Design of the Next Generation of Constructed Wetlands

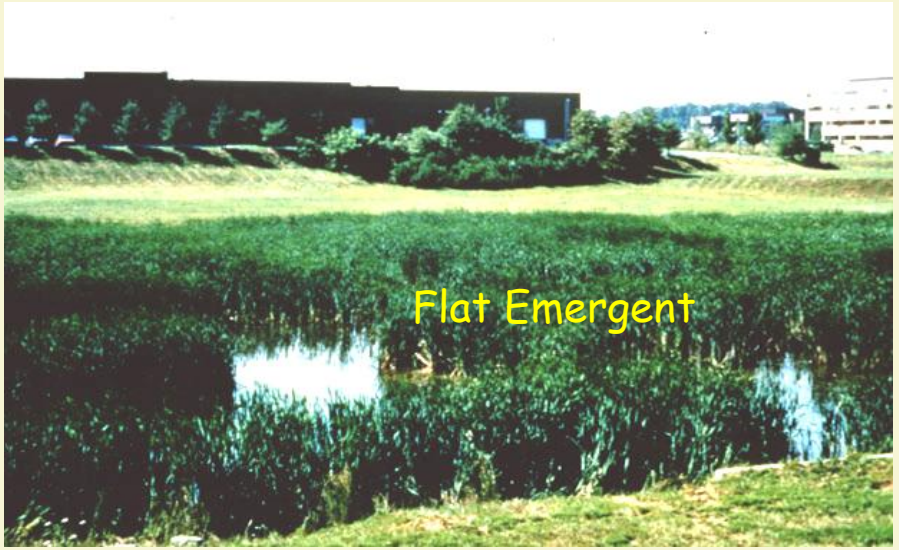
AGENDA

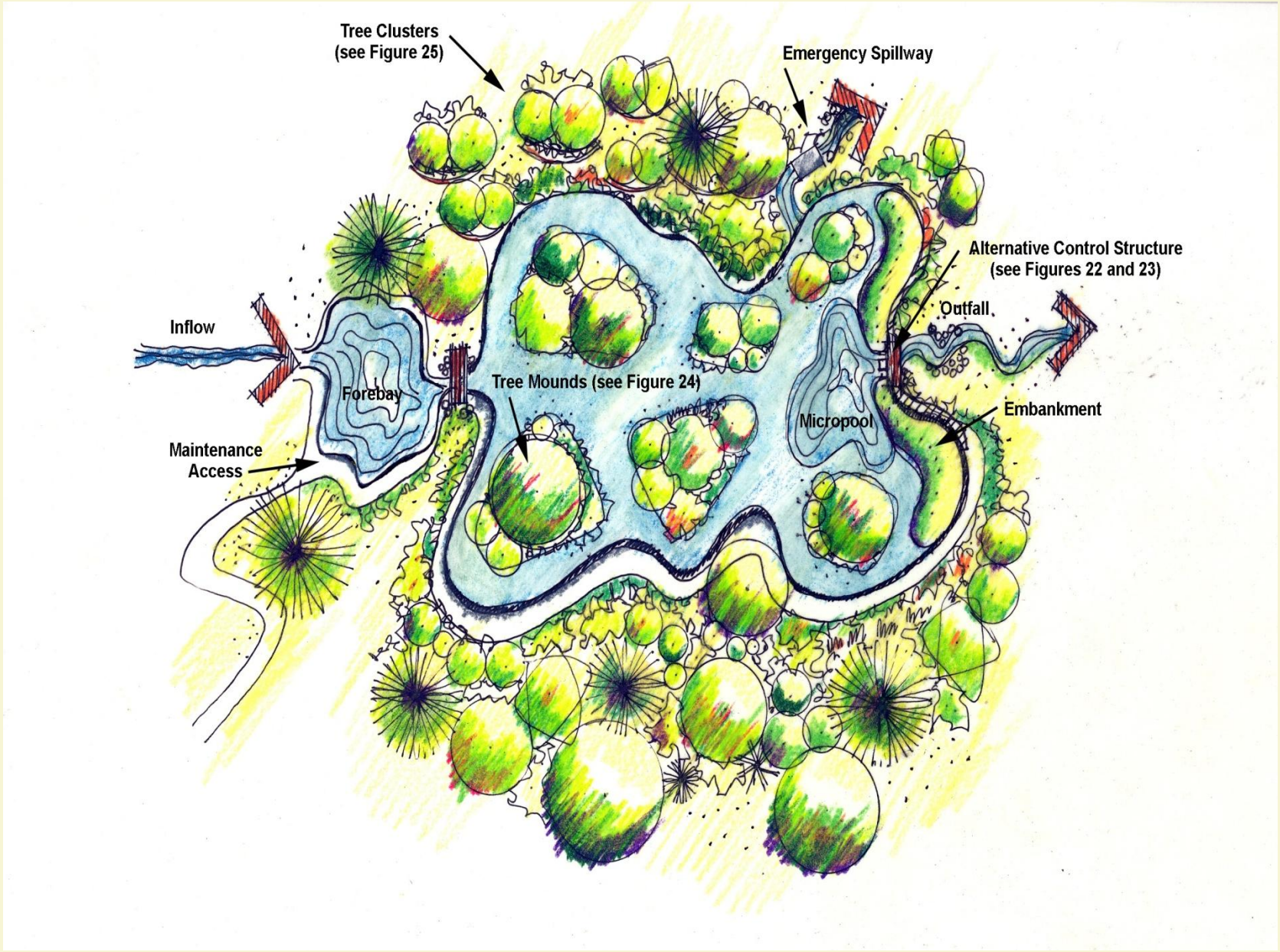
- The Curious Evolution of Stormwater Wetlands
- The Improved Stormwater Wetland Design
- Key Design Choices for Stormwater Wetlands
- The Regenerative Conveyance System Design
- Notes of Submerged Gravel Wetland

Evolution of Stormwater Wetlands

- Current emergent design evolved from wastewater, early wetland mitigation and stormwater wetland demonstration projects
- Not much change in design specs since DSW published in 1992
- Dry ponds slowly evolving into forested wetlands
- Not much actual implementation in recent years due to West Nile, land consumption, and pond alternatives
- 2005: Wooded wetland concept advanced

Evolution of Stormwater Wetlands





The Third Generation: The Forested Wetland

Lessons Learned In the Past 15 years

- Initial wetland plant community doesn't persist
- Mosquito problems not severe
- Dry ponds evolving into wooded wetlands
- ED & Water level fluctuations promote invasive species
- Wetlands too deep, sparse cover, "shallow ponds"
- Lousy micro-topography
- Habitat quality provided appears to be marginal
- Few designers are building them now because it is easier to do a dry or wet pond instead
- No changes in design to enhance nutrient processing (denitrification, uptake, storage)

Lessons Learned (continued)

- Very low reported runoff reduction capability (0 to 10%)
- Confusion about minimum drainage area, inflow rates, constant water elevation…are these really needed?
- No LID wetland design exists
- Works well in flat coastal plain w/ high water table
- One of the most cost-effective STPS when land is available
- Little control over the target vegetative community over time
- Woody growth (e.g., willows)
- Sediment removal is difficult without forebay
- Sensitive to high road sand or salting

