Slide 1

Dakota County Soil and Water Conservation District

Comprehensive Bioretention Maintenance

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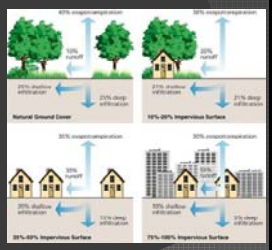
Slide 2

Review of Stormwater Management

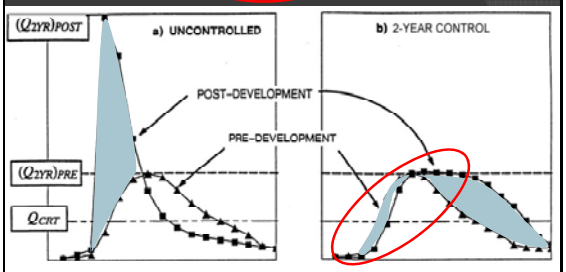
It is a wholesale reorganization of the process of runoff generation, and it occurs throughout the developed landscape.



Urban Stormwater Management In the United States, October 2008, National Research Council of the National Academies

Slide 3

The Issue: Too Much & Too Fast



Runoff Pre-pond

Runoff Post-pond

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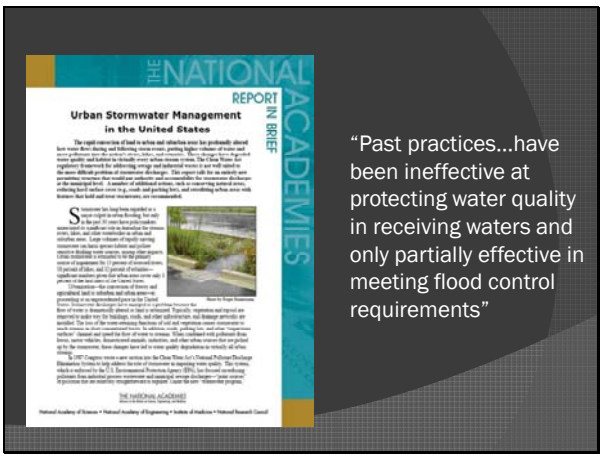

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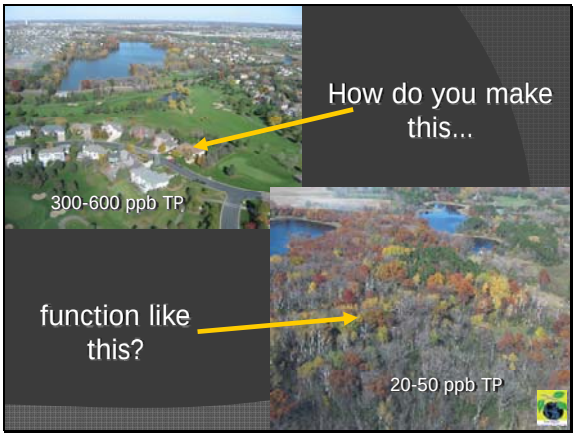

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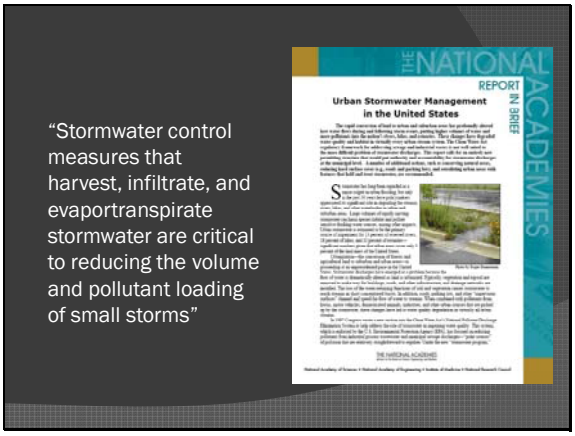

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The essence of LID:

- Identify, conserve, and protect the highest quality and most sensitive natural areas whenever possible. (wetland pic)

Conserving natural drainages, trees and other vegetation, and soils is the first step in low impact development. Trees and natural forest cover are terrific "sponges" for storing and slowly releasing stormwater. Comprehensive land use planning, watershed or basin planning, habitat conservation plans, and stream and wetland buffers are good tools to identify and set aside natural areas within a community and on an individual site.

Once conservation areas are established for each site, the designer can then work within the developable area envelope and evaluate the effects of design options on these areas. A significant portion of trees and other vegetation should be left in a natural state and not developed.

- Minimize impacts of development. (narrow street pic) (more on this later)

- Soils and plants! (worm and parking lot swale) LID is about taking advantage of nature's free services. HEALTHY SOIL (not compacted, aerated, and having deep rooted plants and other organisms (like bacteria and fungus) growing in it), can make a huge difference in a landscape's ability to help water soak into the ground instead of running downstream. And the bacteria in the soil can break down hydrocarbons (like oil from your car and other pollutants) and plants can take up heavy metals, keeping all that pollution from running downstream. Even if all the water does not stay in the ground, simply exposing stormwater to a healthy soil can filter out pollutants.

The goal is to maintain the historic, pre-developed volume, rate, frequency and duration of stormwater discharges so that discharges are not excessively high during wet, winter months or excessively low during dry, summer months. A number of techniques are available to achieve this. In this example, runoff is directed to this vegetated swale, which slows down flows and allows for infiltration.

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Multifunctional green space. Our slides on pervious alternatives in the previous section gave you an idea of what types of vegetated areas can be built to accept stormwater. Here's a more wholistic example, taken from a charrette detailed in a 2001 article by Bruce Ferguson of Univ. of Geogria in *Stormwater* magazine. This is from an urban area near Pittsburgh, PA. It shows that in addition to more conventional bioretention areas, things like ball parks and even public squares (in this case a sunken plaza) can be designed to help handle urban runoff during storm events.

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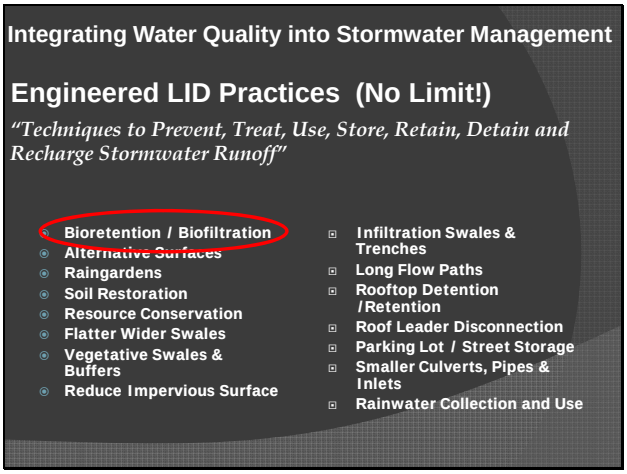

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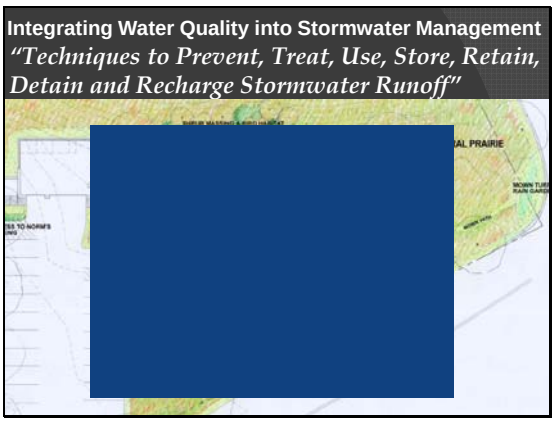

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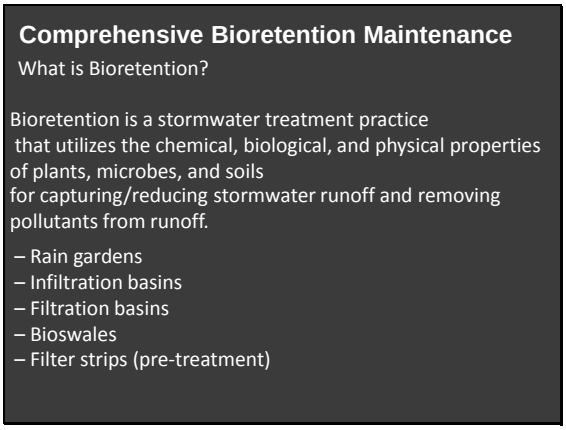

The term bioretention includes many subcatagories. The most common term used is Rain Garden.

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Crystal Lake, Burnsville MN is impaired for phosphorous and total suspended solids.

