Adapting Stormwater Practices to Work In Island Environments

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Key Themes

- Why Islands are Different
- Stormwater Design Objectives
- Designing Innovative Practices
  - Bioretention
  - Infiltration
  - Swales
  - Ponds

Why Islands are Different

1. Rainfall and ET
2. Sensitive Near-shore Ecosystems
3. Terrain
4. Development Patterns
5. Soils
6. Vegetation
7. Local Expertise and Construction Materials

1. Rainfall and ET

- Highly variable annual rainfall depending on elevation and aspect--10 to 300 inches per year
  - (Mainland 15 to 60 inches)
- Leeward areas have extensive dry seasons
- Evapotranspiration sends 60 to 70 inches back to the sky (mainland 15 to 30)
- Fog as much as 30% of annual rainfall at high elevations

Impacts of Land Development on Island Ecosystems

- Nitrogen
- Sediment Loads
- Bacteria
- Groundwater Contamination
- Aquatic Diversity in Near-shore Ecosystems

Findings Oahu USGS Urban Stream Study

- High nutrients
- Insecticides
- Bacteria
- Sediment
- VOCs
- Impaired stream habitat

Nutrients in Island Runoff

- High Loadings of Nitrogen and Phosphorus
  - Stormwater runoff and septic systems
  - Harm to coral reefs, seagrasses
  - Very hard to remove
  - Hi delivery

Concentrations exceed
Levels to protect coral
Reefs by 100 to 1000 times

Urban bacteria levels in runoff can close beaches and shellfish beds

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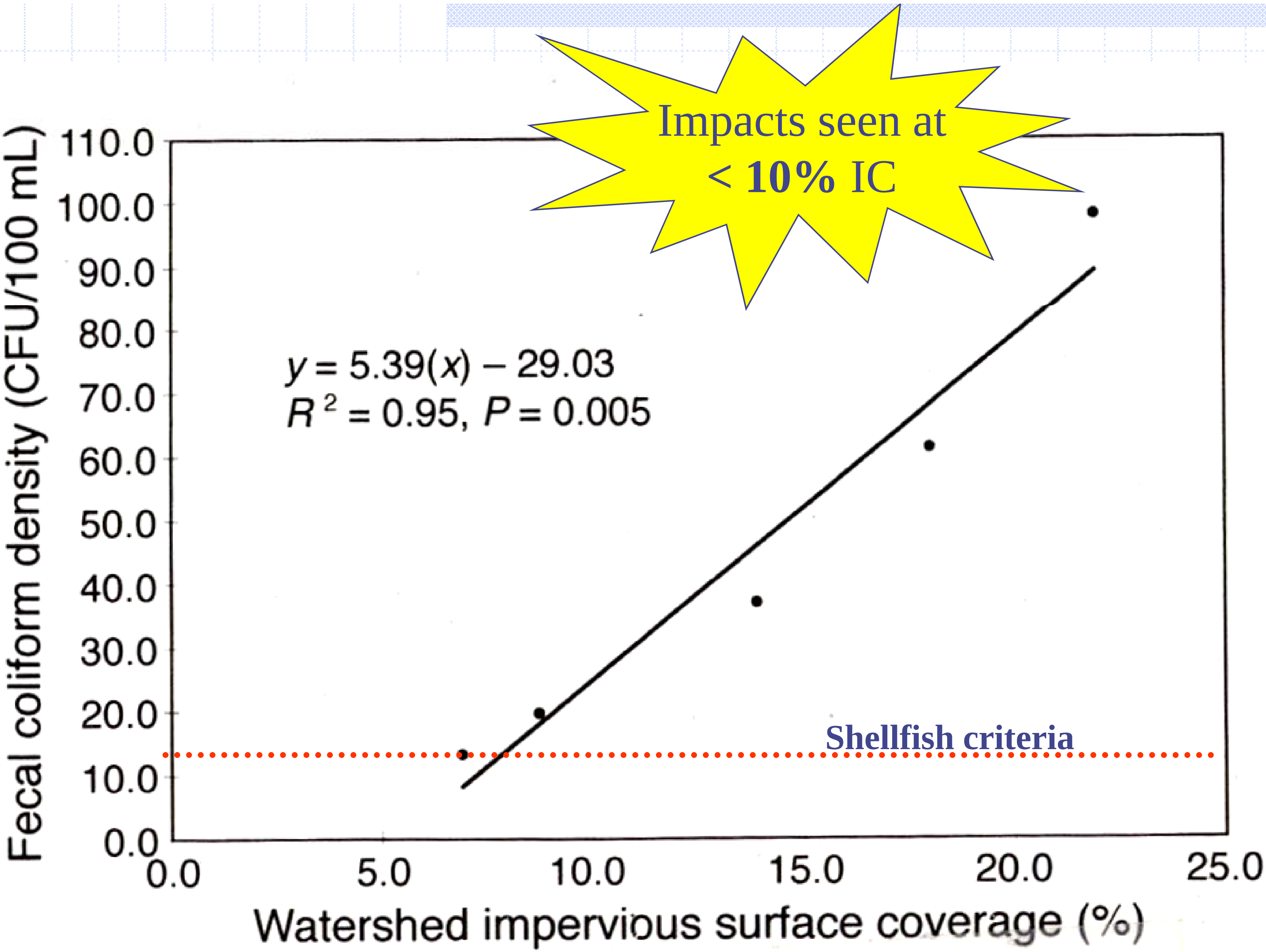


Mallin et al., 2000

Challenges in managing bacteria in urban watersheds-

- Swimming, shellfish harvesting and recreational contact limited in many urban watersheds
- Storm water f.coli levels exceed standards by factor of 20 to 50
- Stormwater practices need to reduce bacteria levels by 99% to meet standards

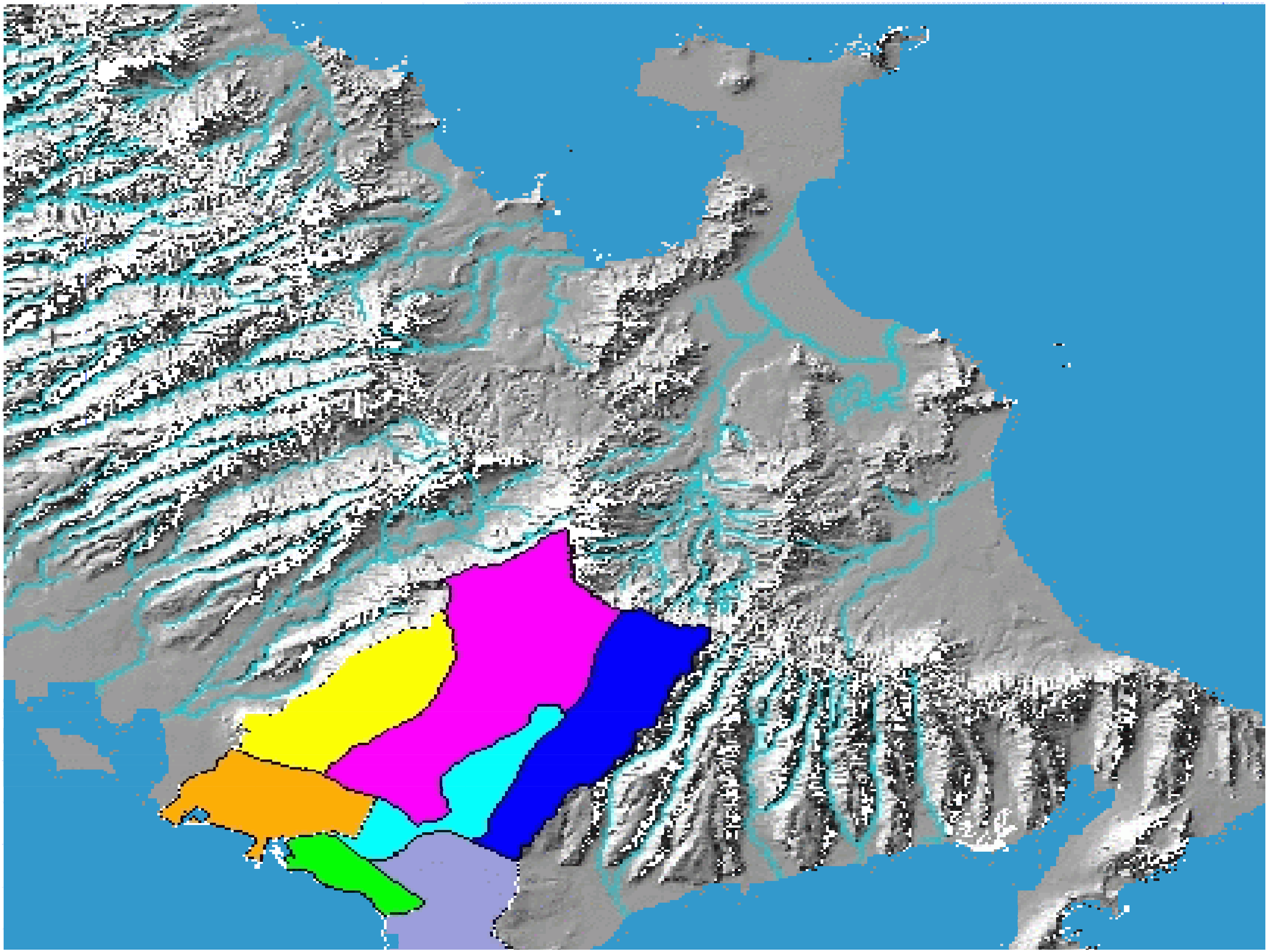
Severe bank erosion and mass wasting in headwaters