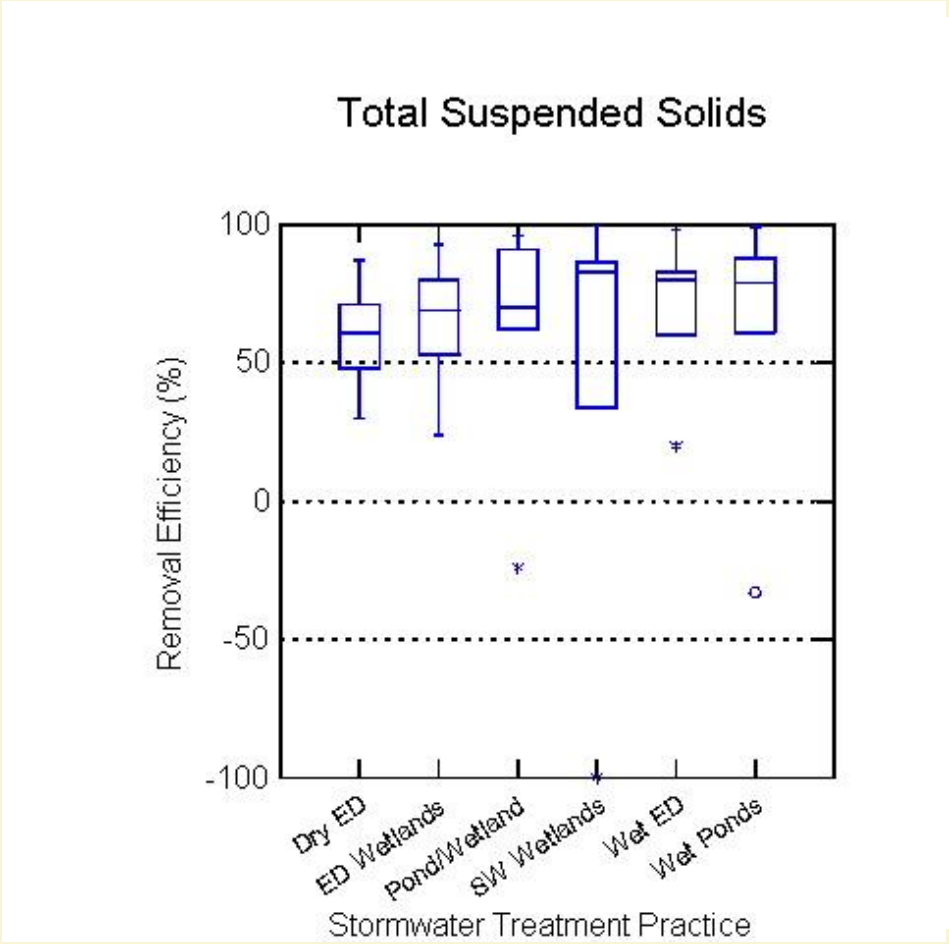
Summary of Stormwater Functions Provided by Constructed Wetlands		
Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Reduction	0%	0% *
Total Phosphorus Removal [1]	50%	75%
Total Nitrogen Removal [1]	25%	55%
Channel Protection	Yes. CPv can be provided above normal pool up to **one foot**	
Flood Mitigation	Yes. Flood control storage can be provided above normal pool	

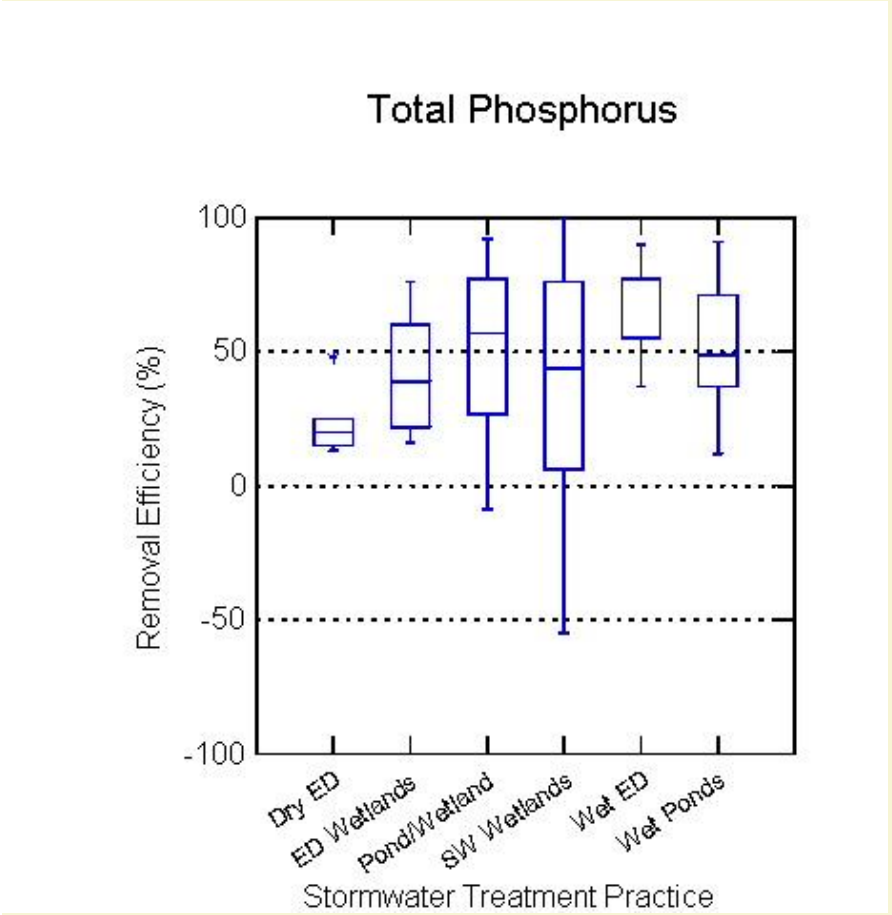
[1] Change in event mean concentration (EMC) through the practice. Actual nutrient mass load removed is the product of the removal rate and the runoff reduction rate. **Sources:** CWP and CSN (2008), CWP, 2007

Wetland Pollutant Removal Performance

- Performance much the same as ponds, except more variable
- Phosphorus removal may decline with age
- Majority of research sites have been shallow ponds with partial emergent wetland cover
- Stormwater wetlands also have irreducible concentrations
- New generation designs should boost removal rates

Pollutant Removal Performance of Stormwater Ponds and Wetlands





Pollutant removal by Emergent Stormwater Wetlands

Range of Reported Removal Rates for Stormwater Wetlands			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	45	70	85
Total Phosphorus	15	50	75
Soluble Phosphorus	5	25	55
Total Nitrogen	0	25	55
Organic Carbon	0	20	45
Total Zinc	30	40	70
Total Copper	20	50	65
Bacteria	40	60	85
Hydrocarbons	50	75	90
Chloride	0	0	0
Trash/Debris	75	90	95

Notes: 40 monitoring studies were available to define rates for total suspended solids, total phosphorus, soluble phosphorus, total nitrogen, organic carbon, total zinc and total copper for constructed wetlands.

Pollutant Removal Pathways within Stormwater Wetlands

- Sedimentation
- Adsorption to sediments/vegetation/detritus
- Physical filtration of runoff
- Microbial uptake/transformation
- Uptake by wetland plants
- Uptake by algae
- Extra detention and/or retention

Impacts of Stormwater on Wetland Hydroperiod

- Stormwater Increases the Water Level Fluctuation (WLF) within the wetland.
- Even a modest WLF or "bounce":
  - Reduces wetland plant diversity
  - Reduces thin stemmed species
  - Promotes invasive species
  - Reduces amphibian diversity

