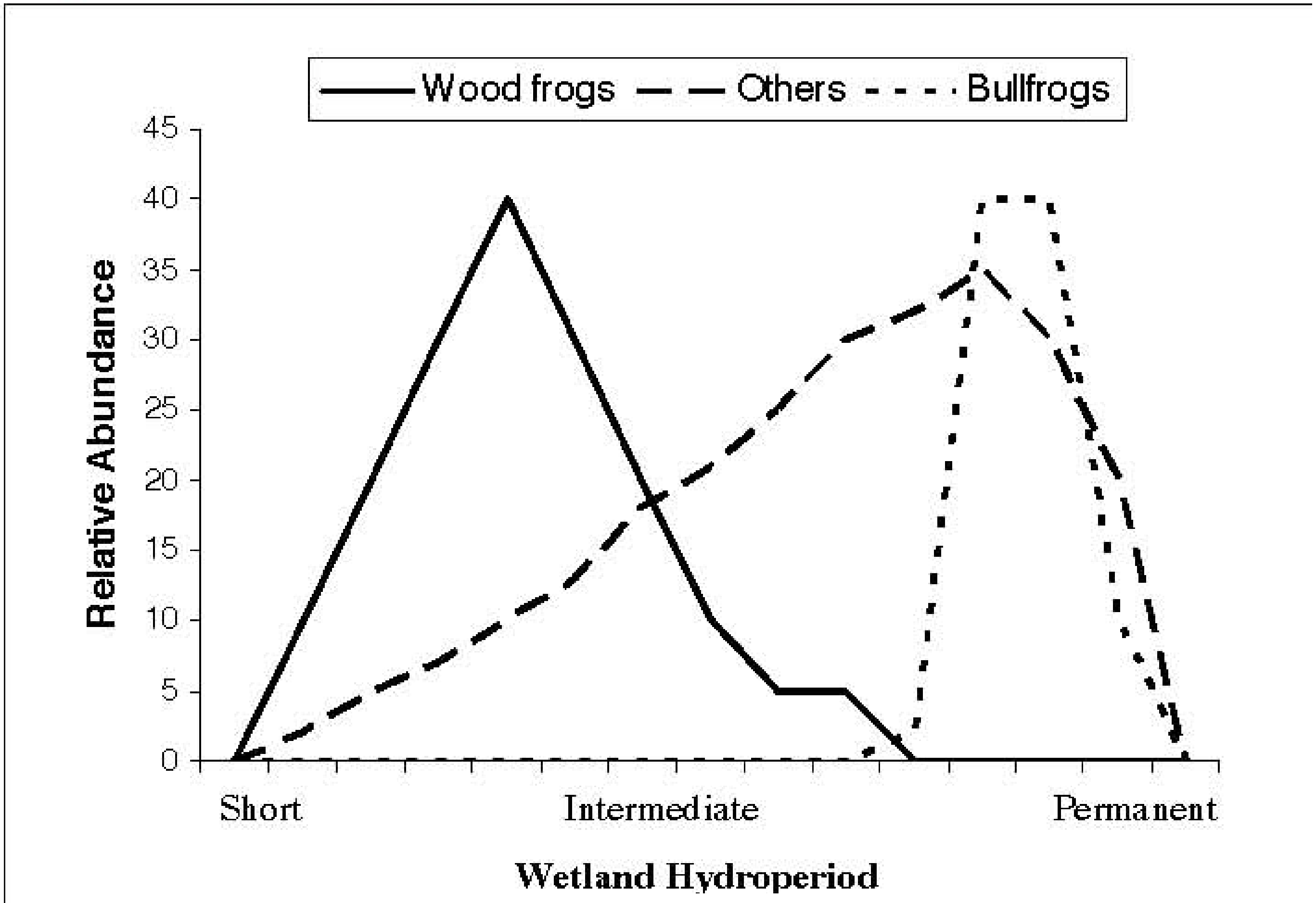
(From: Mitsch and Gosselink 2007)

Hydroperiods/Hydropatterns can be used to infer the following:

- permanence of inundation
- predictability
- phenology (seasonal timing) of drying and inundation
- duration of inundation
- harshness or extremes of both

Wetland Hydroperiod or Hydropattern – Water Inhabiting Biota

Figure 1. Difference in relative abundance of pond breeding amphibians across the hydroperiod gradient.