Deposited in sensitive nearshore ecosystems

NOAA, 2000

3. Terrain

- Most islands have
  - areas of steep and flat terrain
  - very small watersheds
  - Very short streams
- Steep terrain is recharge area for aquifers used in flat terrain



Steep Terrain

- Extremely steep slopes
- Hillslope erosion and landslides
- Extensive erosion from road system
- Erodible but thin soils
- Receive 3 to 10X more rain
- Forest slopes are primary island recharge area
- Small short streams

Flat Terrain Factors

- Low Head
- Ditch drainage (streams are rare)
- Deeper soils
- High water table
- Lot of water to move
- Wetlands present

4. Island Development Patterns

- Rapid growth focused on flatter terrain
- New growth spreading up the hills
- Hi land prices
- Small parcels
- On-site wastewater disposal
- Scarce fresh water
- Rainwater harvesting

Photograph by Clarence Taylor, St. Thomas

VIEW OF CHARLOTTE-AMALIA FROM LUCHETTI'S HILL, ST. THOMAS

Deboy and Faris, 1918

5. Most Island soils are:

- Thin (a few feet deep)
- Nutrient poor and acidic
- Highly permeable (6 to 20 inch/hr)
- Poor water holding capacity
- Highly erodible
- Vary depending on whether are of volcanic or coral origin

Makes it hard to establish dense vegetative cover after soils are exposed during construction

6. Vegetation

- Year round growing season
- Invasive species a problem
- Warm season grasses vary widely in their tolerance and nitrogen requirements
- Some site preparation and soil amendments may be needed to get vegetation started
- More native plants are available from HI nurseries
- Traditional HI plants may show promise (coir, taro)

7. Local Expertise

- Many designers, contractors and reviewers are not familiar with innovative BMPs
- Simple construction techniques desirable
- Plan on limited long term maintenance, beyond vegetative management
- High sediment loads should be expected, even w/ ESC controls

7. Construction Materials

- Many BMP construction materials may not be available or extremely expensive to import (e.g., peat, hardwood mulch, riverstone, geotextiles, etc)
- Other indigenous materials should be promoted (sand, local stone, shredded coconut fiber, native plants)
- Seed and compost sources should be locally derived to prevent introduction of invasive plants

Did we miss any important island factors that might influence the design and construction of stormwater practices?

Island Stormwater Design Objectives

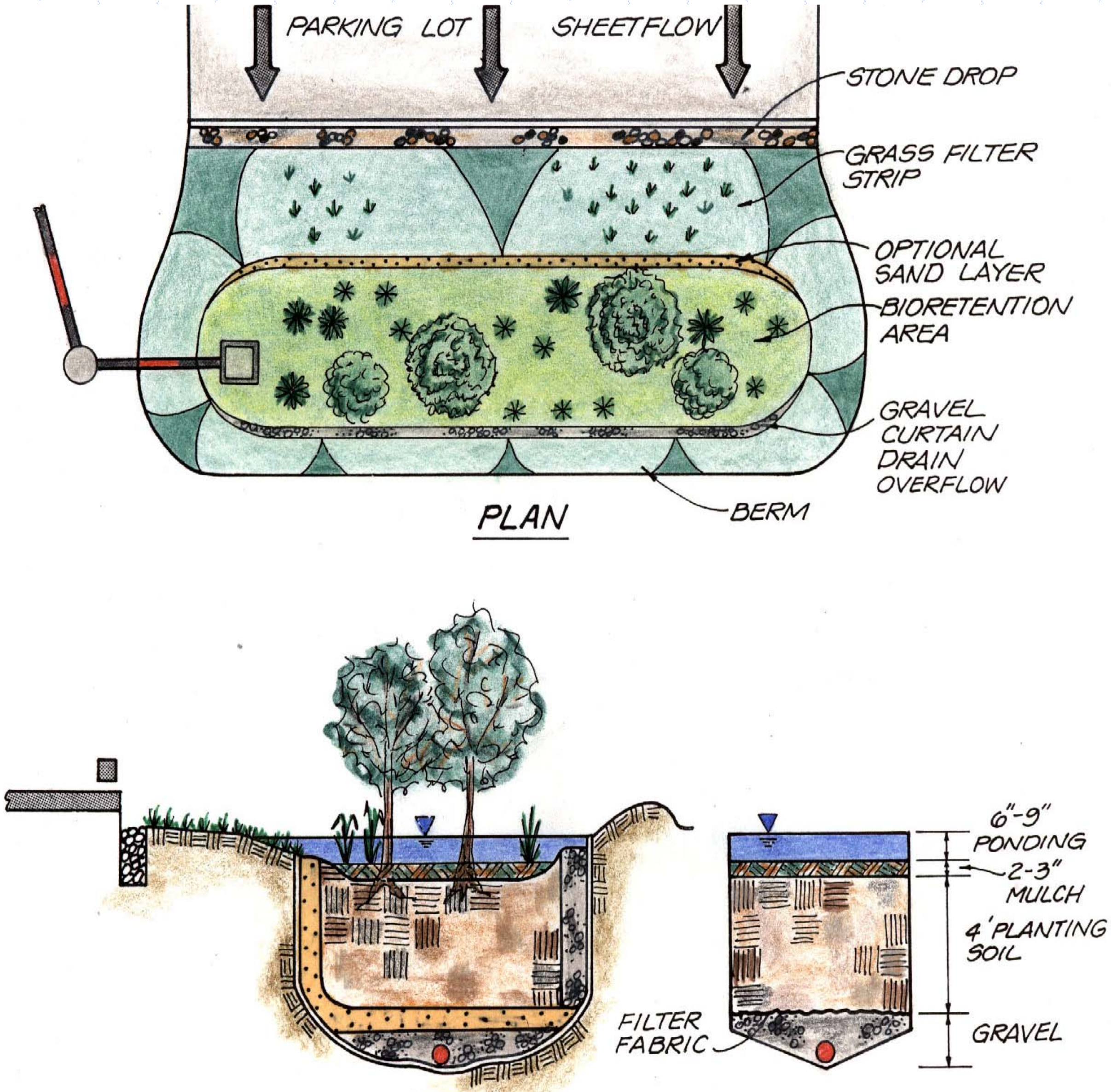
- Keep sediment and pollutants out of coral reefs
- Promote recharge rates to replenish groundwater resources
- Keep pollutants from entering groundwater
- Prevent serious floods and mudslides
- Protect streams and wetlands

Treat rain as a resource!