Design Choices for Stormwater Wetlands

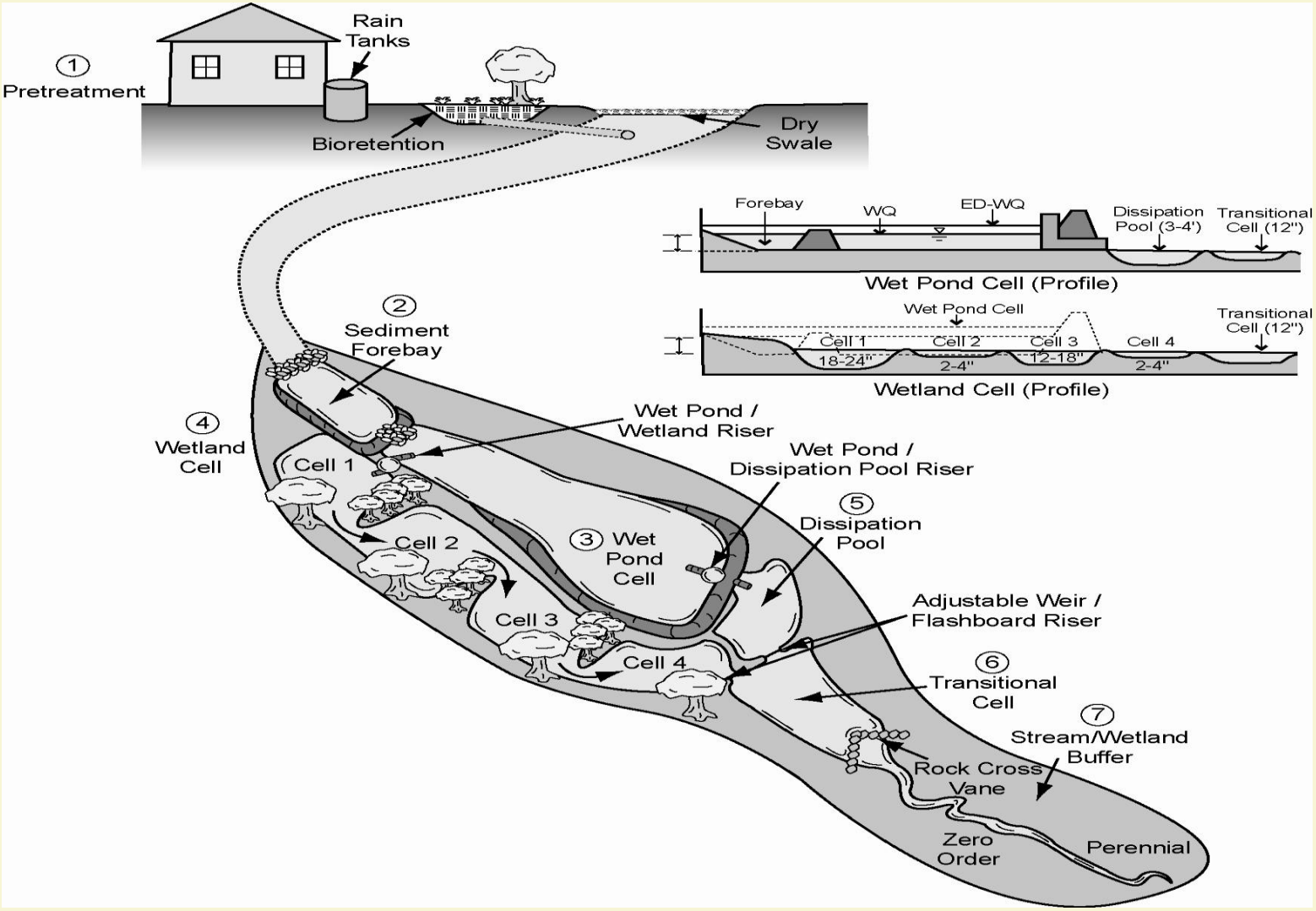
Need to Upgrade Design to Reflect Lessons Learned in Last 15 years

Level 1 or Level 2 Design?	
Level 1 (RR:0; TP:50; TN:25)	Level 2 (RR:0; TP:75; TN:55)
TV= (Rv)(A	TV = 1.5(Rv) (A)
Single cell (with forebay)	Multiple cells or pond/wetland design
ED wetland	No ED in wetland
Uniform wetland depth	Diverse microtopography
Mean wetland depth more than one foot	Mean wetland depth less than one foot
Wetland SA/CDA ratio less than 3%	Wetland SA/CDA ratio more than 3%
Flow path 1:1 or less	Flow path 1.5:1 or more
Emergent wetland design	Wooded wetland design

Design Choices: Forebay

- Essential design element.
- 10 to 15% of wetland surface area.
- Three feet deep at outfall grading up to a foot at the next wetland cell.
- Easy maintenance access to get to it.

Design Choices: Pond/Wetland System



New Pond Wetland Design

- Space-saver for denser development sites.
- Side by side pond and wetland.
- On-line pond and off-line wetland.
- Wetland has 4 to 6 cells that step down a foot of elevation each.
- Pond bleeds water into wetland during dry weather.
- Pond has 70% of total treatment volume.

See CWP 2008. Article 5 The next generation of stormwater wetlands

Design Choices: Acceptable Water Depths

- Keep Emergent Marsh Zones + 6 to - 6 inches from the normal pool
- Eliminate any marsh zones from - 6 to - 18 inches – nothing grows

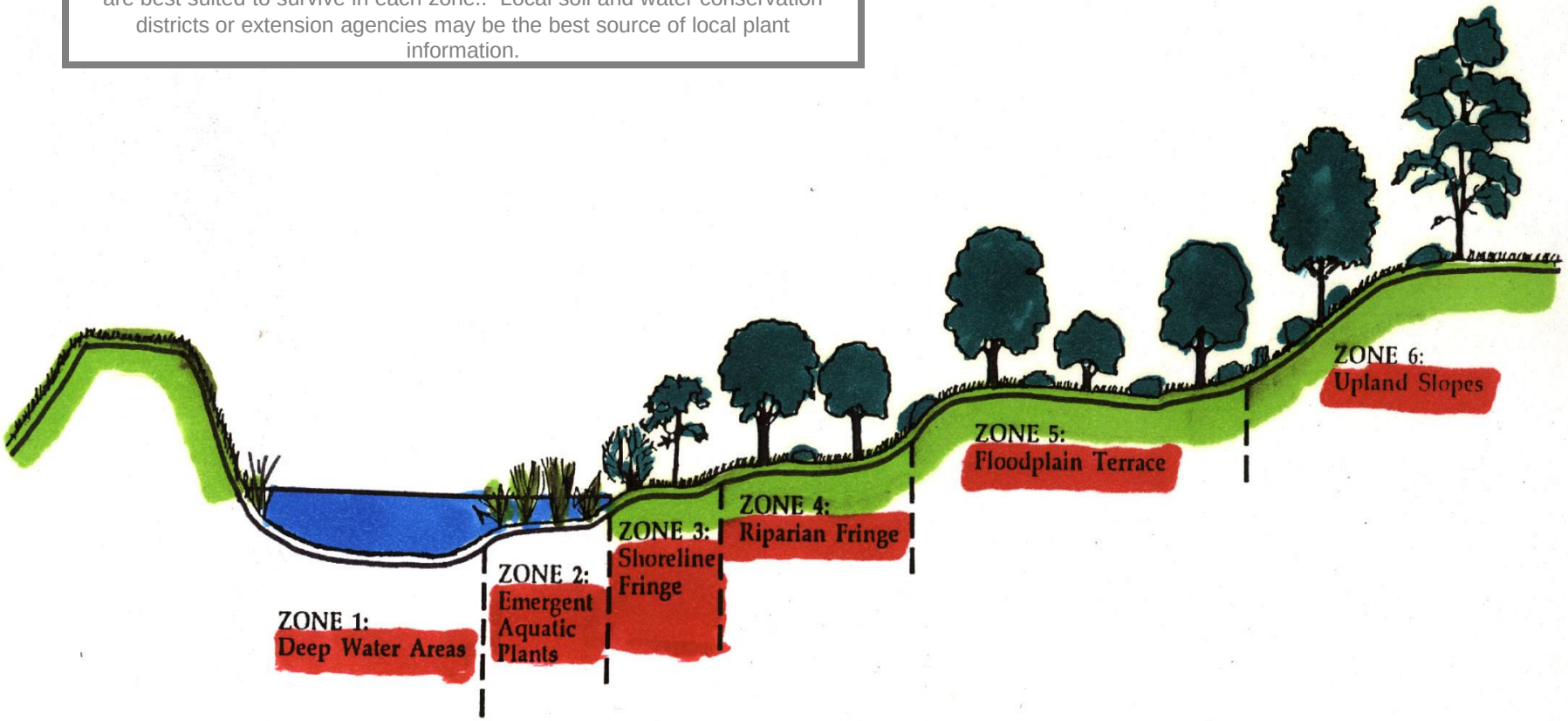
Pondscaping Zones, revised

1. Deepwater	-1.5 to -6.0 feet
2. Deep Marsh *	-1.5 to -0.5 feet
3. Shallow Marsh	-0.5 to 0.5 feet
4. Riparian Fringe	1.0 to 3.0 feet
5. Floodplain Terrace	3 to 6 feet
6. Upland Areas	6 feet +

