The Design of Wet Detention Ponds for Stormwater Quality Benefits

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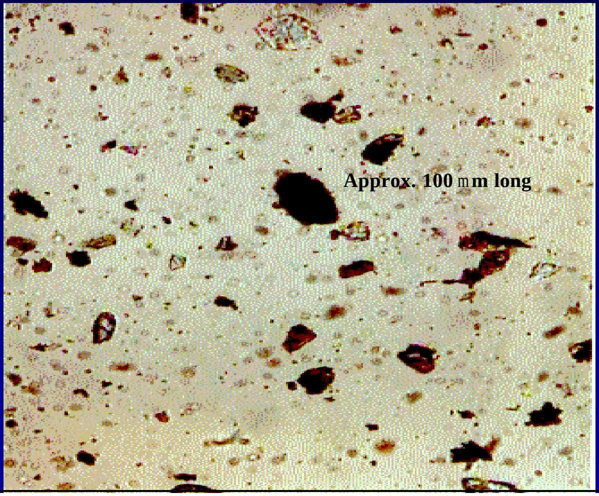
Treatability Testing and the Development of Stormwater Control Design Criteria

- Particle sizes and settling rates
- Relative toxicity after different unit processes
- Laboratory-scale and field pilot-scale tests
- Full-scale tests

Particle Size Analyses Using Cascading Sieves

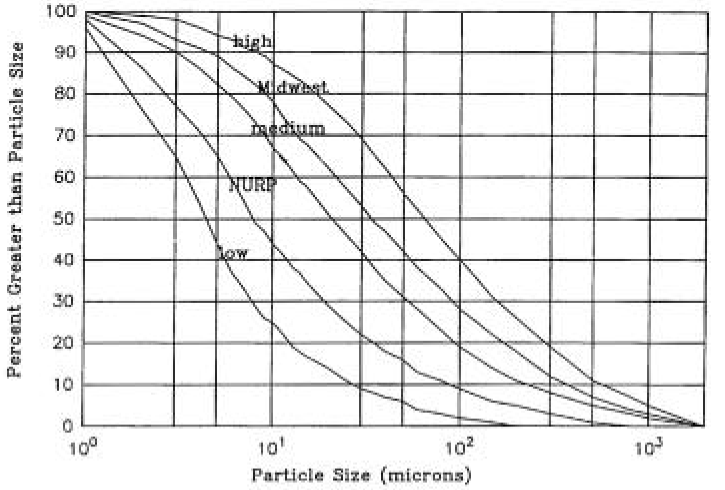
Particle Size Analyses Using Video Microscope and Computer

Micrograph of Road Surface Sediment Washoff

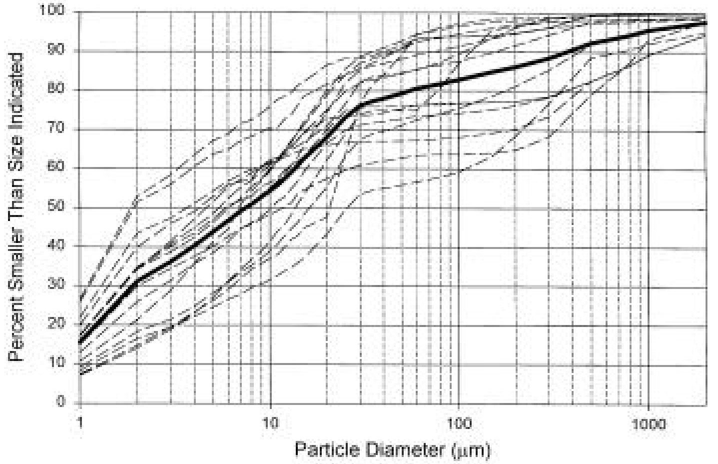


Particle Size Analyses Using Coulter Counter Multi-Sizer 2

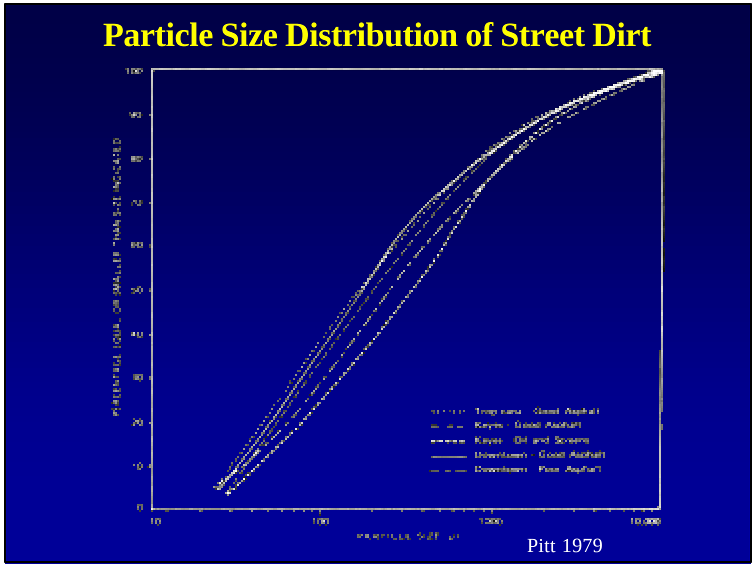
Typical Stormwater Particle Size Distributions for Outfall Samples