Designing Innovative Practices

- Bioretention
- Infiltration
- Swales
- Ponds

Bioretention



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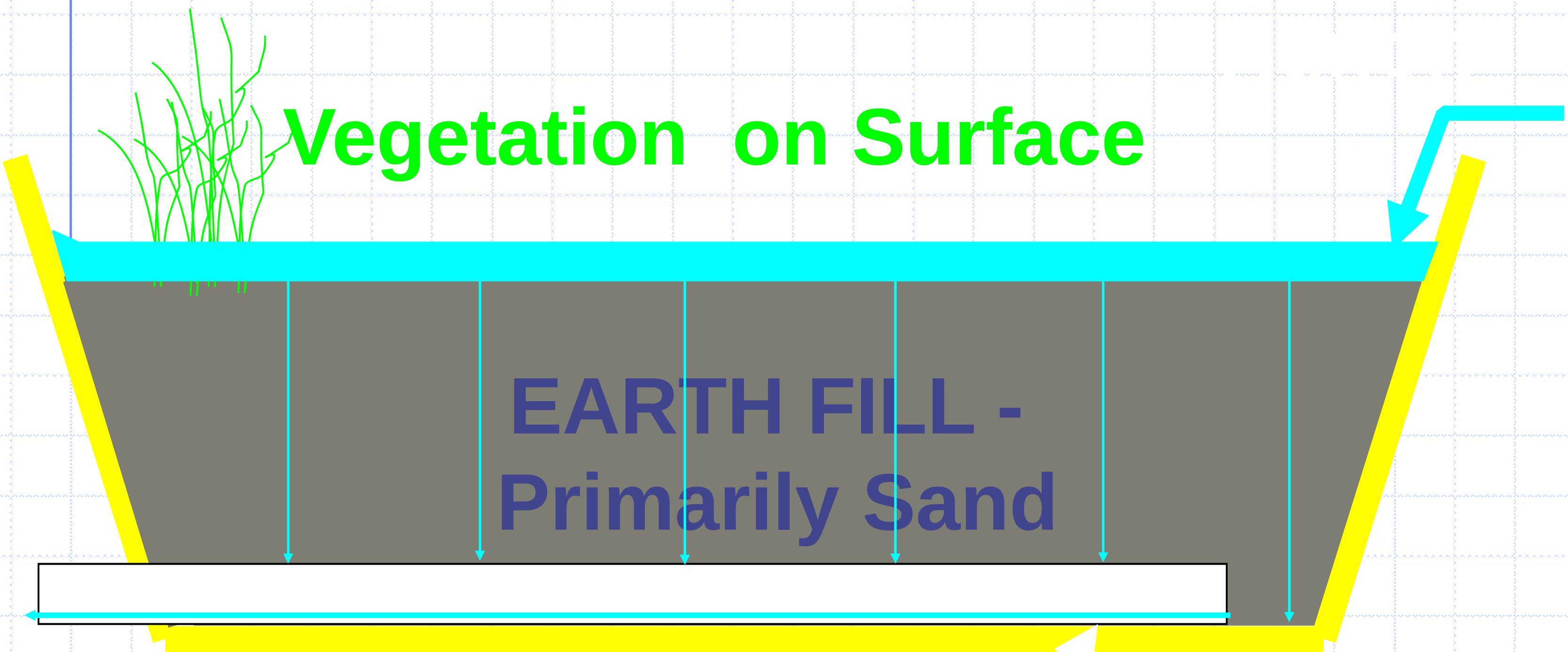
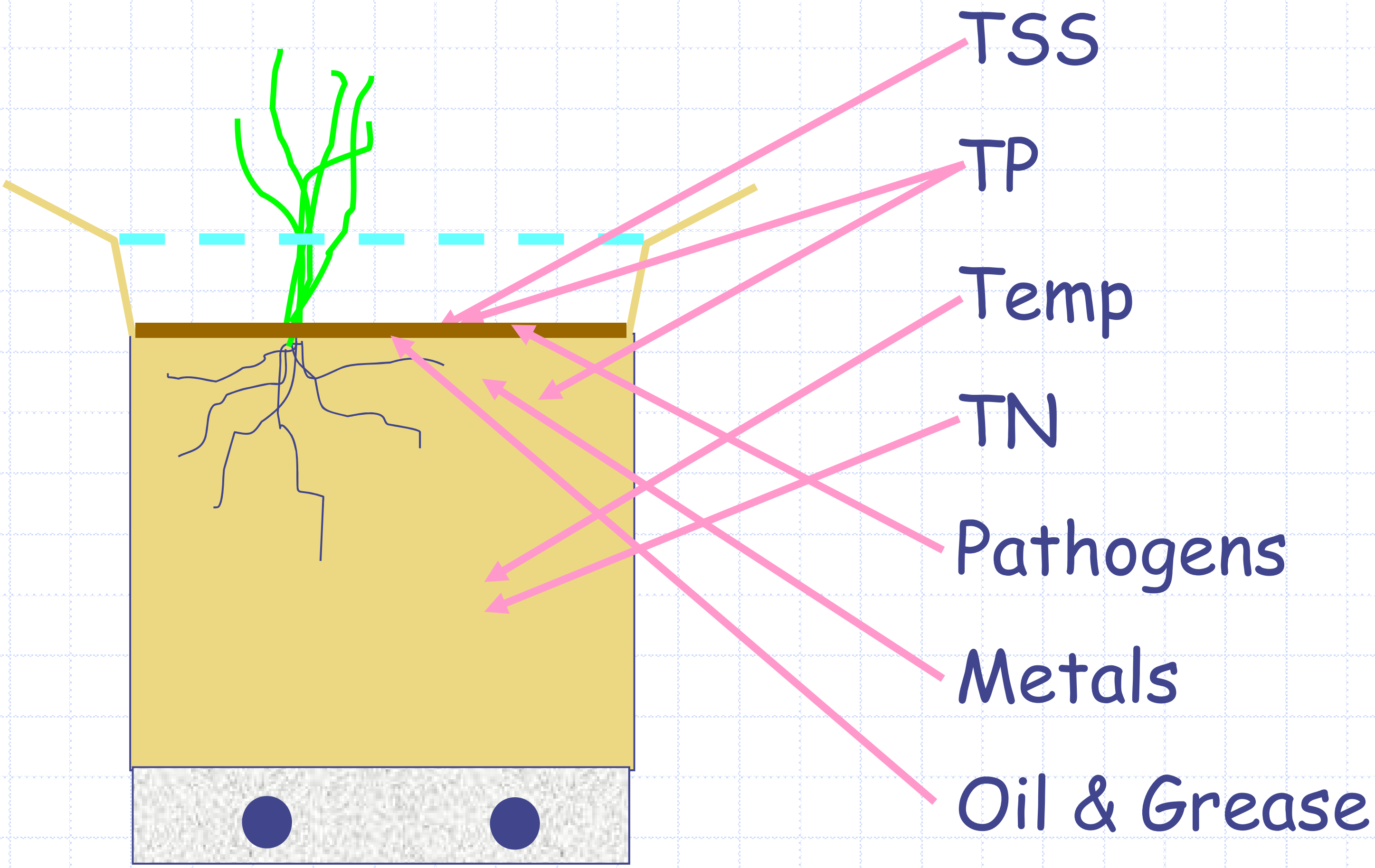
Bioretention Schematic



Where are pollutants removed?



Reduction in Runoff Volume

Greensboro (4 ft soil depth)

56% to 62% lost to ET and Exfiltration

Charlotte (4 ft)

52% lost to ET and Exfiltration

Louisburg (2.5 ft)

25-30% lost to ET and Exfiltration

Key Factors:

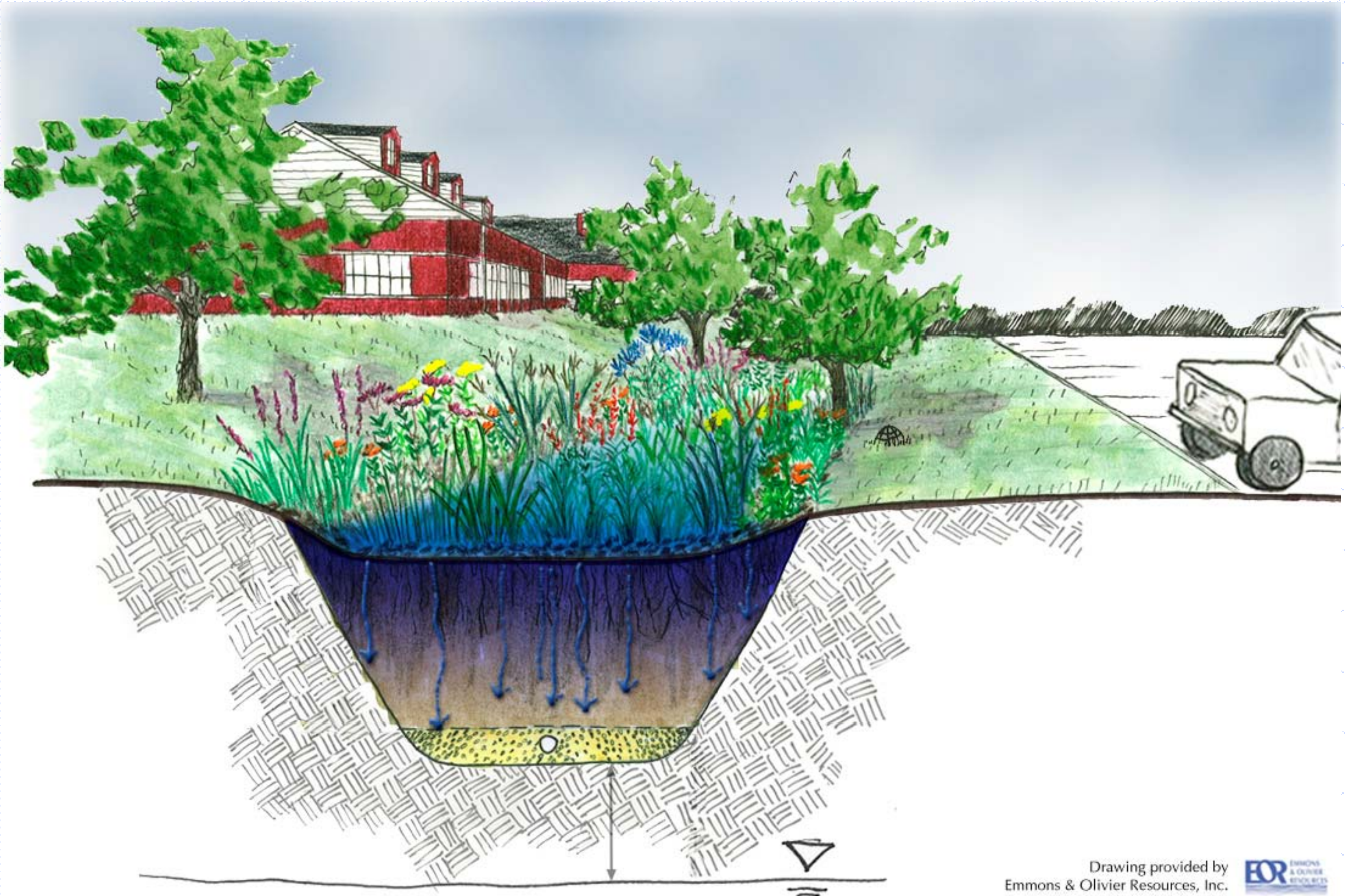
Soil Depth & Hydraulic Gradient

New River MCAS
Officer's Club

Vegetation Management Important

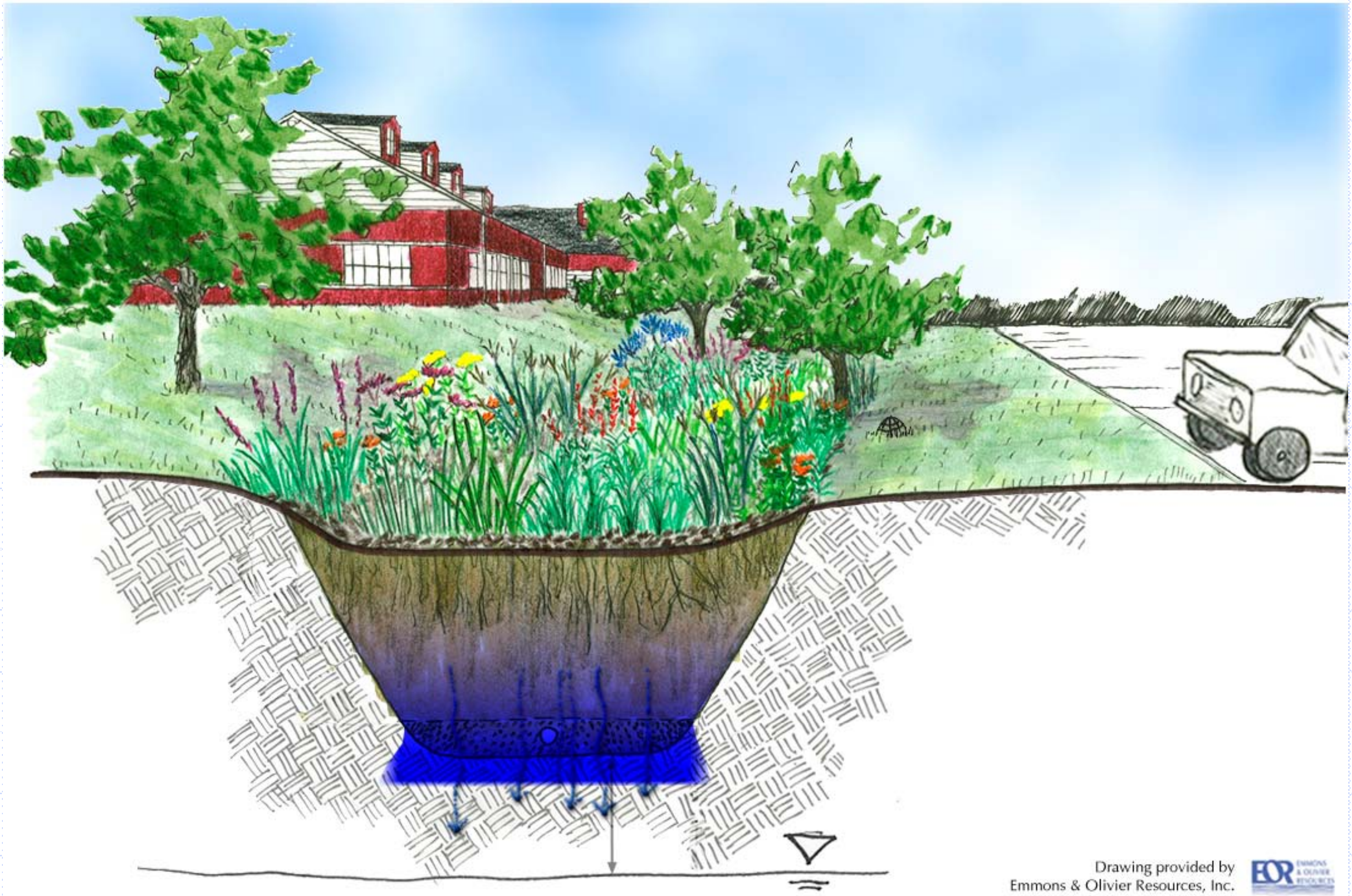

575
FORD


Failure because contributin g area was not stabilized



Annual Rainfall 26 to 74 inches:
Underdrain and surface overflow

Annual Rainfall Greater than 75 inches: Underdrain and surface overflow

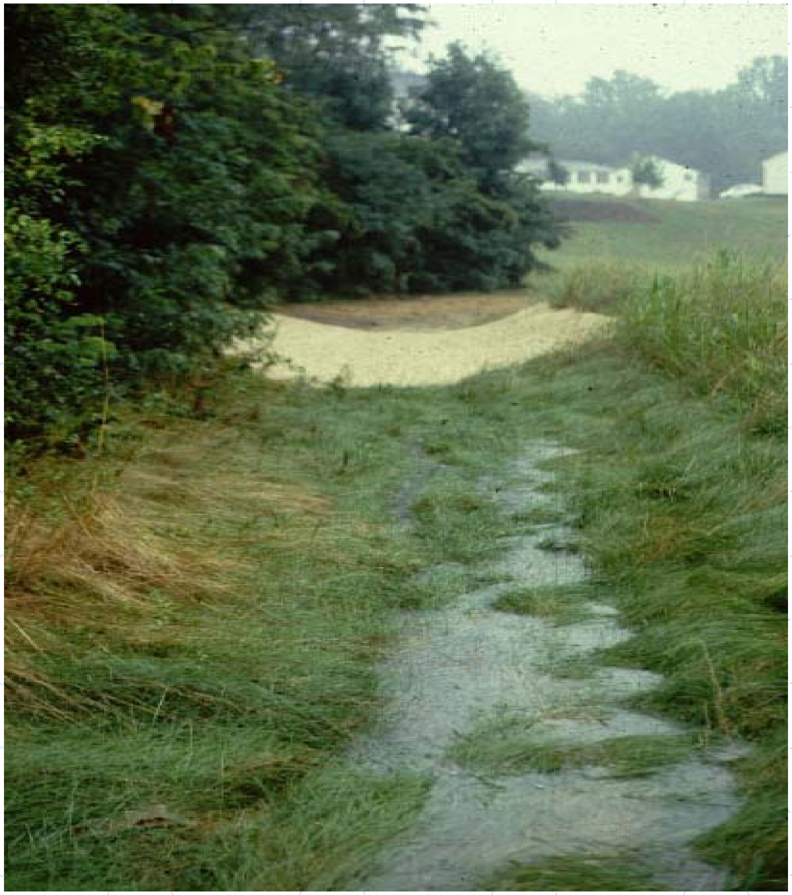


Annual Rainfall Less Than 25 inches:
No under drain (use ET Pump) may need irrigation

Design Guidelines for Island Bioretention Practices

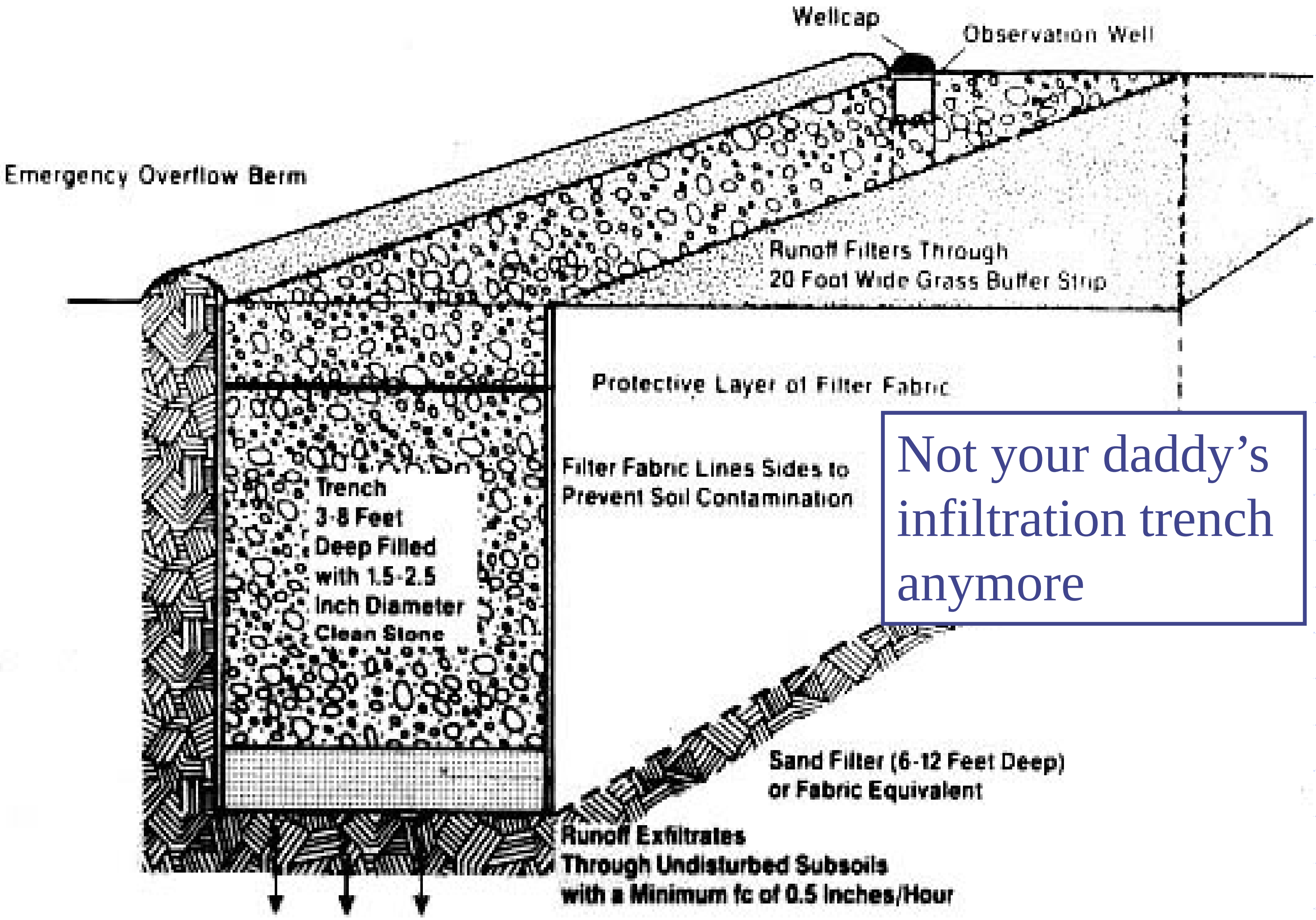
- Two size stone filter to protect underdrain
- Coral or pumice in lieu of mulch for top
- Two cell design- first pretreats sediment
- Shallow filter depth (2 to 3 feet OK)
- Media: 50% sand, 20% leaf compost 30% parent soil
- Three design variations based on annual rainfall
- Need Good plant list for HI
- Avoid invasive species.