* very hard to maintain wetland vegetation at these depths

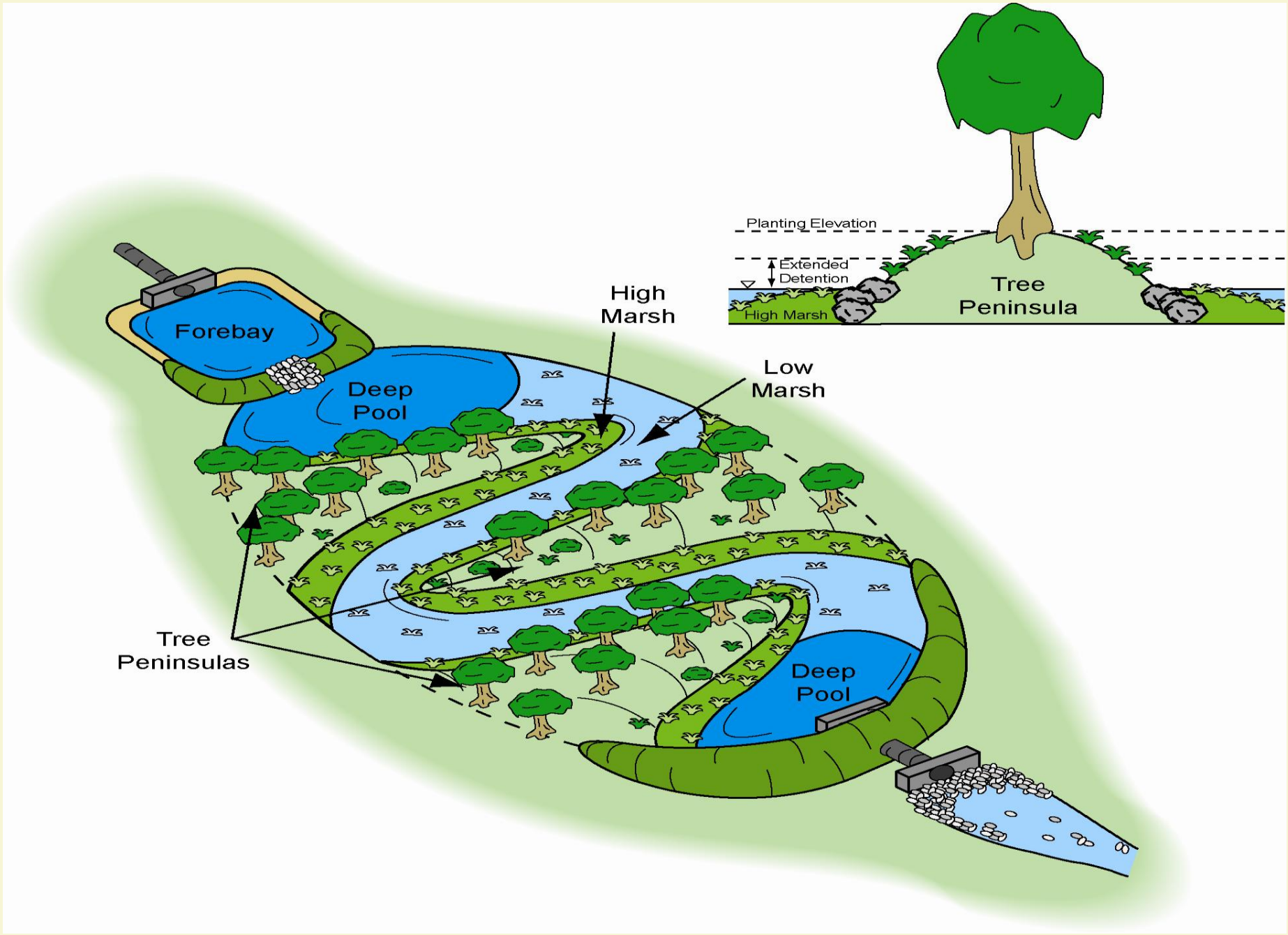
PONDSCAPING ZONES

This slide illustrates possible pondscaping zones to include in a design. Each zone has a separate functional goal. In addition, different types of vegetation are best suited to survive in each zone.. Local soil and water conservation districts or extension agencies may be the best source of local plant information.



Design Choices
Emergent versus Forested Wetlands

- Tree peninsulas.
- Wedges perpendicular to flow.
- Wedges (mild slopes 8 to 10 feet wide).
- May extend all the way across the wetland.
- Trees planted above the ED zone.


Planting Elevation
Extended Detention
High Marsh
Tree Peninsula
Forebay
Deep Pool
High Marsh
Low Marsh
Tree Peninsulas
Deep Pool

Design Choices
How Much Extended Detention (ED) is Too Much?

- ED works against wetland diversity
- Restrict vertical ED to no more than a foot
- OK to have detention, but this works against gentle side slopes (bathtub wetlands)