Measured Particle Sizes, Including Bed Load Component, at Monroe St. Detention Pond, Madison, WI

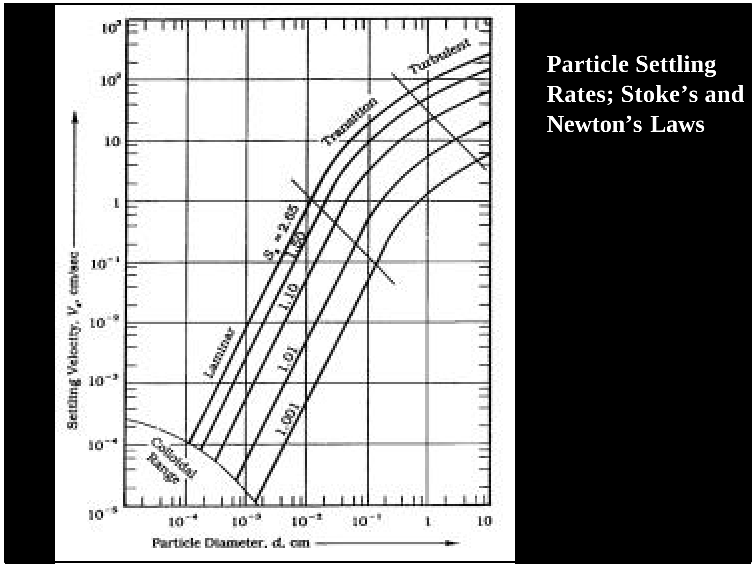


Particle Size Distribution of Street Dirt



Pitt 1979

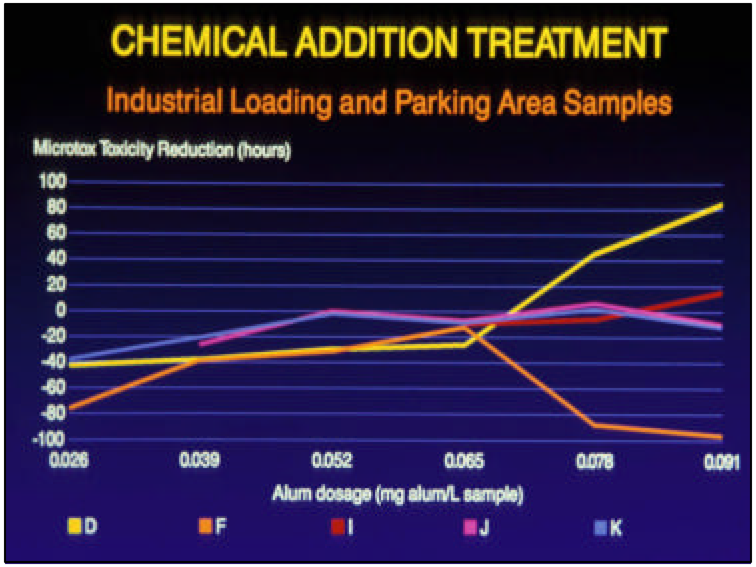
Particle Settling Rates; Stoke's and Newton's Laws