(From: Tarr and Babbitt, University of New Hampshire)

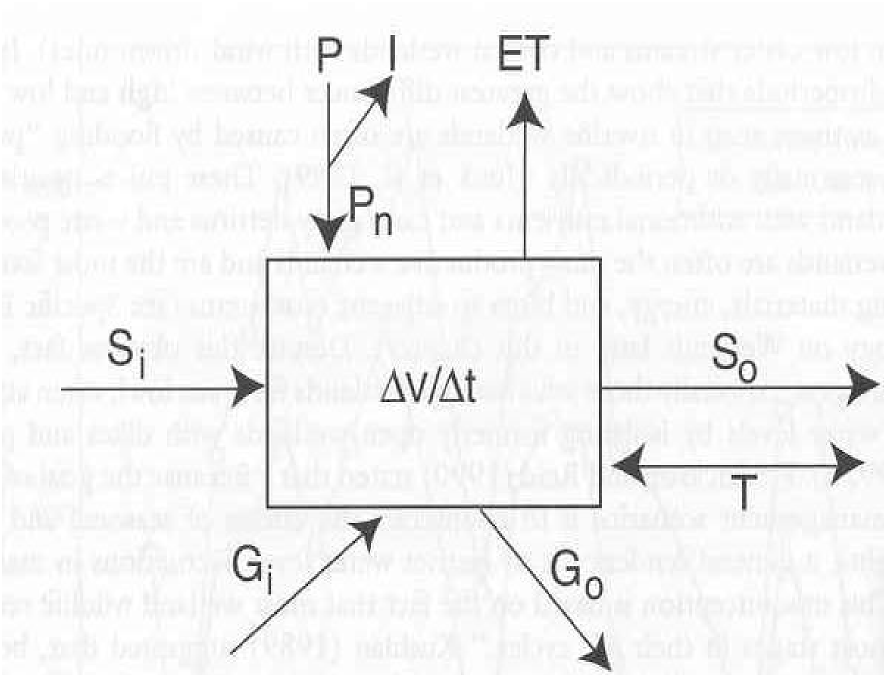
Wetland Water Budgets

- Wetlands are areas of sustained saturation

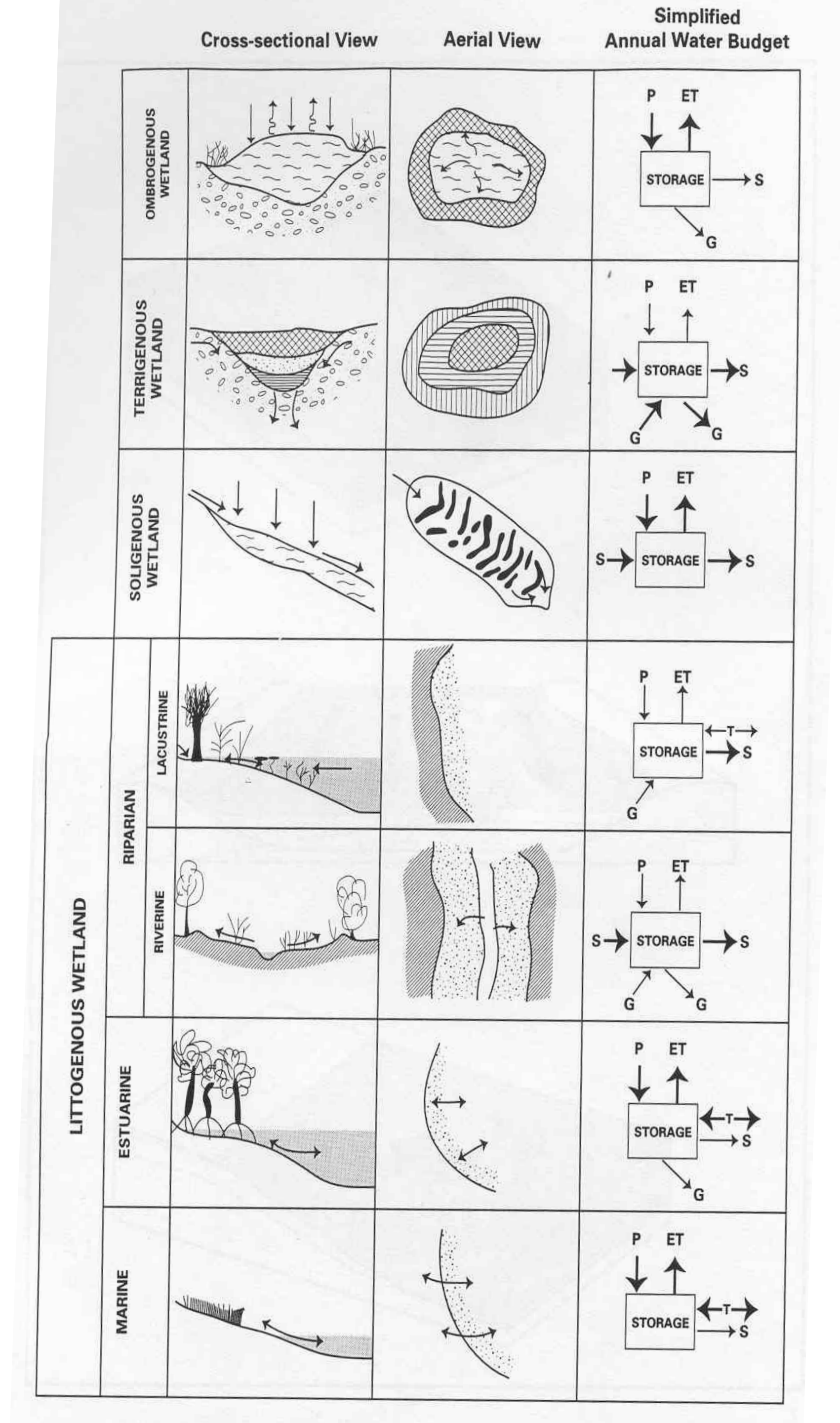
  inputs - outputs =
  changes in storage or changes in water residence times