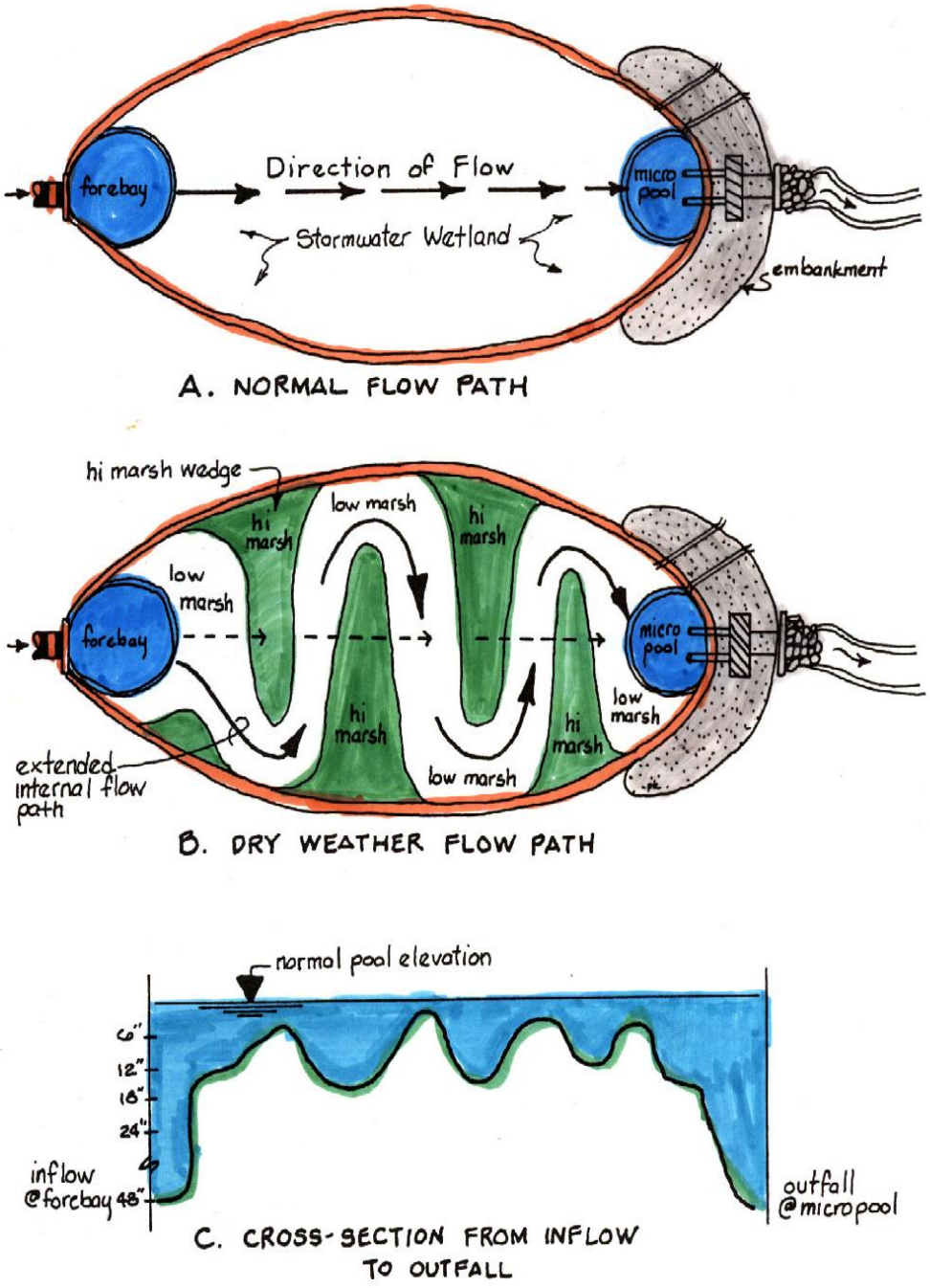
Design Choices: Mosquito Prevention

- Not generally a problem unless cattails are present
- Scatter deep pools around wetland and connect them with channels
- Dragonflies

Design Choices: Natural Geometry

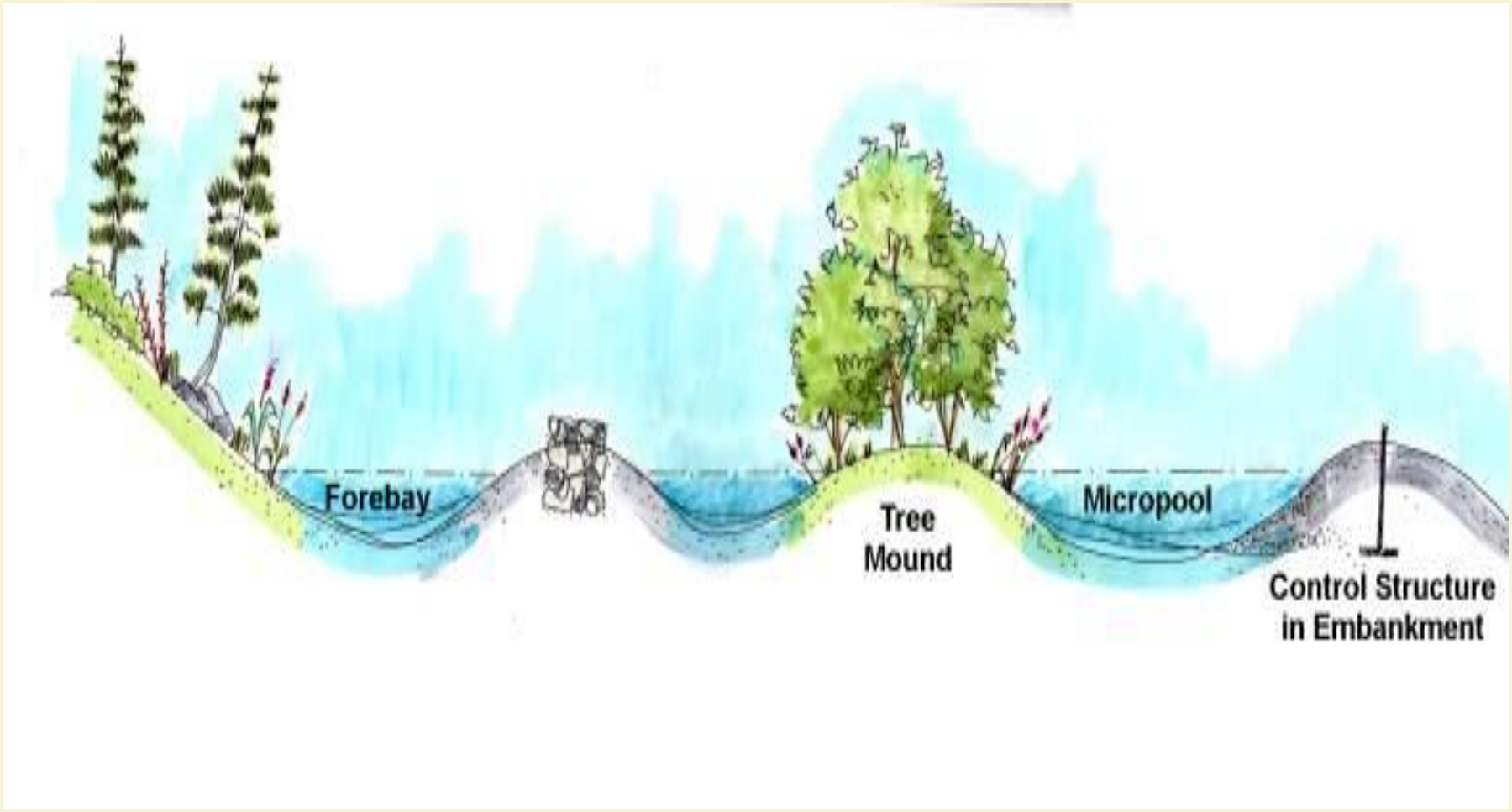
- Max sideslopes 3:1
- Dry weather flow path of 2:1
- Variable width aquatic benches
- Alternating pools and weirs

The effective flow path during dry weather and small storm events can be much greater if hi marsh areas are provided to serve as baffles. Pollutant removal is also enhanced due to the longer residence time. In larger storm events, the flow path will be more direct from the inlet to the outlet.