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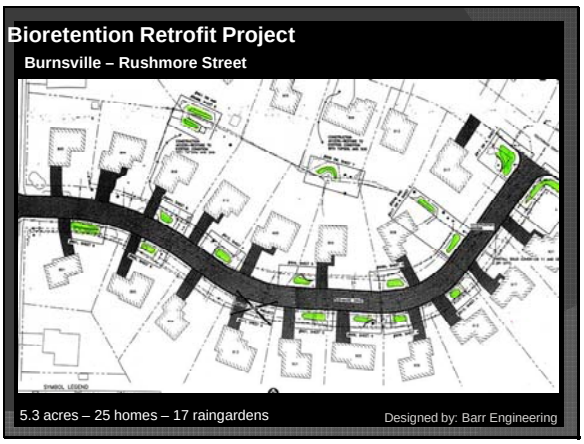

This bioretention retrofit project was developed by Kurt Luethold, P.E. and Fred Rozumalski, L.A. at Barr Engineering.

The primary components:

- Site Evaluation
- Capture Street Runoff
- Treatment Volume/Infiltration Rates
- Cascading treatment Effect

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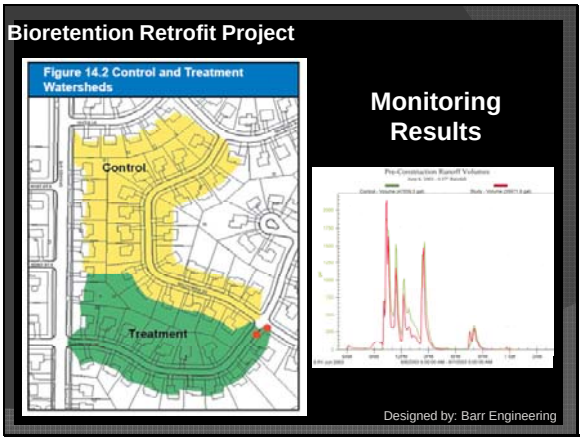

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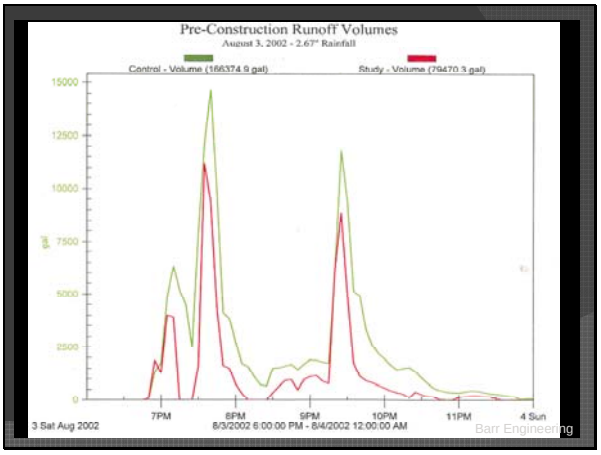

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Bioretention Retrofit Project- Sizing

1. Determine Design Requirements/Goals
2. Calculate Storage Volume
3. Determine Allowable Depth
4. Calculate Surface Area
    1. Input Basins into Hydrologic Model
5. Iterate until Requirements/Goals are Met

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Bioretention Retrofit Project- Sizing

$$V = A \times I$$

A = Tributary Impervious Area (SF)
I = Inches of Runoff/12 (Ft)
V = Storage Volume (CF)

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Bioretention Retrofit Project- Sizing

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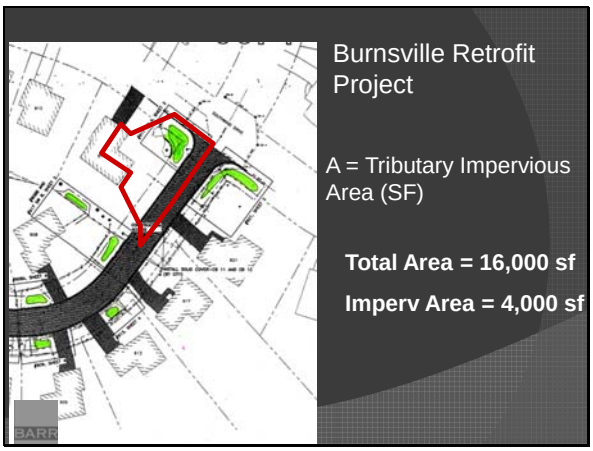

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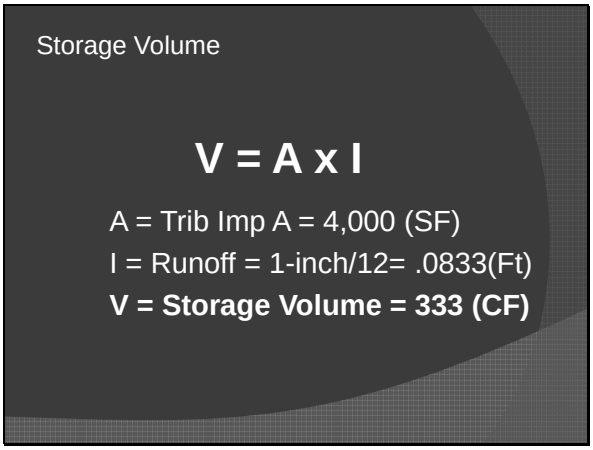

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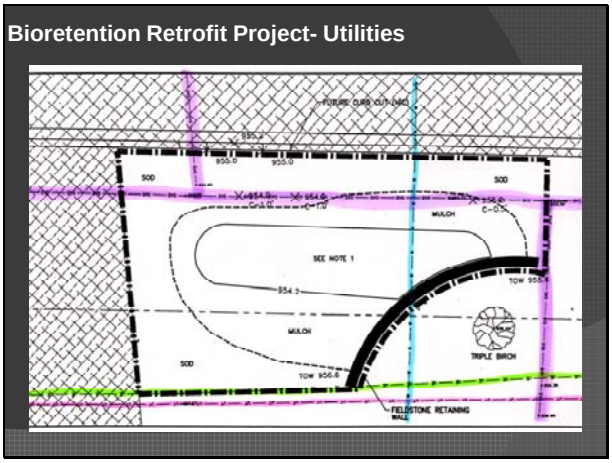

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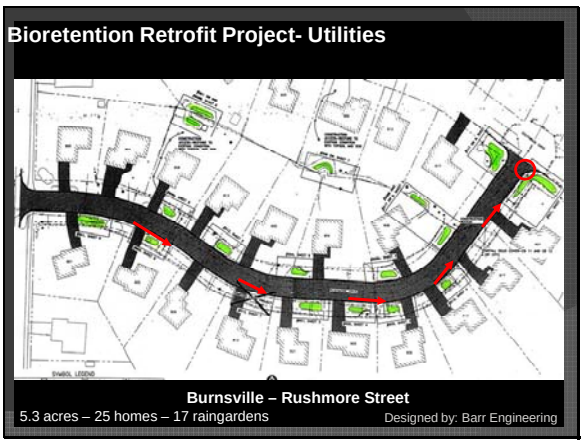

RWG Design

- Site Evaluation
- Capture Street Runoff
- Treatment Volume/Infiltration Rates
- Cascading treatment Effect

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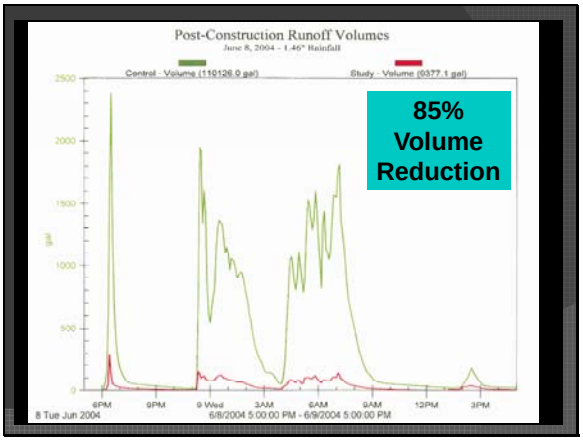

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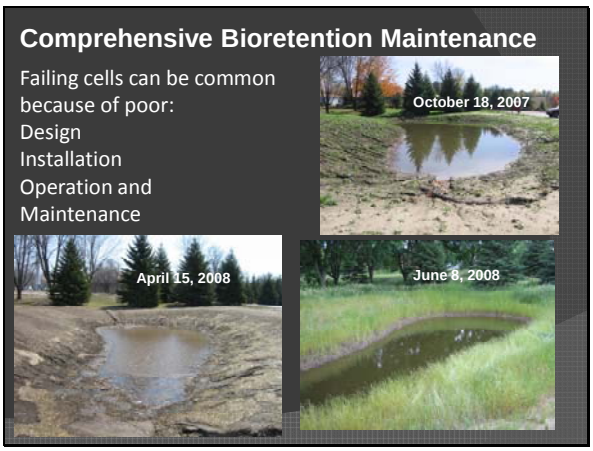