Small Infiltration Practices



Poised for a resurgence?

Infiltration Trench



Not your daddy’s infiltration trench anymore

Groundwater Concerns

- Soluble pollutants will not be treated by infiltration practices and will enter groundwater
- So will spills and leaks
- Preventative approach: Restrict infiltration near groundwater supply areas (wells) and restrict infiltration at hotspot land uses

Longevity and Maintenance

- Terrible track record in the past
- Failure rates of 50% or more in 1980s
- New soil testing and pretreatment has sharply reduced failures when applied at small sites
- Infiltration is true post-construction practice– will fail if installed prior to full site stabilization
- Works well in many regions with porous soils

Key Island Design Issues

- Measure soil infiltration rate on-site
- Surface pretreatment prior to infiltration (25 to 50% of WQv)
- WQv a function of annual rainfall
- Design based on three infiltration rates
- Stabilize site prior to installation
- Keep overhead vegetation away

More on Soil Infiltration Rates

- The real infiltration rate is what the practice actually does several years after construction – research indicates it should be reduced in half
- Trees and shrubs promote infiltration through macropores
- Try not to force a lot of infiltration depth over a small surface area

Truly Bad Infiltration Practices

- Vote for your favorite practices that are born to fail or look ugly

Nominee No. 1: Engineer’s no karma version of Japanese Rock Garden

Nominee No. 2: The infiltration trench that couldn’t

Nominee No. 3: The right practice in the wrong spot

Really Cool Designs

- Despite the past failures, infiltration is still the most ideal practice when conditions and right and it is installed properly
- Consider the following cool designs:

Nominee No. 1 Small scale infiltration works best

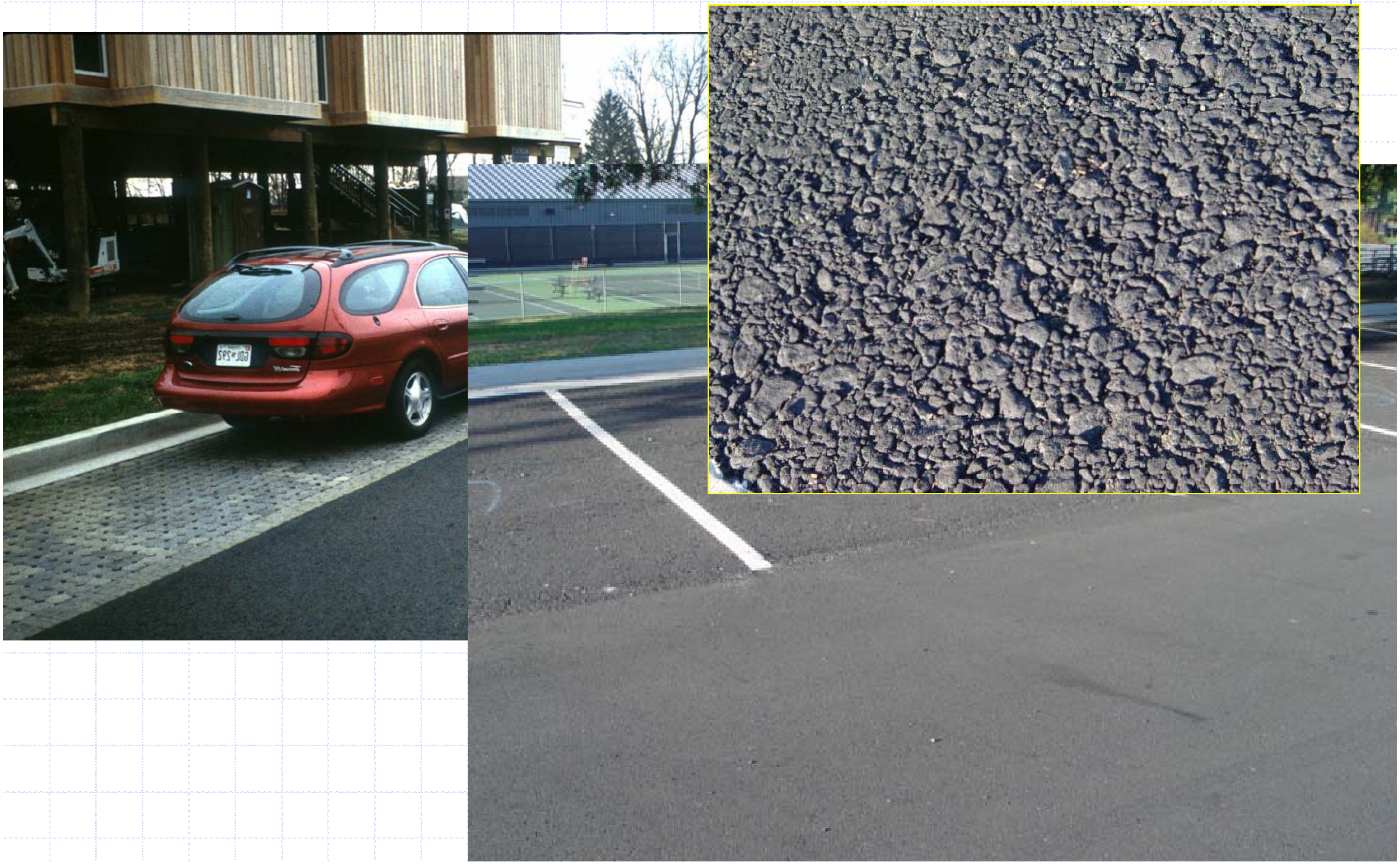
Nominee No. 2: Infiltration trench that could

Nominee No.3: Nice landscaping and cool sign

Infiltration using permeable pavers

20" of Gravel Storage Layer

Typical Applications




Finding Island Sources of Permeable Pavers

Design Guidelines for Island Infiltration Practices

- Lose the bottom liner– bottom sand filter
- Be conservative in design infiltration rate
- Infiltrate shallow depths in small areas close to the source
- Understand the future use and management activity of the contributing land use
- Try to have a least two levels of pretreatment to keep sediment out

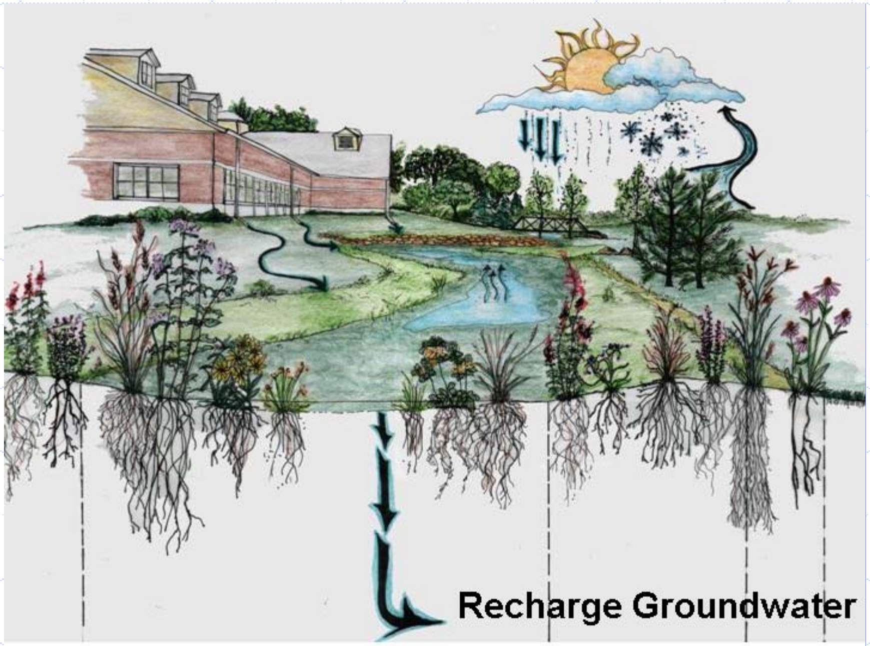
Design Guidelines for Island Infiltration Practices

- Two cell design– first for sediment pretreatment
- Different recharge rates for volcanic and coral-derived soils
- Surface– sand, crushed coral, or pumice
- Shallow depths: two to three feet deep for most areas
- Distributed treatment: less than 20,000 sf of IC to each one.