Design Choices: Single or Multiple Cells

- Specify at least three cells

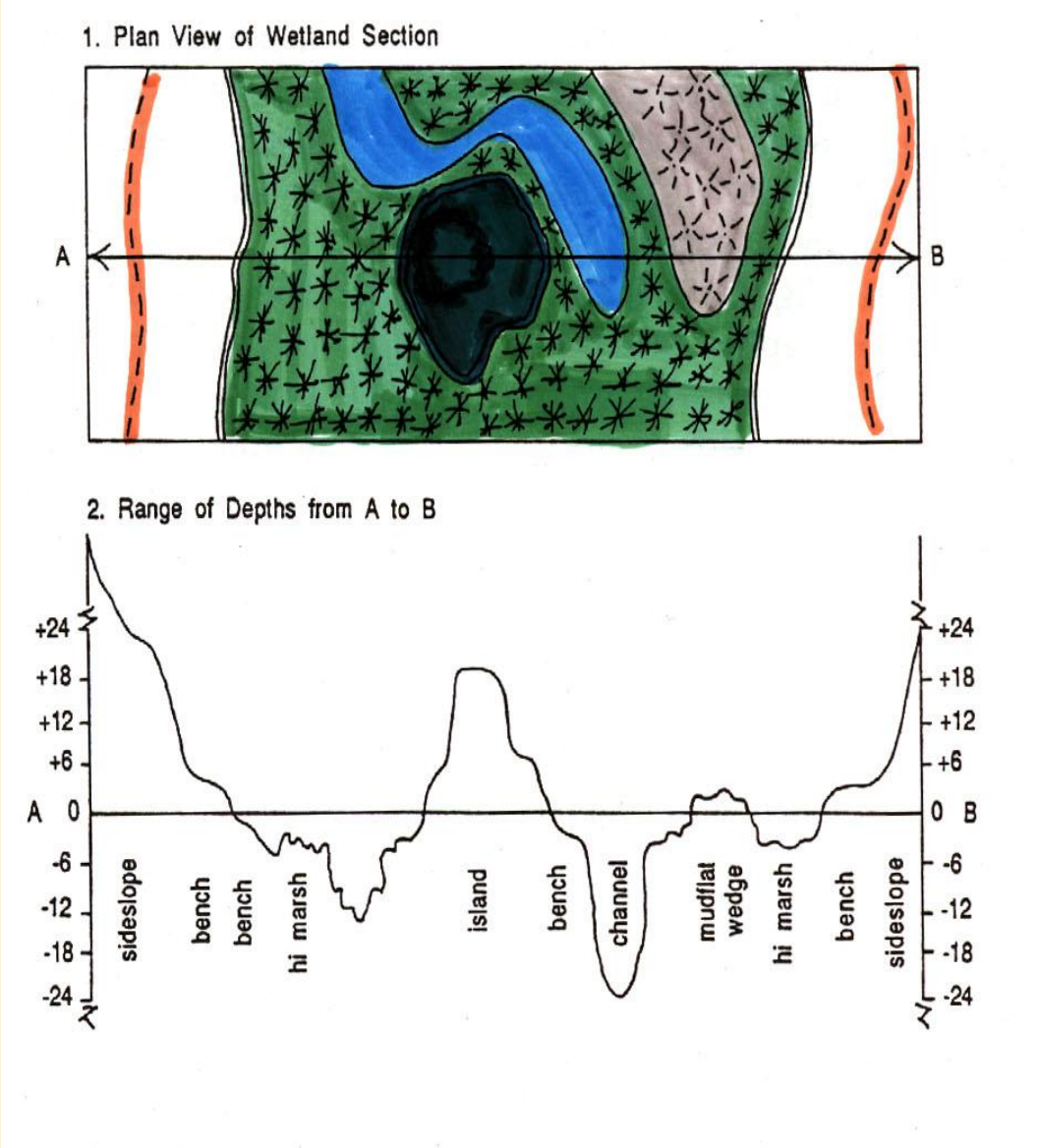


Design Choices: Micro-topography

Specify at least two mechanisms to create better micro-topography

- Snags
- Inverted rootwads
- Gravel layers
- Cobble sand weirs
- Coir fiber logs
- Scattered pools
- Peninsulas

Complex Wetland Microtopography



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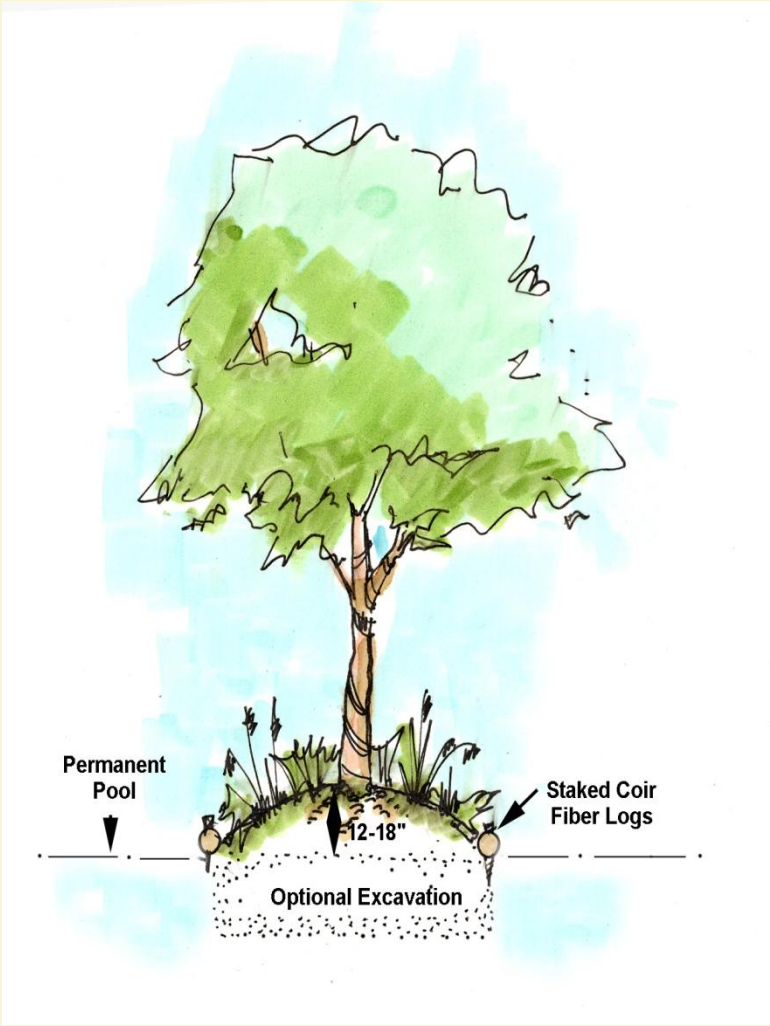
Design Choices: Water Balance

- Avoid hard and fast rules regarding minimum drainage areas, flow rates and constant water elevations.

- Steady drawdown OK but make sure that water in deep pools will persist after a rain free month (see Hunt 2007 equation)

Design Choices: Increasing Runoff Reduction

- Wooded wetland expected to increase runoff reduction rates
- Use the tree ET pump to increase them
- Evaporation also can be enhanced in wetlands (need some modeling)



Design Choices: **Trajectory of Plant Community**

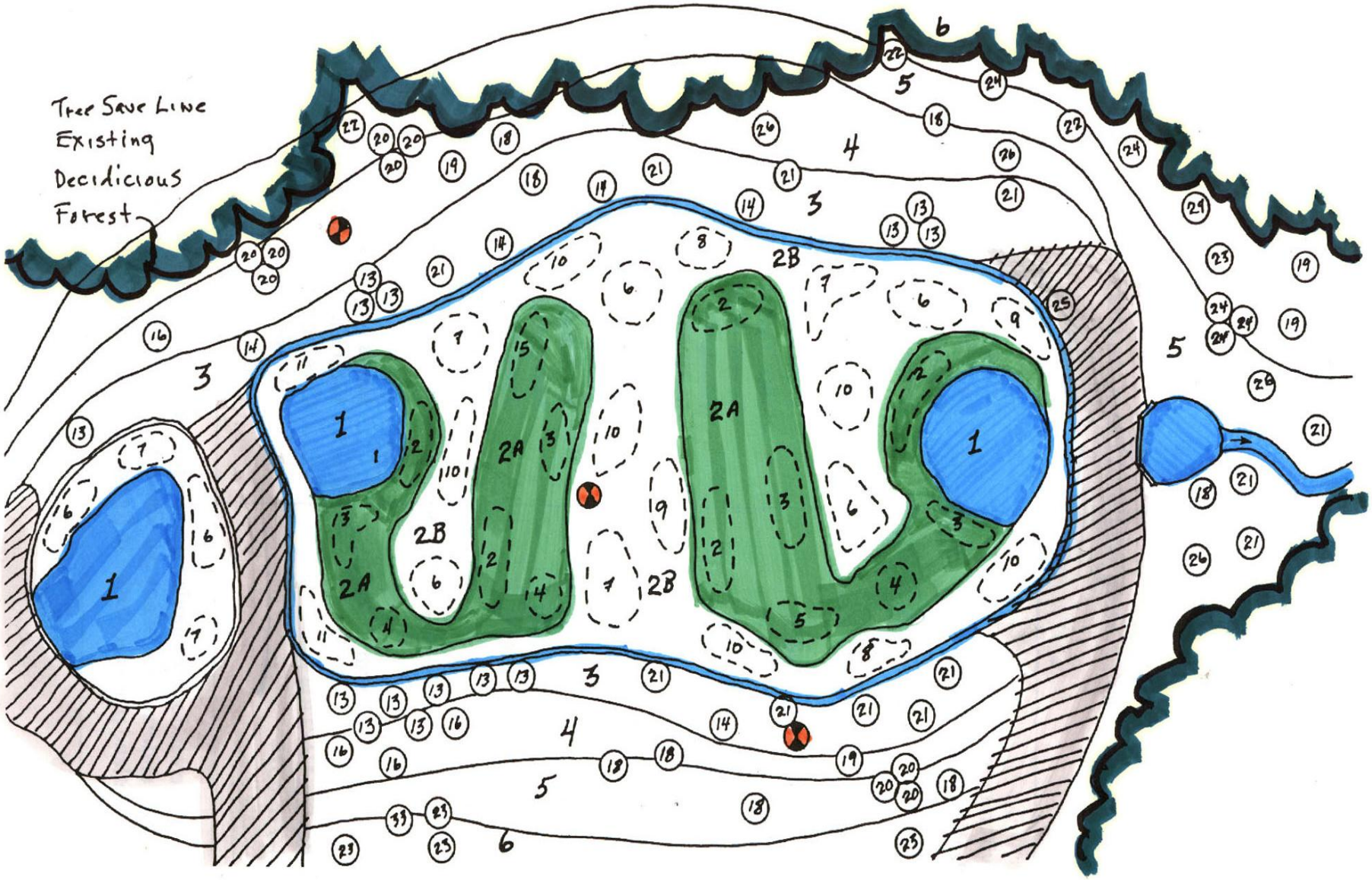
- Tolerate diversity
- Expect invasives to supplant your wetland plants
- Invest in wet-footed trees