However, many owners have experienced high cell failure rates

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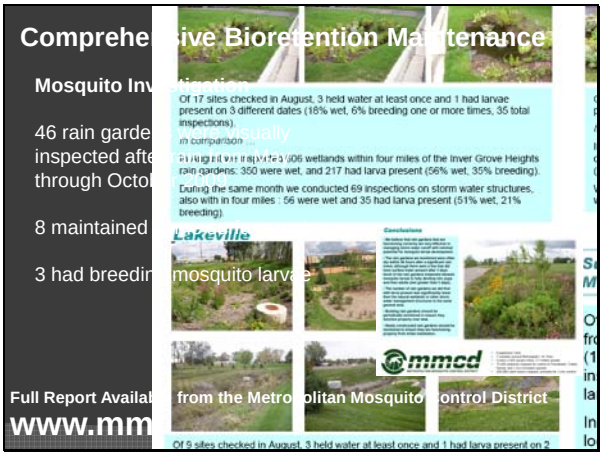

Since properly designed and constructed bioretention cells retain a surface pool of water for less than 5 days, they would not be expected to provide sufficient habitat for larval mosquitoes to emerge as adults. However, issues with design, construction and/or maintenance can result in surface ponding for several days and produce mosquitoes. This review of rain gardens in Dakota County was conducted in 2009 by the MMCD. 6% of the bioretention inspections revealed mosquito larvae present in pools of water that had not infiltrated within 3 days after the last storm event. While the mosquito breeding rate is still low compared to other monitored areas (i.e.- 35% of wetlands and 28% of stormwater structures inspected had mosquito larvae present) adequate design, installation and maintenance can reasonably achieve no mosquito breeding in bioretention cells.

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Excessive ponding depths leading to extended ponding duration results in the death of desirable vegetation that lead to complaints and extensive maintenance.

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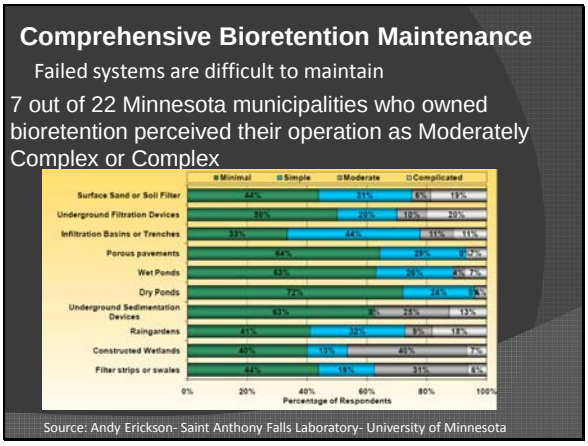

In a maintenance survey conducted by the University of Minnesota, 22 cities were identified as owning and maintaining bioretention systems. Of those 22, 6 (described in the graph as 27%) identified the maintenance as moderately complex to complicated. This could possibly be a result o

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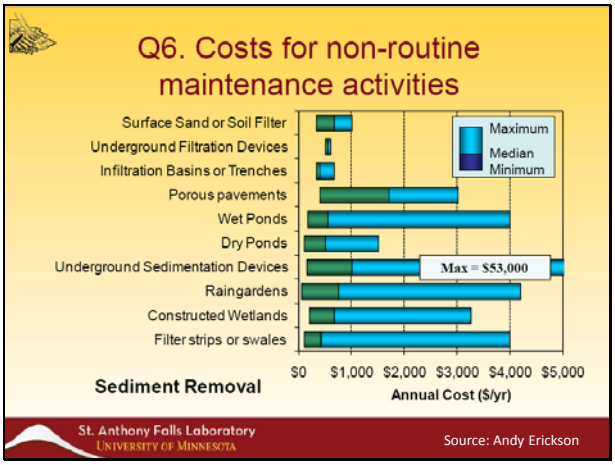

The data from the survey also revealed a large disparity in the annual cost to maintain the bioretention systems. Our hypothesis is the absence or presence of quality: design specifications, installation specification and quality control procedures, establishment maintenance program, regular inspection and maintenance program significantly influences the cost of annual maintenance.

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Comprehensive Bioretention Maintenance

Factors Driving Maintenance

Table 5: Percentage of respondents who indicated the listed factors for most frequently reducing performance in stormwater treatment practices.

Stormwater Treatment Practice Type	Number of responses	Sediment Buildup	Litter & Debris	Pipe Clogging	Invasive Vegetation	Groundwater Level	Bank Erosion	Oil Spill	Structural Problems	Mechanical Problems
Surface Sand or Soil Filter	10	50%	30%	10%	0%	0%	0%	10%	0%	0%
Underground Filtration Devices	8	50%	25%	13%	0%	13%	0%	0%	0%	0%
Infiltration Basins or Trenches	39	36%	21%	10%	5%	13%	5%	3%	5%	3%
Porous Pavements	9	67%	11%	11%	0%	0%	0%	11%	0%	0%
Wet Ponds	90	26%	19%	21%	10%	7%	11%	0%	7%	0%
Dry Ponds	49	24%	31%	18%	16%	2%	8%	0%	0%	0%
Underground Sedimentation Devices	19	58%	21%	11%	0%	5%	0%	0%	5%	0%
Rain Gardens	27	33%	22%	7%	26%	7%	0%	4%	0%	0%
Constructed Wetlands	37	24%	19%	14%	22%	8%	11%	0%	3%	0%
Filter Strips or Swales	19	21%	26%	5%	26%	5%	11%	0%	5%	0%

The 22 cities that owned bioretention cells reported Sediment Build Up, Invasive Vegetation and Litter and Debris as the primary maintenance issue that reduced performance for bioretention cells (81% of responses).

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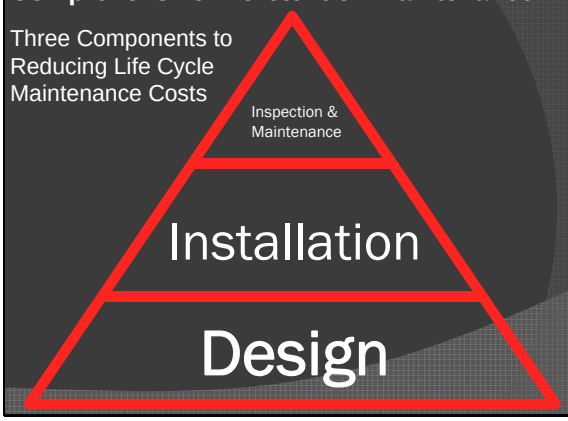
Comprehensive Bioretention Maintenance

Three Components to Reducing Life Cycle Maintenance Costs



Field observations of operating bioretention systems over a five year period demonstrate that functional reliability can be increased while decreasing long term maintenance and operation costs through better design, proper installation and an annual inspection and maintenance program. This presentation will review the major components of Design, Installation and long term Inspections and Maintenance.

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Comprehensive Bioretention Maintenance

Design
- Soils
- Cell Configuration
- Offline Design
- Pre treatment
- Vegetation

Installation
- Installation Specifications

Operations and Maintenance
- Inspections and Maintenance Program

Putting it all together: Case Study
- Inspections and Maintenance Program

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Proper design is the foundation of decreased long-term maintenance. We will begin by explore over a dozen key design considerations and practical applications that will substantially reduce future bioretention maintenance.