$P + G_{in} + Of_{in} + Sf_{in} + OBF_{in} – ET - G_{out} – Sf_{out} – OBF_{out} = \Delta S = \Delta V/\Delta t$

(P=precipitation; G=groundwater; Of=overland (non-channelized) flow; Sf = surface (channelized) flow; OBF=overbank flow; S=storage)



After: Mitsch & Gosselink 2007



From: Damman & French 1987

Wetland Water Budgets

- can be as complex as you like
- errors associated with estimating inputs and outputs
  - P And SW: $< 10\%$
  - GW: up to 100s%
  - E: up to 100s%
- measuring inputs and outputs: you get what you pay for
- how accurate do I need to make water budget
- water quantity and water quality important in most wetland water budgets
- chemical budgets sometimes can be independent check

Wetland Water Residence Time

- hydrologic residence time: the time required for a hydrologic input to pass through the wetland
- often not constant everywhere in wetlands

t = V/Q; where *t = residence time*

V = volume of water in wetland with constant volume and flow rate

Q = flow rate

- where V and Q are not constant then *t* is not actual *t*; then only estimate of average *t*

Water residence time or detention time (nominal residence time)

- Estimate of time water remains in wetland; few accurate figures
- Theoretical value often greater than reality because of non-uniform mixing
- Theoretically: $t^{-1} = \frac{Q_t}{V}$

t^{-1} = residence time; Q_t = total inflow rate (vol./time); av. vol. of storage in wetland

Storage

- Capacity or space available to store water
- Consists of:
  - **Dynamic storage**: the volume of water which changes daily or seasonally; reflected in water levels
  - **Static storage**: the water stored in the soil which does not change greatly annually
- Higher the water table; less capacity to store water
- Storage capacity increases with growing season