Design Choices: Pocket Wetlands

- Not one of Schueler's better ideas
- Recommend dropping this design option
- Could be reinvented as a LID practice
- Augment water supply with rain tank or underdrain discharges

Design Choice: Wetland Plantings

- Pondscaping Plan
- Mix of emergents trees and shrubs
- Consult landscape architect or wetland expert



PLANTING CLUMPS
SOIL TEST LOCATIONS
PONDSCAPING ZONES
MOWING AREAS (3YRS)

N
SCALE
1" = 50 FEET

PONDSCAPING PLAN FOR CASEY ED WETLAND

ALL PLANTING LOCATIONS ARE APPROXIMATE & MAY CHANGE AFTER STANDING TIME

C.J. LANDSCAPING, INC.; PREPARED BY C.J.S. 4/92

SHEET 1 OF 2

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PLANT MATERIALS By Pondscaping Zone

KEY	SPECIES	QTY	SIZE
▶ **Zone 1: Deep Pool**			
1	Wild Celery	25	Tubers, cheesecloth sinkers.
▶ **Zone 2A: Low Marsh**			
2	Duck Potato	375	Containers or peat pot 18" o.c.
3	Pickerelweed	300	
4	Arrow Arum	275	
5	Wild Rice	150	
▶ **Zone 2B: High Marsh**			
6	Common 3-Square	500	Container or peat pot 18" o.c.
7	Softstem Bulrush	500	
8	Lizards Tail	150	
9	Sweet Flag	150	
10	Rice Cutgrass	150	
11	Sedge spp.	150	
▶ **Zone 3: Shoreline**			
12	Switchgrass over Red Fescue		
13	Button Bush	8	Container
14	River Birch	6	Container
21	Black Willow	12	1" caliper container.
▶ **Zone 4: Riparian**			
15	Tall Fescue, wildlife mix	100 lbs/ac	Hydroseed
13	Button Bush	4	Container
16	Green Ash	4	2" B & B
17	Arrowood Viburnum	24	Container on embankments.
18	Silky Dogwood	4	2" B & B
19	Sycamore	4	2" B & B

KEY	SPECIES	QTY	SIZE
▶ **Zone 5: Floodplain**			
15	Tall Fescue	100 lbs/ac	Hydroseed
18	Silky Dogwood	4	2" B & B
26	Tulip Poplar	4	2" B & B
20	Elder Berry	9	Container
21	Black Willow	12	1" B & B
22	Shad Bush	4	1" B & B
▶ **Zone 6: Upland**			
23	Willow Oak	6	2" B & B
24	Spice Bush	3	Container
19	Tulip Poplar	4	2" B & B
18	Silky Dogwood	2	2" B & B
▶ **Embankment**			
23	Periwinkle	48	Container

PONDSCAPING SEQUENCE

1. Temporary stabilization of all disturbed areas within 72 hours of final grade.
2. Aquatic planting window 4/1 - 6/15.
3. Reconfirm planting elevations one week prior to planting.
4. Revise plan, stake and flag.
5. De-water wetland 24 hrs before planting.
6. Plant wetland, remaining trees/shrubs.
7. Mulch, water stock, as needed.
8. Inspect pondscape twice/yr.
9. Reinforce planting at end of 1st and 2nd growing season.
10. Restrict mowing to designated areas.
11. Suppress weeds/vines on trees/shrubs during years 2 and 3.

PONDSCAPING NOTES

1. No trees in embankment or along mowed maintenance access area.
2. Tree-save line denotes limit of disturbance during wetland excavation.
3. Pondscaping zones and marsh planting zones to be confined in field after excavation.
4. Existing topsoil to be stockpiled and used to dress pondscaping zones 4,5,6.
5. Reinforcement planting after first growing season based on field inspection of marsh plant survival / colonization rates.
6. Three soil pit tests taken to confirm general soil properties.
7. Switchgrass overseeded on Red Feecue in Pondscaping Zone 3, Tall Fescue and Wildlife grass mix used in Zones 4,5,6 within three days of final grading for erosion control.
8. Six inches of wood mulch around all trees and shrubs, planting holes to be threetimes rootball diameter.

PLANTING CLUMPS
SOIL TEST LOCATIONS
PONDSCAPING ZONES
MOWING AREAS (3X16)

N
SCALE
1" = 50 FEET

PONDSCAPING PLAN FOR CASEY ED WETLAND

ALL PLANTING LOCATIONS ARE APPROXIMATE & MAY CHANGE AFTER STANDING TIME

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Preparing the Wetland Bed: Seven Steps

1. Prepare grading plan
2. Grade to interim elevations
3. Add topsoil and/or mulch amendments
4. Grade to final elevations (provide microtopography)
5. Allow wetland to fill for a few months to verify planting depths
6. Measure and stake planting depths
7. De-water wetland prior to planting period

Coastal Plain:
Reconfiguring the ditch system to promote linear wetlands

Design Adaptations for Coastal Plain

- PREFERRED practice
- Shallow, linear, multi-cell configurations
- OK to excavate to 6 inches below water table for wetland, and 3 ft for deeper pools to prevent mosquitoes
- No deduction for WQv if basic geometry met
- Flashboard risers recommended
- Forested wetlands using cypress, tupelo and Atlantic white cedar
- Recommend the Regenerative Conveyance System