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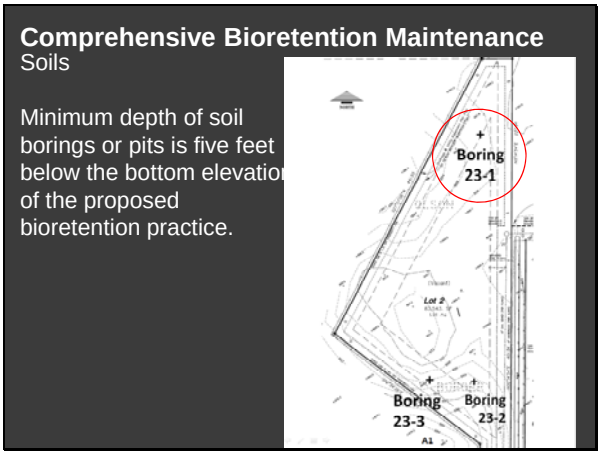

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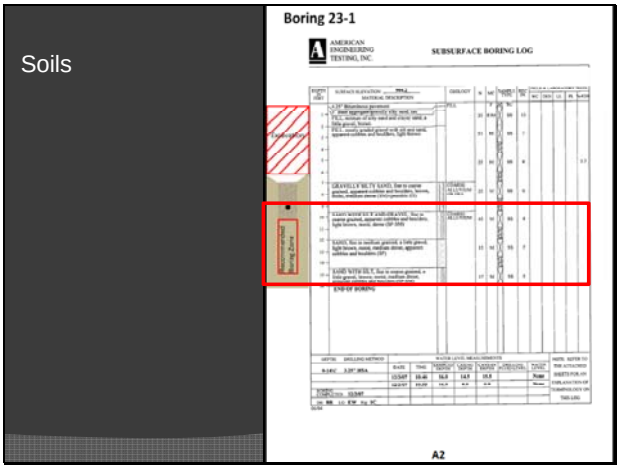

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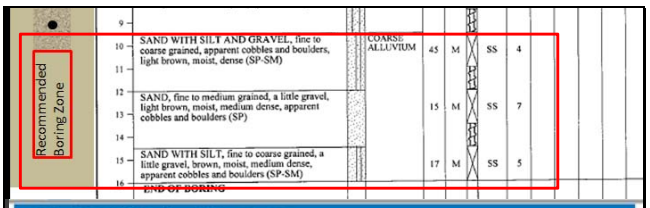

Table 12.BIO.8 Design Infiltration Rates

Hydrologic Soil Group	Infiltration Rate [inches/hour]	Soil Textures	Corresponding Unified Soil Classification
A	1.6*	Gravel, sandy gravel and silty gravels	**GW** - Well-graded gravels, sandy gravels **GP** – Gap-graded or uniform gravels, sandy gravels **GM** - Silty gravels, silty sandy gravels **SW** - Well-graded, gravelly sands
	0.8	Sand, loamy sand or sandy loam	**SP** - Gap-graded or uniform sands, gravelly sands
B	0.6	Silt loam	**SM** - Silty sands, silty gravelly sands
	0.3	Loam	**MH** – Micaceous silts, diatomaceous silts, volcanic ash
C	0.2	Sandy clay loam	**ML** - Silts, very fine sands, silty or clayey fine sands

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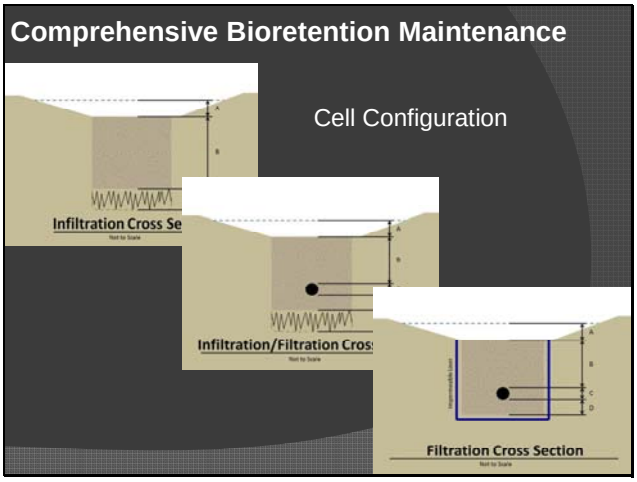

Once the saturated infiltration rate of the soil is identified, the designer can choose from three base bioretention configurations.

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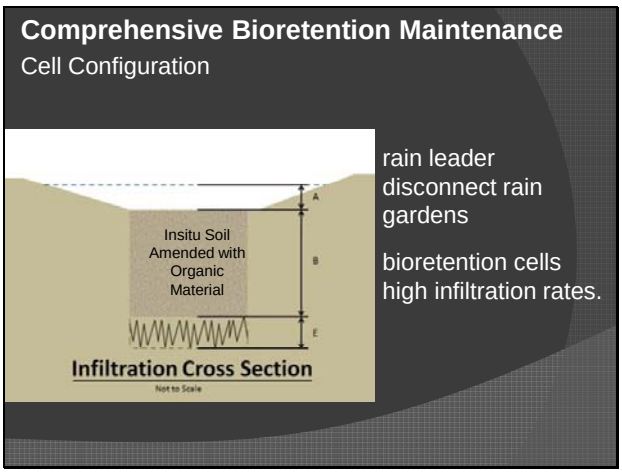

The infiltration cross section consists of on site soils with an organic soil amendment (typically leaf litter compost). T

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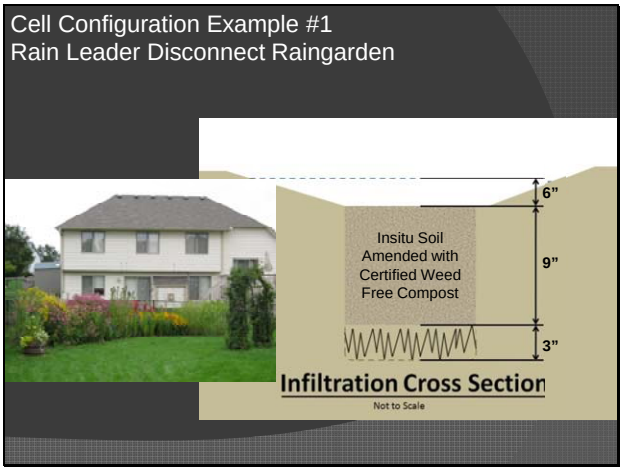

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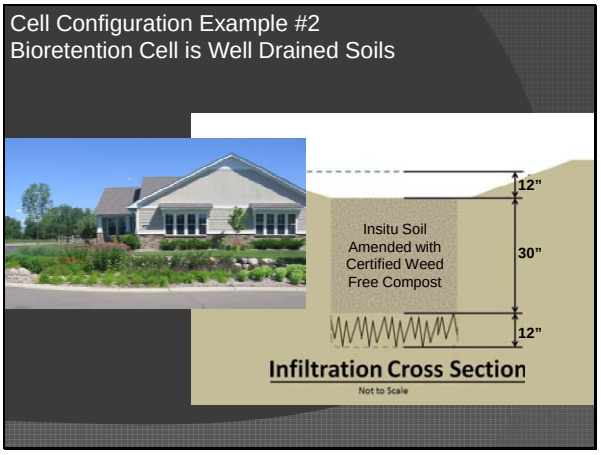

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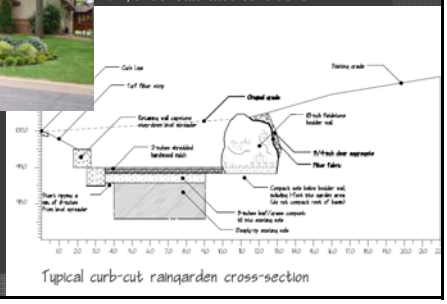
Cell Configuration Example #3
Bioretention Cell is Well Drained Soils

In-situ soils below the excavated grade of the raingarden basins are Type A and infiltrate at 1.63-in/hr, under saturated conditions.



Shawn Tracy, Metro Association of SWCDs

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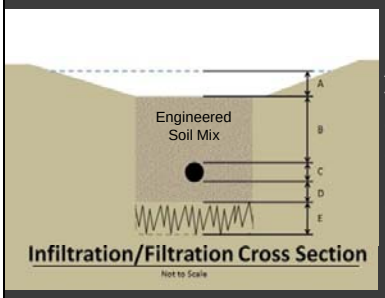
Comprehensive Bioretention Maintenance
Cell Configuration



Areas where target treatment volumes exceed the anticipated hydraulic conductivity of the insitu soils.

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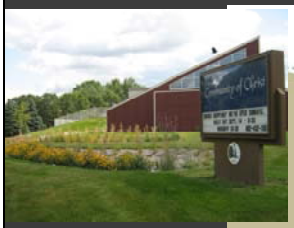
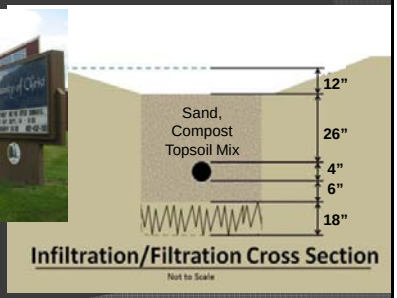
Infiltration/Filtration Cell Configuration Example #1

Areas where target treatment volumes exceed the anticipated hydraulic conductivity of the insitu soils.