Lose the Liner

Grass Channels and Dry Swales

Does not include ditches

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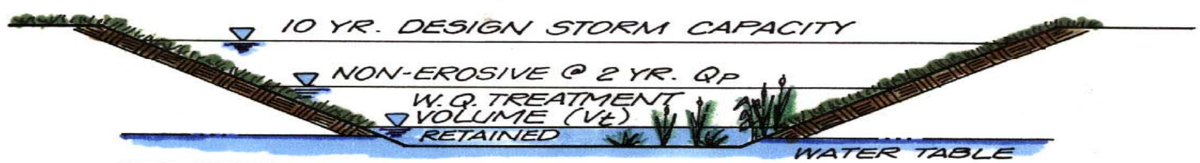
(a) DRAINAGE CHANNEL

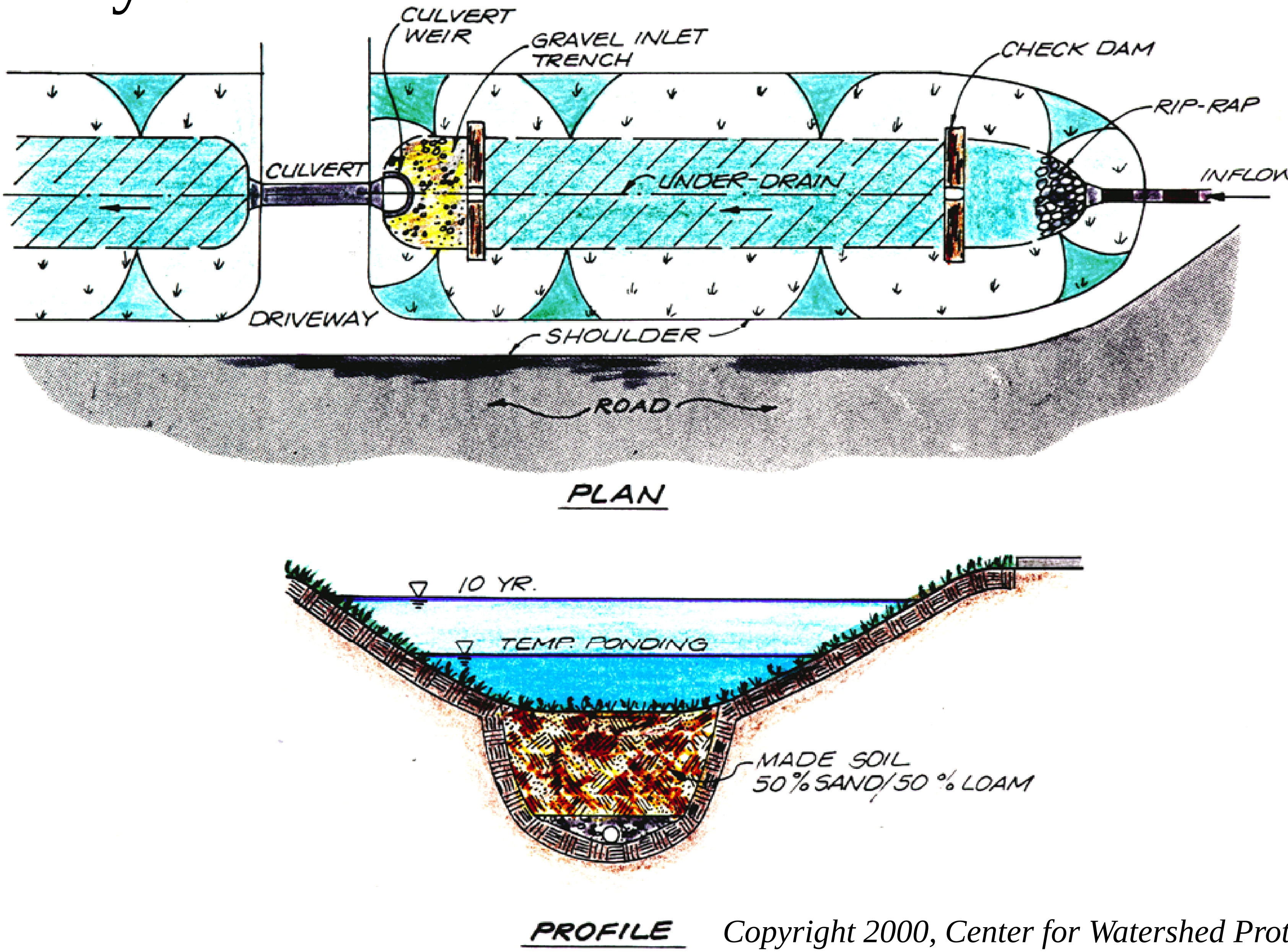
(b) GRASS CHANNEL

(c) DRY SWALE



(d) WET SWALE

Dry Swale



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Dry Swale Performance

- Excellent research in recent years
- Significant reduce runoff volume (mean 40%)
- May be as high as 80% with trees/shrubs (ET) and
  less efficient underdrain collection
- Grass height/mowing regime does not appear to influence removal capability
- Removal drops sharply when vegetative cover in bioswale >80%

Grass Channel Performance

- Changes in pollutant concentration are not always great as they pass through grass channel
- TSS, metals and nitrogen show some decline in concentration
- Phosphorus and fecal coliform levels often do not drop (in some cases, increase)
- Runoff reduction is the key to swale load reduction
- In nearly all cases, the bulk of pollutant removal occurs by infiltration rather than filtering

Longevity and Maintenance

- Engineered designs in the right settings experience few initial maintenance problems
- Field studies indicate that most grass swales did not achieve their hydraulic residence time
- Application on slopes greater than 2% is problematic w/o cells or checkdams
- Long-term vegetative management is major issue: to mow or not to mow?

Truly Bad Swale Designs

- A ditch is not a swale and a grass swale is not a dry swale
- Designers have been missing out on opportunities to treat most if not all runoff in the conveyance system
- Check these ones out:

Nominee No. 1 The hi input swale with curb

Nominee No. 2 The 90 second swale

Nominee No. 3 Everyone likes to mow soggy grass swale

Really Cool Bioswale Designs

- Swales with real style and panache .
- Some of these designs make revolutionary changes to street rights of way
- Vote for the swale of the year

Nominee No. 1 Bioswale with a ton of bio

Nominee No. 2 A pretty dry swale

Nominee No. 3: Best ever State highway swale

Nominee No. 4: Swale in area with lo rainfall

Nominee No. 5: What you don’t see is really impressive dry swale

No. 6 The Swale of Century


9. 15. 2004

Coir Fiber Log as a Check Dam

Design Guidelines for Island Grass Channels

- Gentle grades and side slopes
- Select the most appropriate warm season grass expected swale conditions
- Add some perennial rye to get rapid cover
- Erosion control fabric for steeper grades
- May need some topsoil, fertilization and liming to get grass started
- Design for at least 10 minutes contact time in swale for a one-inch storm (or)
- Add Check dams to promote trapping and storage

Design Guidelines for Island Grass Channels

- Stone or coir logs to reduce flow velocities channels
- Spacing similar to water bars
- Provide limited sediment trapping
- Ineffective on slopes > 10% or if not regularly cleaned out

Design guidelines for dry swales

- Lose the filter fabric (choker stone is enough)
- Utilize trees, shrubs and landscaping
- Shallow media (2 to 3 ft) and large (6 inch), inefficient underdrains
- Turf (and mowing) not always desirable
- Think through long-term vegetation management