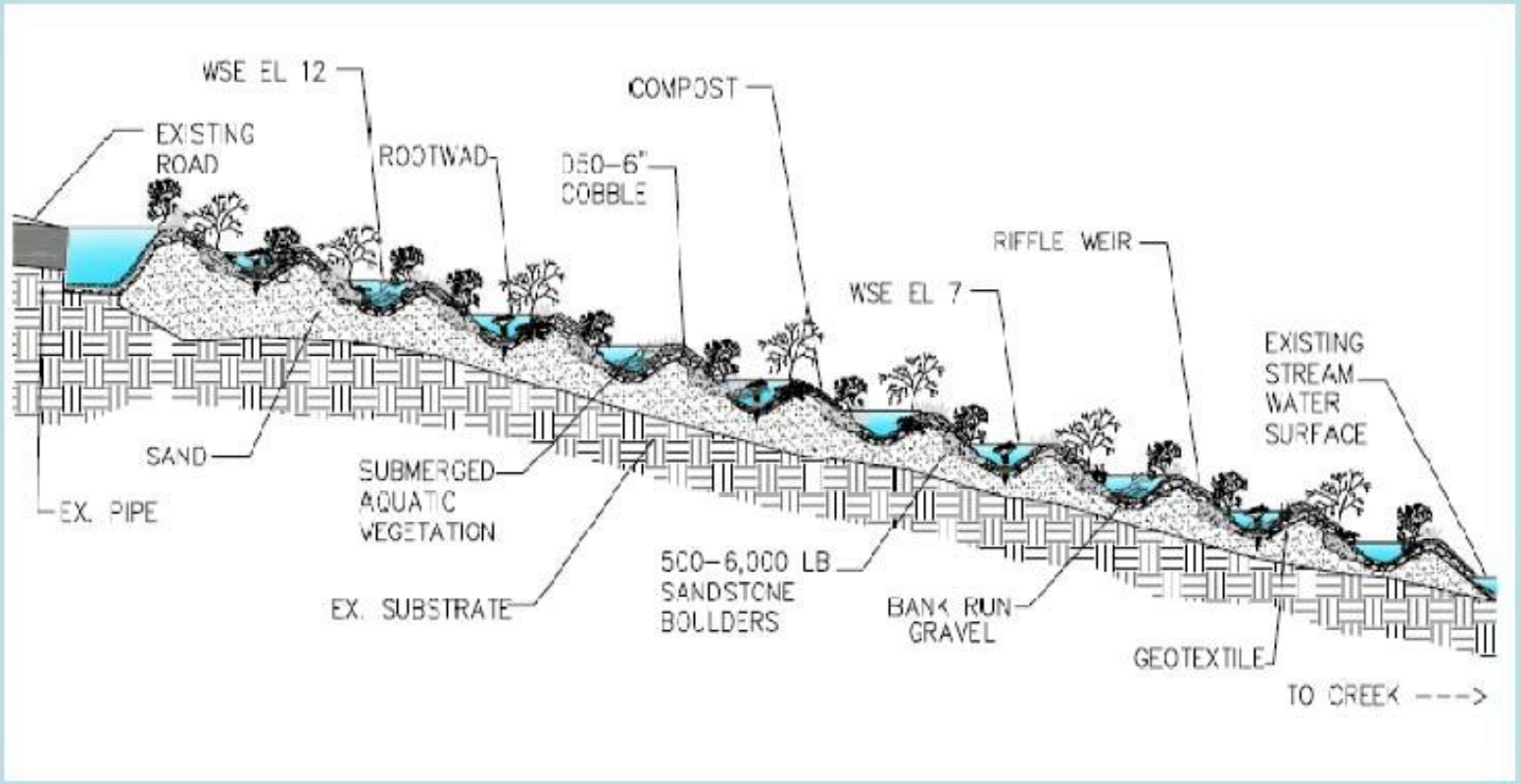
Chesapeake Bay Program

Regenerative Conveyance System

- Also known as coastal plain outfall wetland
- A linear multiple cell wetland that relies on riffle weir grade control structures
- For more details on this innovative design developed by Keith Underwood and Joe Berg, please consult pdf slideshow titled CSNRCS

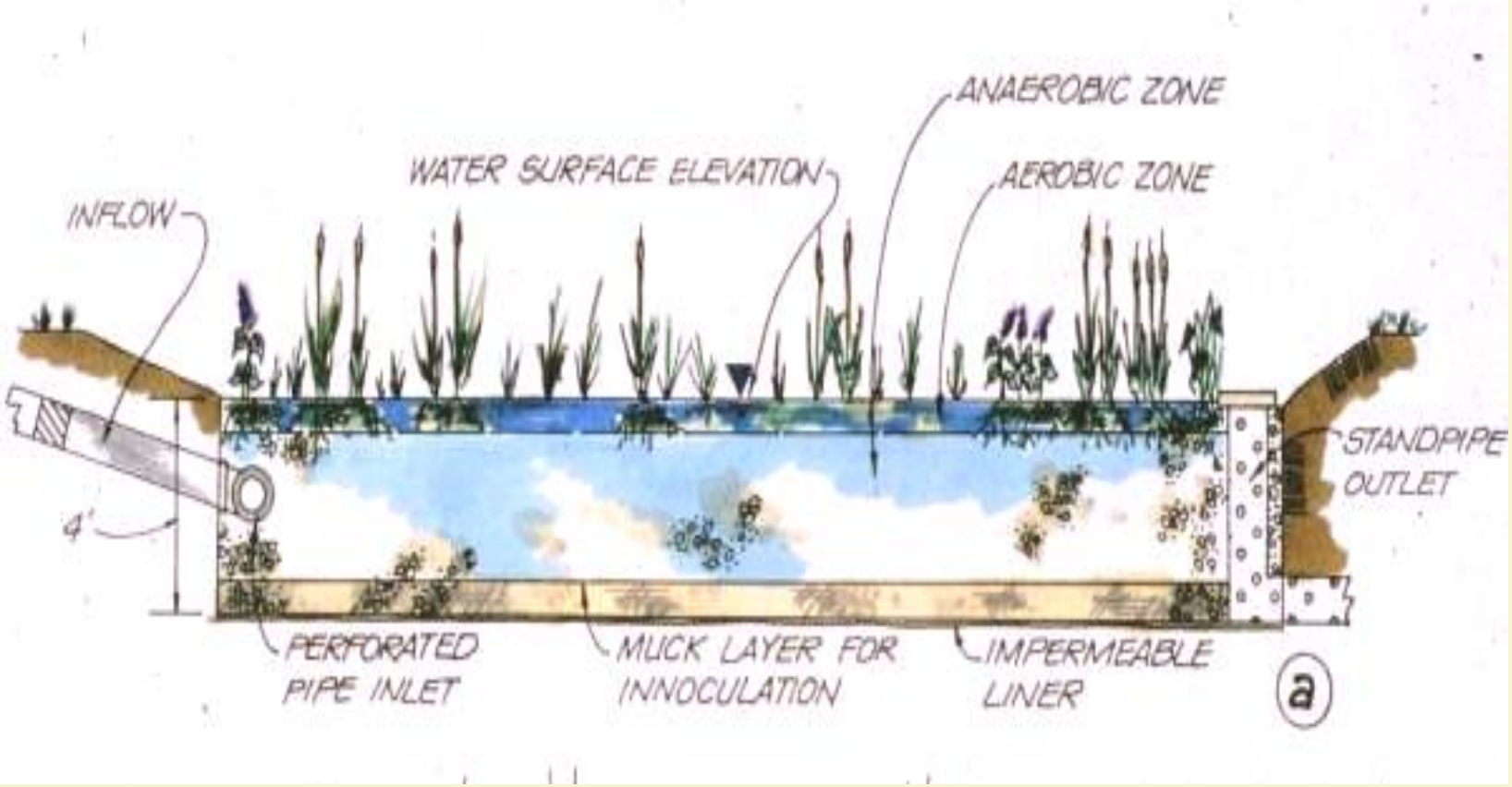
Basic Building Blocks

Regenerative Stormwater Conveyance



Riffle Weir Grade Control Structure

Submerged Gravel Wetland



Submerged Gravel Wetland

- C or D Soils
- High Water Tables and Eastern Shore
- Minimum CDA of 1 acre
- 18 to 48 inches of gravel
- Pretreatment required
- Updated design guidance available from UNH

Some Key Considerations with Submerged Gravel Wetlands

- Research indicates very high nitrogen removal
- Sediments and plant debris stored in the forebay may be re-suspended and released in subsequent storms.
- Routine harvesting/cleanout is an important component in maintaining performance—2-3 year intervals
- May have some nuisance problems (odors, mosquitoes)