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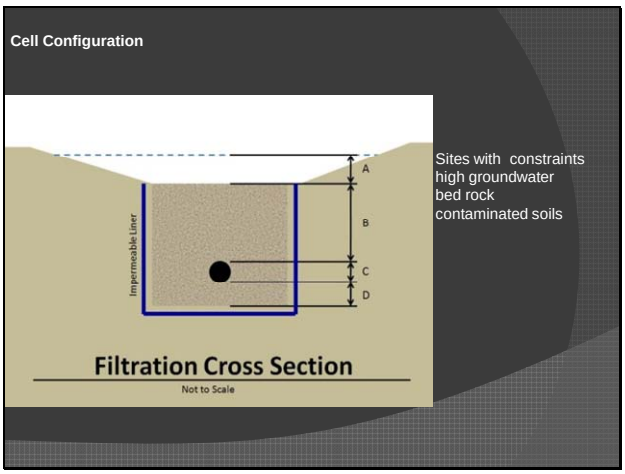

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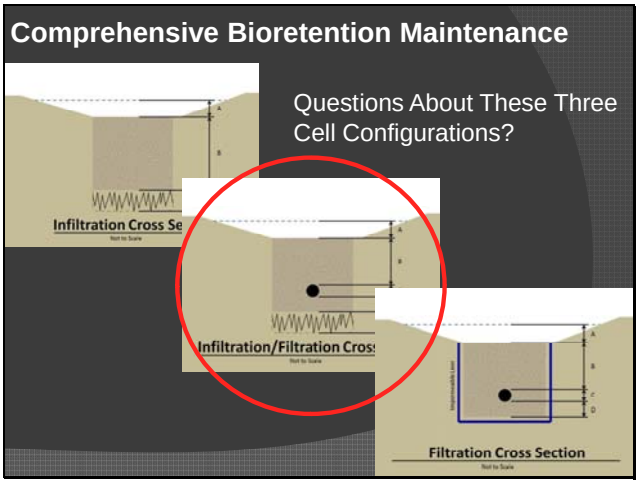

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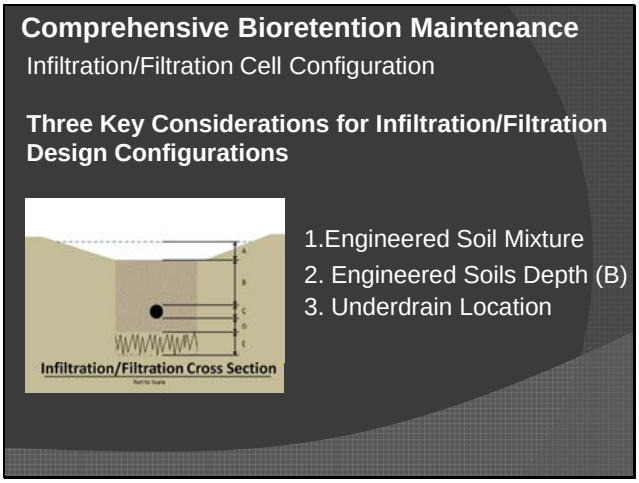

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Comprehensive Bioretention Maintenance

Cell Configuration- Engineered Soil Mixture

4.1 Soil Medium / Filter Media Content

Mix 4.1.a: Water Quality Blend A well blended, homogenous mixture of 55-65% construction sand: 10-20% top soil; and 25-35% organic leaf compost is necessary to provide a soil medium with a high infiltration/filtration capacity.

- Sand: Provide clean construction sand, free of deleterious materials. AASHTO M-6 or ASTM C-33 with grain size of 0.02"- 0.04"
- Top Soil: sandy loam, loamy sand, or loam texture per USDA textural triangle with less than 5% clay content
- Organic Leaf Compost: Mn/DOT Grade 2

Mix 4.1.b: Enhanced Infiltration Blend A well blended, homogenous mixture of 50-70% construction sand and 30-50% organic leaf compost is necessary to provide a soil medium with a higher infiltration/filtration capacity.

- Sand: Provide clean construction sand, free of deleterious materials. AASHTO M-6 or ASTM C-33 with grain size of 0.02"- 0.04"
- Organic Leaf Compost: Mn/DOT Grade 2

Note: Hydrometer Test May be Required for Top Soil

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Comprehensive Bioretention Maintenance

Cell Configuration- Engineered Soils Depth

TABLE 2. BIORETENTION DESIGN GUIDELINES FOR SPECIFIC POLLUTANTS.

Target Pollutant	Minimum Fill Media Depth	Target Infiltration Rate	Other Design Guidance
TSS	No minimum fill depth required	Any rate is sufficient. 2 to 6 inches per hour recommended	If high TSS influent, frequent maintenance required.
Pathogens	No minimum fill depth required	Any rate is sufficient. 2 to 6 inches per hour recommended	Limiting plant coverage allows more direct sunlight to kill pathogens.
Metals	18 inches	Any rate is sufficient. 2 to 6 inches per hour recommended	Must keep top layer of cell from being saturated for extended periods.
Temperature	To be determined. Conservatively, at least 36 inches	To be determined. Slower rates may be preferable (less than 2 inches per hour)	Introduction of IWS volume at the bottom of the cell may reduce effluent temperature.
Total Nitrogen (TN)	At least 30 inches (36 inches preferred)	1-2 inches per hour. Slower rates are better.	Introduction of IWS volume may reduce TN concentrations.
Total Phosphorus (TP)	24 inches	2 inches per hour	A low P-Index is essential. Recommended range is from 10 to 30.

www.bae.ncsu.edu/stormwater/PublicationFiles/Bioretention2006.pdf

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Comprehensive Bioretention Maintenance

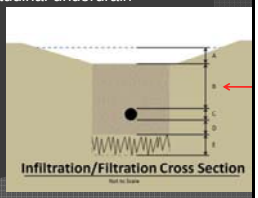
Cell Configuration- Underdrain Location

"Filtration systems must have a reasonable chance of achieving approximately 80% removal of total suspended solids."

"The bed of the dry swale consists of a permeable soil layer of at least **30 inches in depth**, above an 8-inch diameter perforated PVC pipe (AASHTO M 252) longitudinal underdrain"

"the recommended depth of the prepared soil is **30 inches"**

"Field experiments show that pollutant removal is accomplished within the top **30" of soil depth** with minimal additional removal beyond that depth"



"The filter bed in the swale is **30 inches** of prepared soil"

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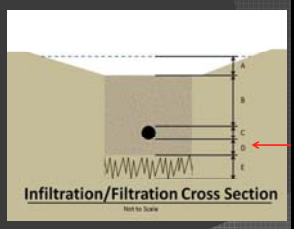
Comprehensive Bioretention Maintenance

Cell Configuration- Underdrain Location

Evidence has shown that the raised underdrain configuration results in volume loss through infiltration and if the media remains saturated for a significant period denitrification of nitrate is possible .



Davis P. A., W.F. Hunt, R.G. Traver, M. Clar (2009). Bioretention Technology: Overview of Current Practice and Future Needs. Journal of Environmental Engineering, Vol. 135 No. 3

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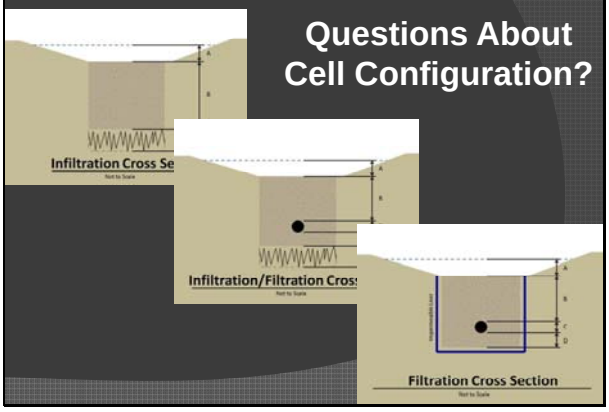
Comprehensive Bioretention Maintenance

Questions About Cell Configuration?