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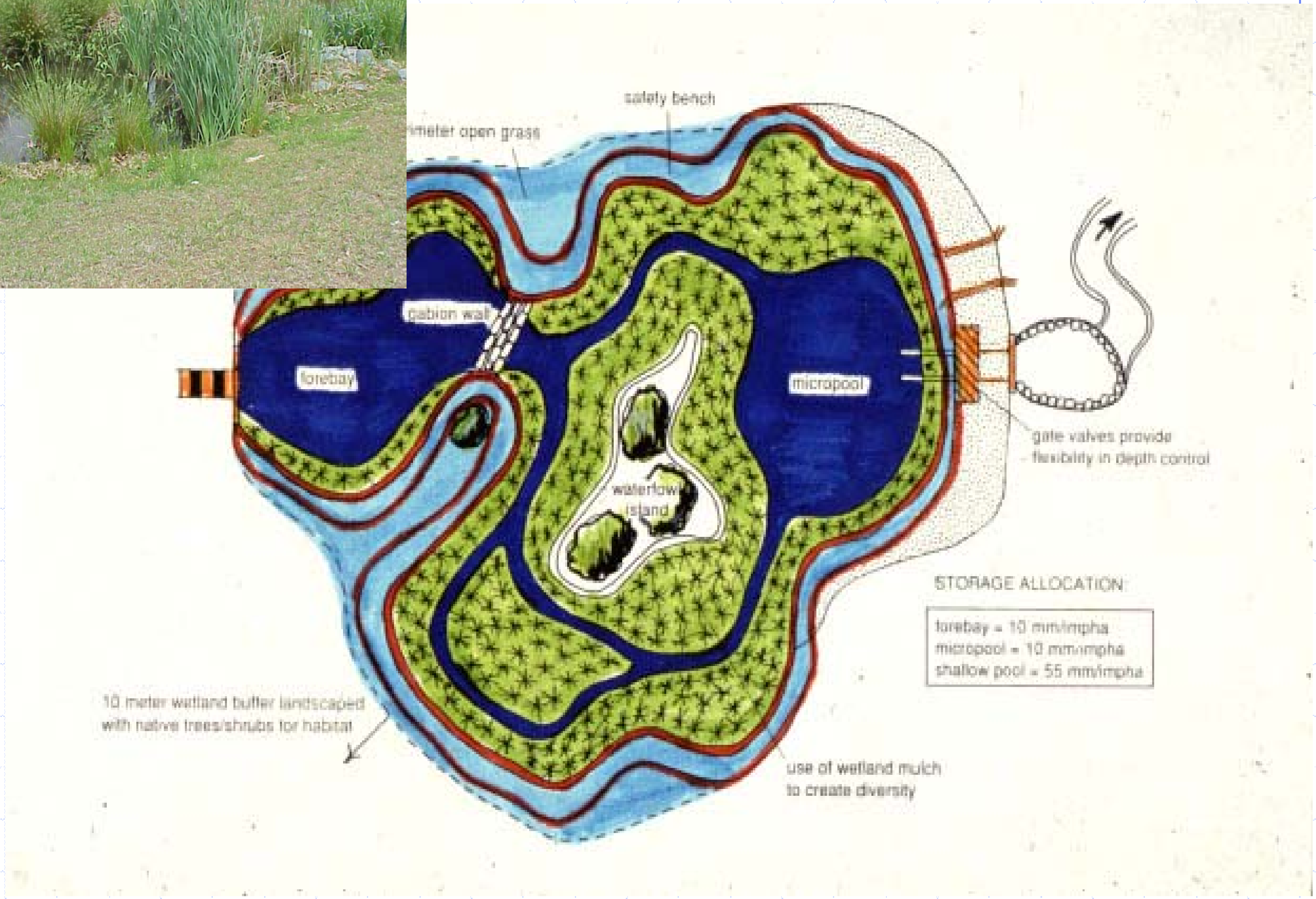
Stormwater Ponds



Design Based on Annual Rainfall and Soil Infiltration Rate

- 45 inches or less– Micropool extended detention
- 46 to 74 inches: Shallow marsh extended detention control over the target vegetative community over time
- 75 inches or more: Wet extended detention pond

- Measured infiltration rate 2 inches/hr or greater: need a bottom liner.

Truly Bad Designs

- Sadly, so many to choose from!
- You must vote for one of the six nominees to enshrine in the Stormwater Hall of Shame

Nominee No. 1: Perfectly square wetland

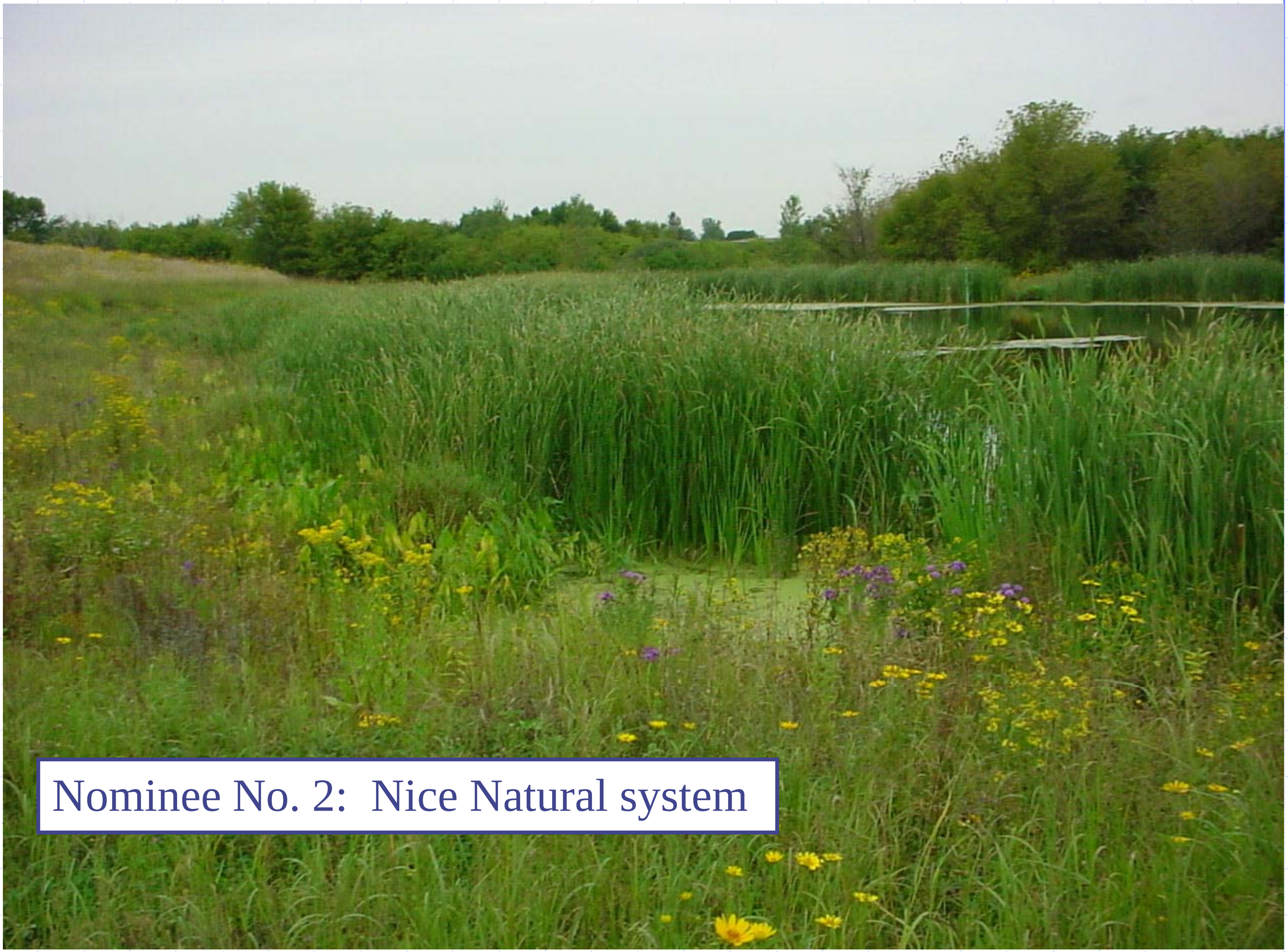
Nominee No. 2: the McWetland- shortest distance from inlet to outlet

Nominee No. 3: Stormwater wetland that is really only a shallow wet pond (too deep for plants, too tiny to matter)

Really Cool Designs

- Some designers have really worked to create effective and natural designs.
- Please vote for the nominee that really rates being termed a BEST management practice