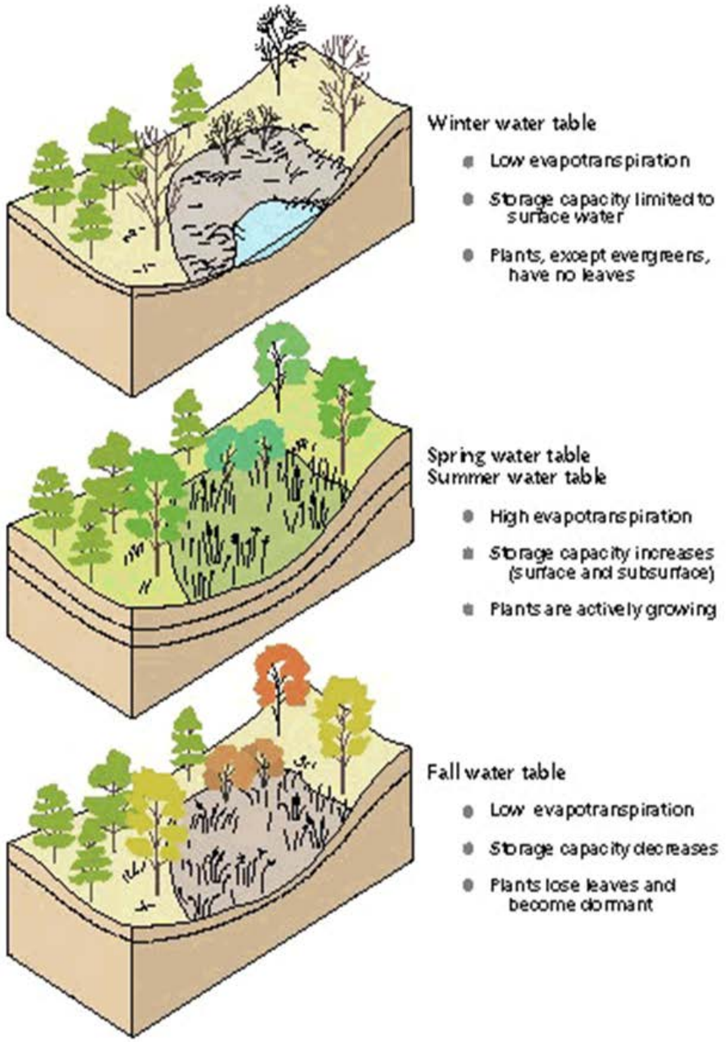


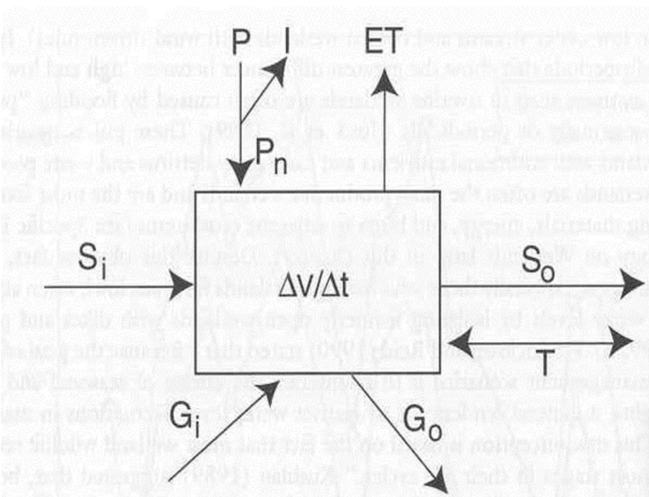
Figure 23. Seasonal changes in storage capacity and evapotranspiration. (ET) in wetlands.

Classification - Hydrological Regimes

- *ombrogenous* - precipitation sources
- *terrigenous* - groundwater and surface flow
- *soligenous* - seepage from surface flow (mostly for peatlands)
- *littogenous* - freshwater and marine shorelines (=riparian)

Water Budget Components

- Water budgets important for characterizing water sources and sinks, and hence behaviour of wetlands



After: Mitsch & Gosselink 2007

(modified from USEPA Rpt, 2008, EPA-822-R-08-024)

Swamps

- strong surface and/or groundwater input = minerogenous
- high runoff
- ET may be high because of trees

Fens

- small to moderate groundwater input = minerogenous
- ET is high (basin shape, plants important influences)
- runoff can be high when the water is above the surface
- when water table is low, flow decreases markedly

Marshes and Shallow Waters

- high ET
- dominant loss because of open water
- groundwater recharge may be significant
- runoff may not be present

Bogs

- Input from precipitation only = ombrogenous
- Not well served by streams
- ET is often the dominant loss; recharge less so

Key References

- See Module #20 – Hydrology
  – http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/wetlands/index.cfm
- Winter et al. 1998. Groundwater and surface water: A single resource. USGS Circular 1139.
  – http://pubs.usgs.gov/circ/circ1139/