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Comprehensive Bioretention Maintenance

Bioretention Design

Soils
Cell Configuration
Offline Design
Pre treatment
Vegetation

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Comprehensive Bioretention Maintenance

Off Line Design

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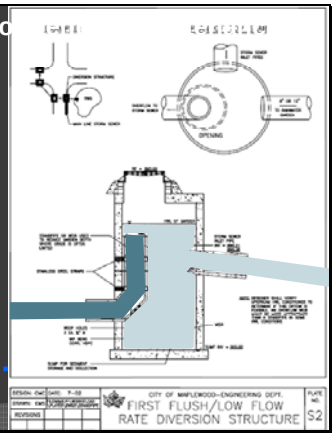
Comprehensive Bio

Off Line Design



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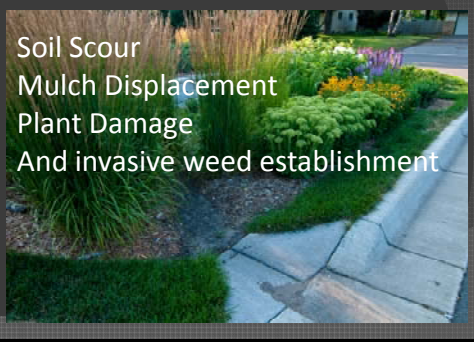
Comprehensive Bioretention Maintenance

Off Line Design

Decreases



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Comprehensive Bioretention Maintenance

Off Line Design

Easy Stormwater Bypass During Construction

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Comprehensive Bioretention Maintenance

Bioretention Design

Soils
Cell Configuration
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Pre treatment
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Comprehensive Bioretention Maintenance

Inlets and Pretreatment

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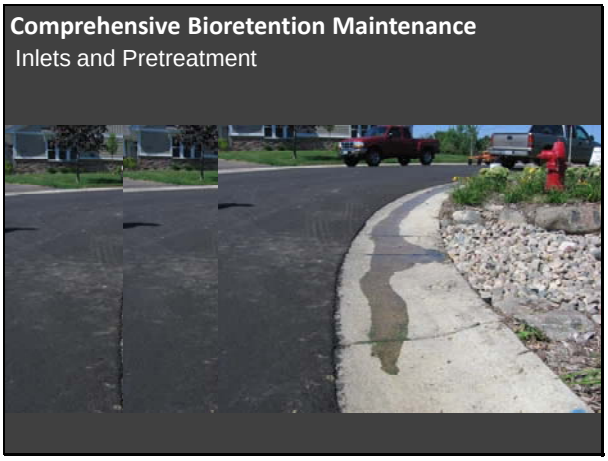

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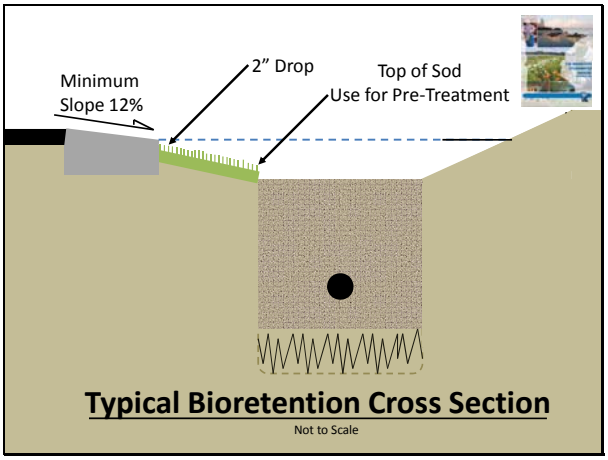

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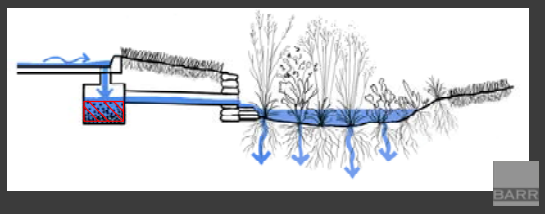
Comprehensive Bioretention Maintenance

Inlets and Pretreatment



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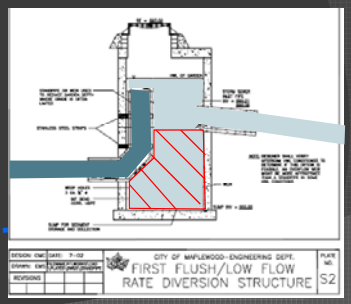
Comprehensive Bioretention Maintenance

Inlets and Pretreatment



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Comprehensive Bioretention Maintenance

Inlets and Pretreatment

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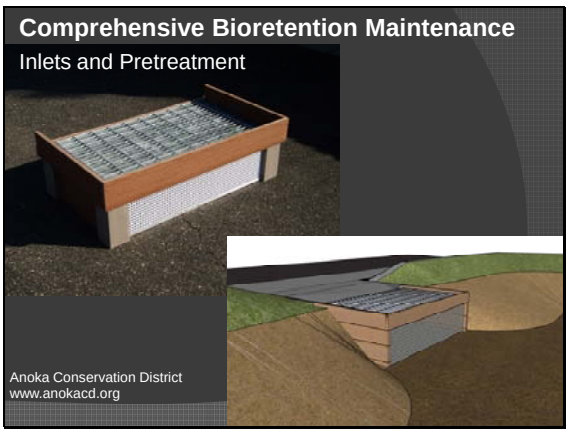

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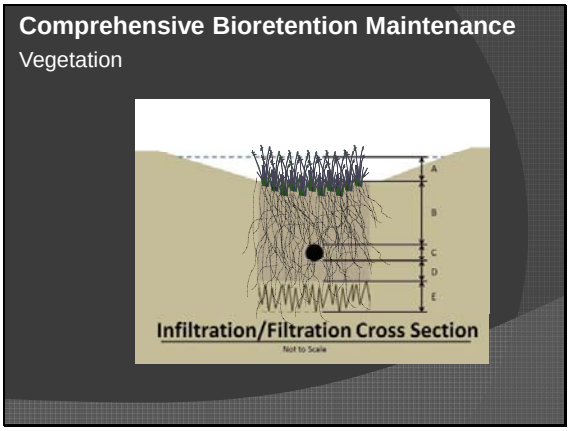

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While little quantitative evidence exists identifying the role of vegetation in the functionality of bioretention systems, field experience dictates that robust vegetated systems generally exceed performance expectations. A few recent studies provide preliminary evidence that supports these observations.

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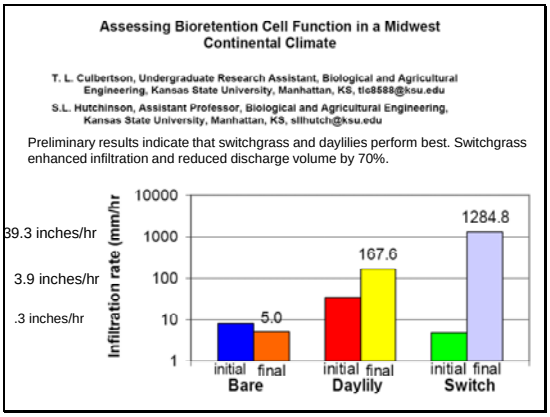

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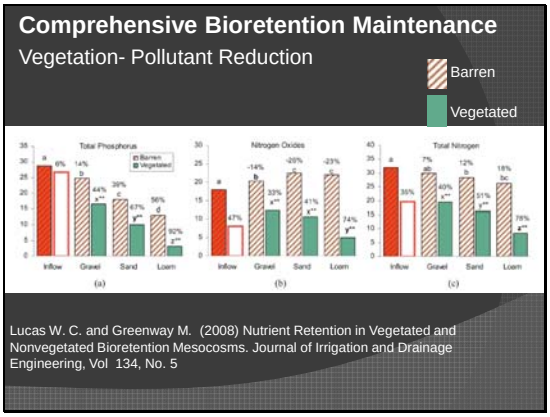

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Comprehensive Bioretention Maintenance

Vegetation- Pollutant Reduction

Various phytoremediation processes

Phytoextraction- uptake and concentration of substances from the environment into the plant biomass.

Phytostabilization- reducing the mobility of substances in the environment, for example by limiting the leaching of substances from the soil.

Phytotransformation- chemical modification of environmental substances as a direct result of plant metabolism, often resulting in their inactivation, degradation (phytodegradation) or immobilization (phytostabilization).

Phytostimulation - enhancement of soil microbial activity for the degradation of contaminants, typically by organisms that associate with roots. This process is also known as *rhizosphere degradation*.

Phytovolatilization - removal of substances from soil or water with release into the air, sometimes as a result of phytotransformation to more volatile and / or less polluting substances

Rhizofiltration - filtering water through a mass of roots to remove toxic substances or excess nutrients. The pollutants remain absorbed in or adsorbed to the roots.

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Comprehensive Bioretention Maintenance

Vegetation- Volume Reduction

Evapotranspiration accounts for 15 to 20% of all inflow on an annual basis.

Sharkey, L. J. (2006). "The performance of bioretention areas in North Carolina; A study of water quality, water quantity and soil media." Thesis, North Carolina State University., Raleigh, N.C.