Nominee No. 1: Longest flow path in pond ever seen



Nominee No. 2: Nice Natural system

Nominee No. 3
Freshwater Emergent Marsh

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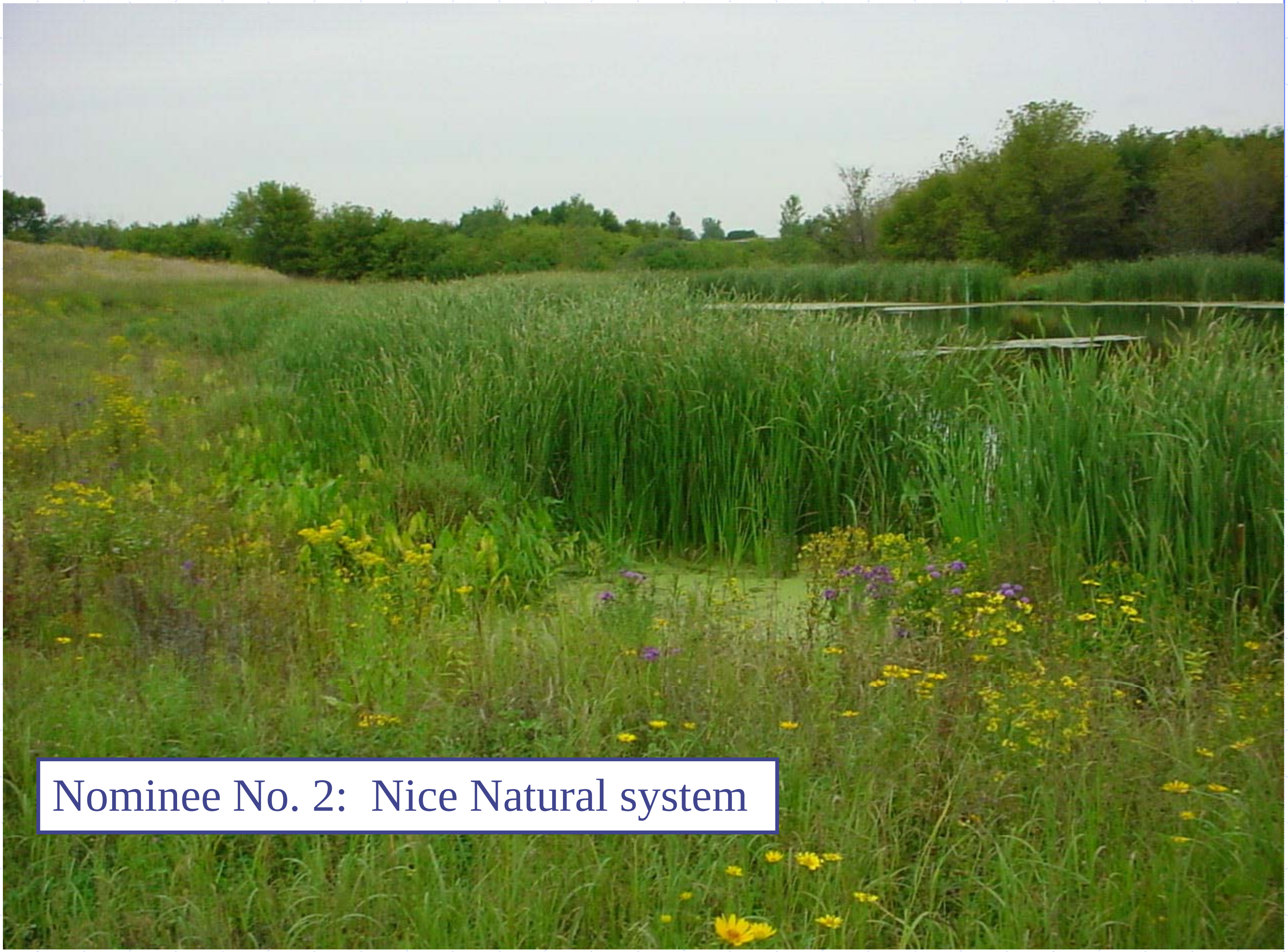
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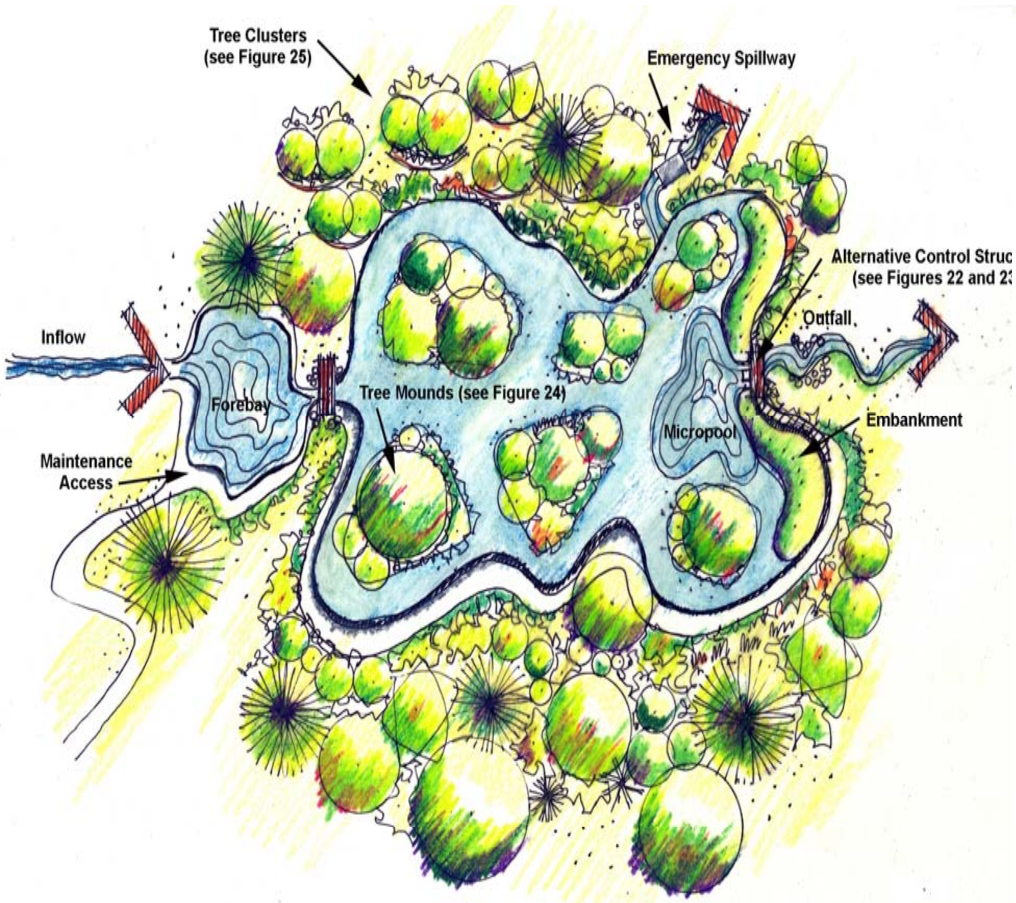

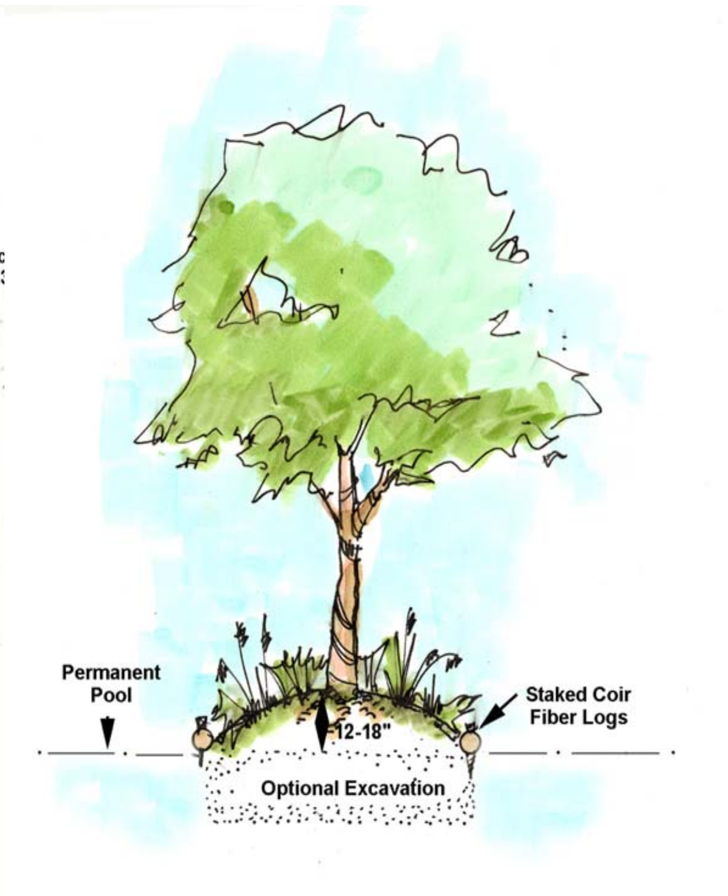

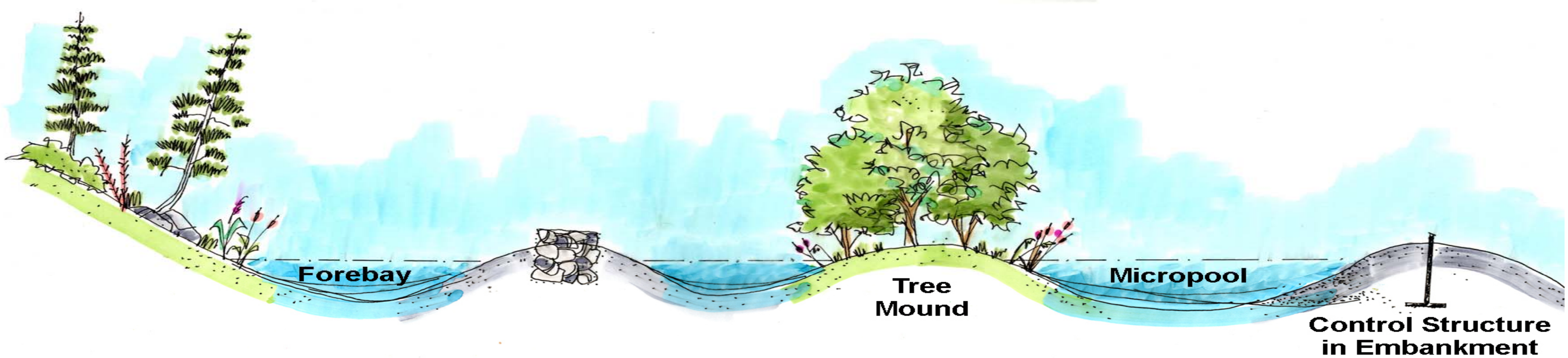

The Third Generation: The Forested Wetland

Design Guidelines for Island Wetland Practices

- The forested wetland concept
- Greater range of depth zones above and below normal pool
- Don’t worry so much about startup planting– its just an initial framework
- Match pre-and post-project hydrology &

groundwater at proposed site to plant types