Heasom, W., Traver. R., and Welker, A. 2006. "Hydrologic modeling of a bioinfiltration best management practice" J. Am. Water Resour. Assoc., 42((5), 1329-1347

Hunt , W.F., Jarett, A.R., Smith, J.T., and Sharkey, L. J. (2006). Evaluating bioretention hydrology and nutrient removal at three field sites in North Carolina. " J. Irrig. Drain. Eng., 132(6) 600-608

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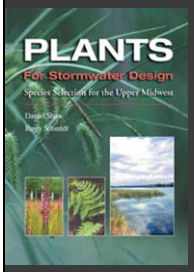
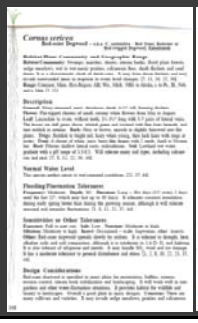
Comprehensive Bioretention Maintenance

Vegetation- Ponding Depth and Duration





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Comprehensive Bioretention Maintenance

Vegetation- Plant Pallet Determined By Ponding Depth and Duration

- Maximum ponding depth 12 inches = 56 plants
- Maximum ponding depth of 18 inches = 19 plants
- Maximum ponding depth of 24 inches = 9 plants
- Maximum ponding depth of 30 inches and above = mud hole

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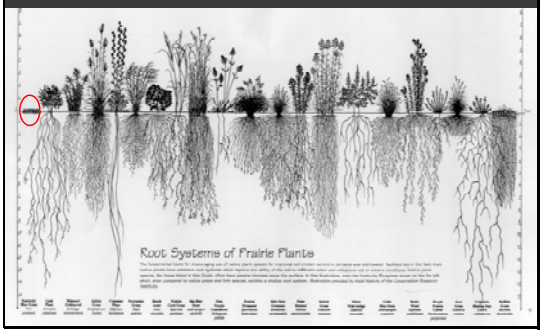
Comprehensive Bioretention Maintenance

Vegetation



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Comprehensive Bioretention Maintenance

Vegetation- Install Plugs or Potted Materials

Seeding should not be used unless the basin can be kept offline for one year.

'plugs" $0.70-1.30 ea.
3-4" pots $3.25 to $5.00 each

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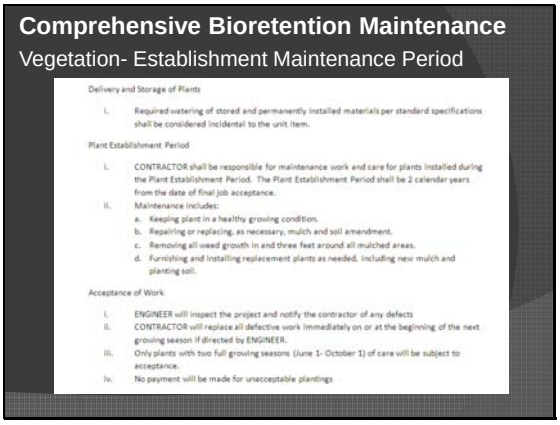

Incorporate establishment period maintenance into the installation specifications. should include one to two years of maintenance and a security or with holding to ensure the maintenance is performed. Visual inspections should be performed in the first year to verify ponding depth and pool draw down in the mandatory timeframes. In the first year of growth after being transplanted as a seedling, the roots of big bluestem, little bluestem, and side oats gramma increased by 72, 86 and 56% respectively (Weaver 1946).

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Comprehensive Bioretention Maintenance

Design
Soils
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Offline Design
Pre treatment
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Installation
Installation Specifications

Operations and Maintenance
Inspections and Maintenance Program

Putting it all together: Case Study
Inspections and Maintenance Program

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Comprehensive Bioretention Maintenance
Installation Specifications

Used	Standard	SUBJECT TO REVISIONS WITHOUT NOTICE
	2.58	The area must be staked off and marked so that heavy construction equipment will not compact the soil in the proposed bioretention area.
	2.59	Bioretention systems shall not be excavated to final grade until the contributing drainage area has been constructed and fully stabilized.
	2.60	During construction of a bioretention system, rigorous erosion prevention and sediment controls (e.g., diversion berms shall be used to keep sediment and runoff completely away from the bioretention area.
	2.61	Keep bioretention systems off-line by restricting stormwater inflow until vegetation is well established in the cell and all gradient areas have been stabilized and impervious surfaces cleared of construction sediment.
	2.62	Installation with dry soil conditions is critical. Remove standing water and mud to avoid mixing with dry soils and preve run-on into excavation. Work shall only be done during periods of dry weather and soil placements completed before precipitation event.
	2.63	Use backhoe with tooth bucket for cell excavation to avoid compacting or smearing of soils.
	2.64	Rip underlying soils 18 to 24" deep to remove compaction. Gently mix the first lift of engineered soils with the loosene underlying soils to avoid stratification and promote permeability. Do not place filter fabric.
	2.65	Care must be taken to avoid contamination of engineered soils with sediment, in-situ or topsoil during and after installa
	2.66	Construction equipment shall not be allowed into the basin area; except that a tracked skid loader may be used to spr the engineered soil mixture after the first 1.5 ft of engineered soil has been placed in the excavated bottom.

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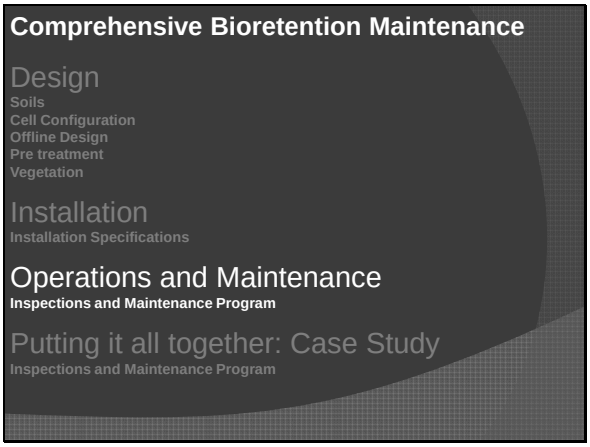

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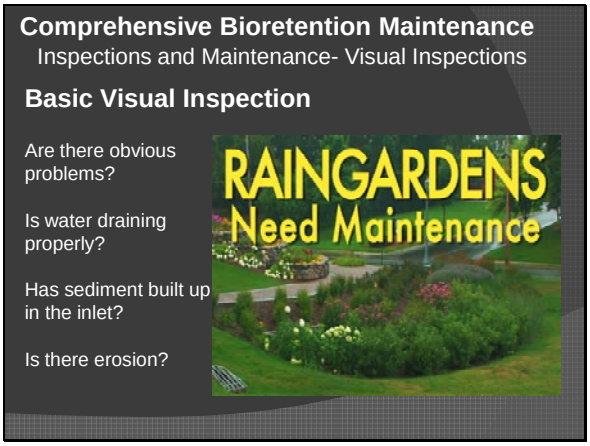

When properly designed, installed and maintained, raingardens are extremely effective. The following are basic guidelines for raingarden maintenance:

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Begin by visually inspecting the raingarden. Are there obvious problems? Is water draining properly? Has sediment built up in the inlet? Is there erosion? If you see major problems, speak with your parks or publics works supervisor.
If not, begin by removing an litter from the raingarden.

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Next remove weeds from the garden by pulling. Weeding is most important during the first three years after a raingarden is installed. Mulch is an effective way to control future weed growth. Weed once in the spring and again in the summer if needed.

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Remove any sediment built up in the inlet. You may also have to replace sections of sod near the inlets. If there is a very large quantity of built-up sediment, investigate where it is coming from and determine if further action is needed.

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Last, but not least, replace any plants that have died over the year. Finish with 3-inches of fresh mulch to prevent weed growth and retain soil moisture.

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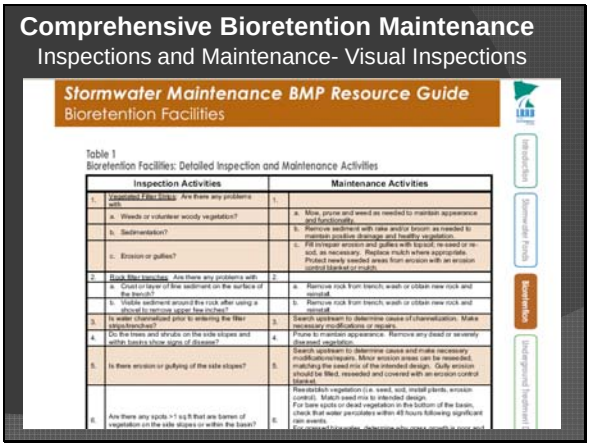

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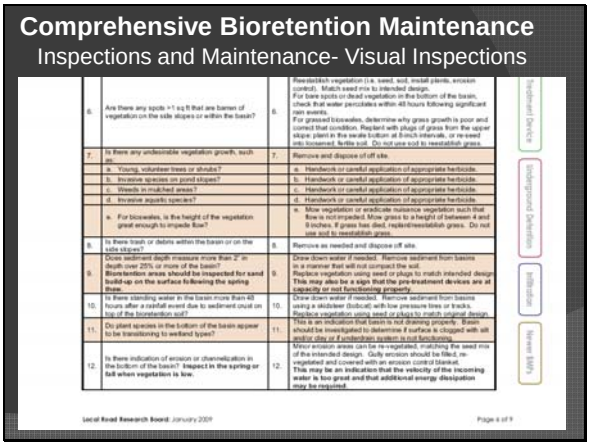

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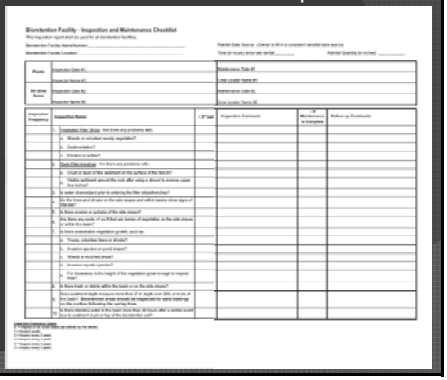
Comprehensive Bioretention Maintenance

Inspections and Maintenance- Visual Inspections

www.lrrb.org/detail.aspx?productid=2301



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Comprehensive Bioretention Maintenance

Design

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Inspections and Maintenance Program

Putting it all together: Case Study

Inspections and Maintenance Program

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Comprehensive Bioretention Maintenance

Putting it all together: Case Study

Design, Installation, Inspections, Maintenance and Costs- City of Plymouth, MN

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Comprehensive Bioretention Maintenance

Putting it all together: Case Study

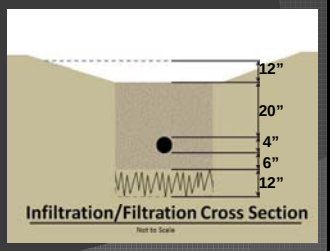
Design, Installation, Inspections, Maintenance and Costs- City of Plymouth, MN

2004 to 2008 the City of Plymouth has installed 21 curb side bioretention cells in conjunction with street reconstruction projects.

Offline Design

Plants: Large containerized native and garden variety perennial flowers and shrubs.

Other: Each cell includes a retaining wall and is edged with steel edging to prevent the encroachment of turf grass.



Source: Derek Asche, City of Plymouth, MN

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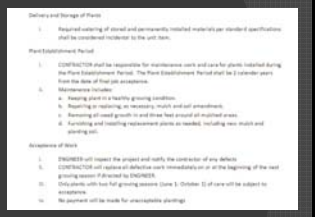
Comprehensive Bioretention Maintenance

Putting it all together: Case Study

Design, Installation, Inspections, Maintenance and Costs- City of Plymouth, MN

Includes a $10/square foot withholding for maintenance for first 24 months

Watering during the establishment period is included in installation contract as well as through homeowner agreements.



Maintenance during the establishment period is performed when the city submits a “punch list” to the contractor.

Source: Derek Asche, City of Plymouth, MN

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Comprehensive Bioretention Maintenance

Putting it all together: Case Study

Design, Installation, Inspections, Maintenance and Costs- City of Plymouth, MN

Average cost for installation and establishment period maintenance for 21 rain gardens from 2004-2009

$20/square foot

Source: Derek Asche, City of Plymouth, MN

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Comprehensive Bioretention Maintenance

Putting it all together: Case Study

Design, Installation, Inspections, Maintenance and Costs- City of Plymouth, MN

Annual Maintenance

The city also hires an independent contractor annually to maintain the 21 bioretention cells.

"Spring Clean Up"

- cutting and removing previous years plant material
- removing accumulated leaves
- remove sediment accumulated at the inlet
- spot mulching

Visual inspections and light weeding and mulching are performed as needed in June, July and August

Annual cost for the maintenance of 21 rain gardens from in 2008 and 2009

$1800/year

or less than $100 per raingarden per year

Source: Maintenance Contractor: Rob Langer, Natural Shoreline Technologies, Maple Plain, MN

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Comprehensive Bioretention Maintenance

Thank You:

Shawn Tracy, Metro. Assoc. of Soil and Water Conservation Districts

Andy Erickson- Saint Anthony Falls Laboratory- University of Minnesota

Kurt Luethold, Barr Engineering

Julie Westerlund, Minnehaha Creek Watershed District

Jay Riggs, Washington Conservation District

Mike Isensee, CPESC
Jim Davidson CPESC, CPSWQ
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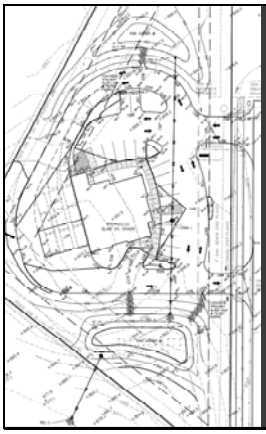

Installation Specifications

New Development- Bank

Total Site Area = 1.91 Acres
Total Impervious= .75 Acres

Water Quality Volume=

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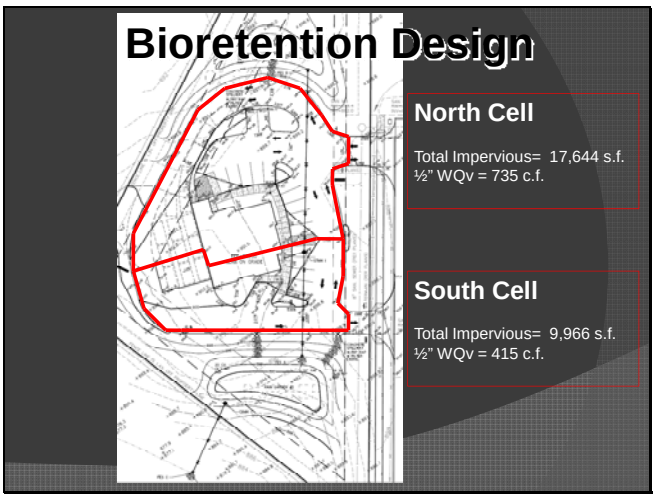

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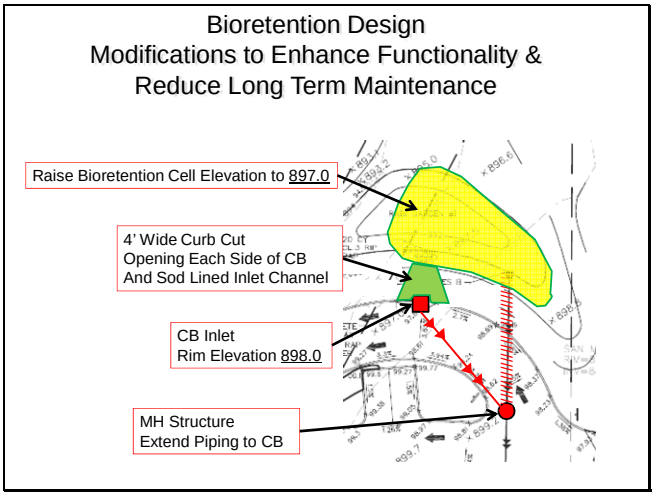

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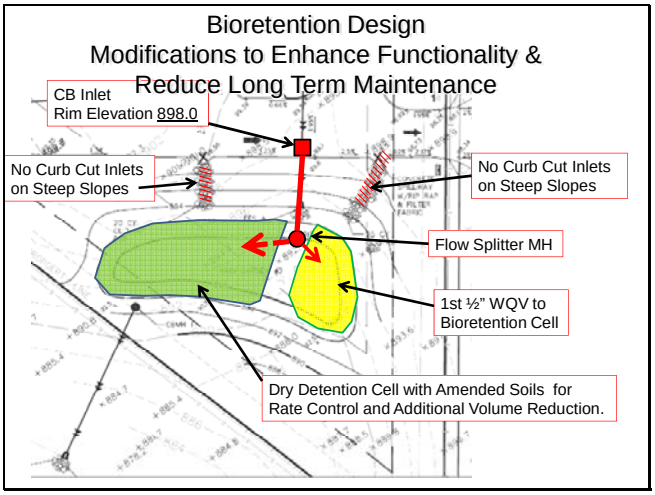

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