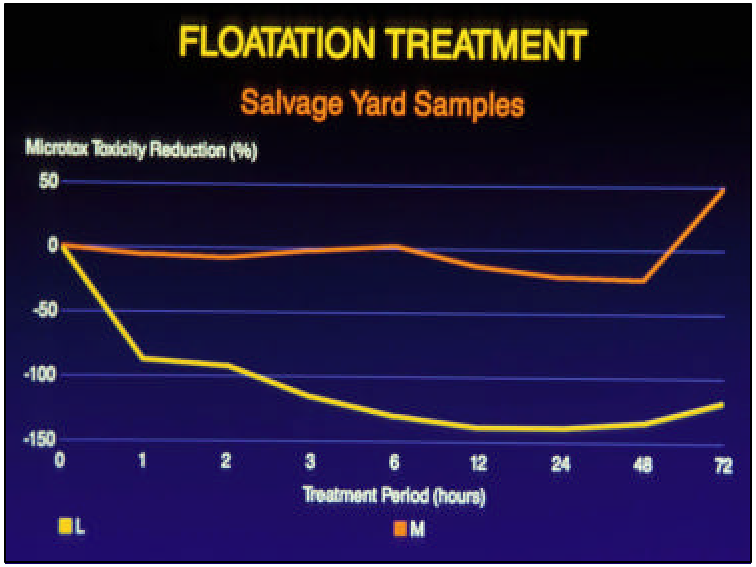


Azur's Microtox Unit used for Relative Toxicity Measurements

CHEMICAL ADDITION TREATMENT

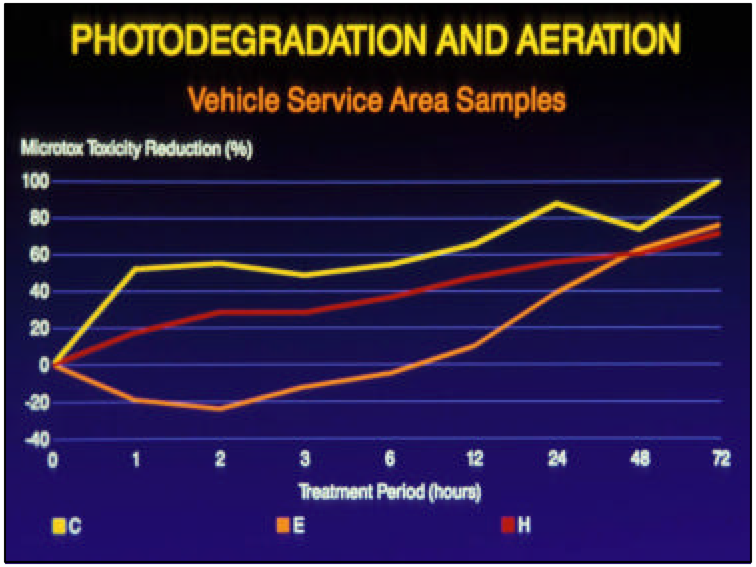
Industrial Loading and Parking Area Samples





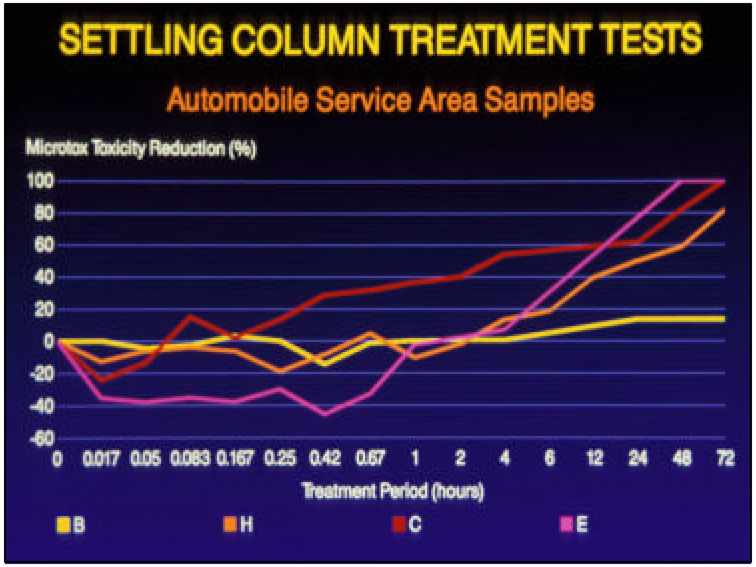
FLOATATION TREATMENT

Salvage Yard Samples



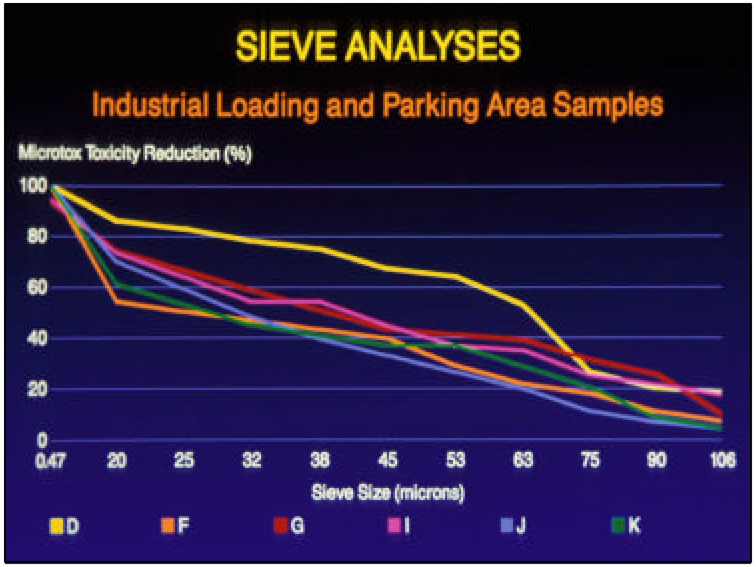
PHOTODEGRADATION AND AERATION

Vehicle Service Area Samples



SETTLING COLUMN TREATMENT TESTS

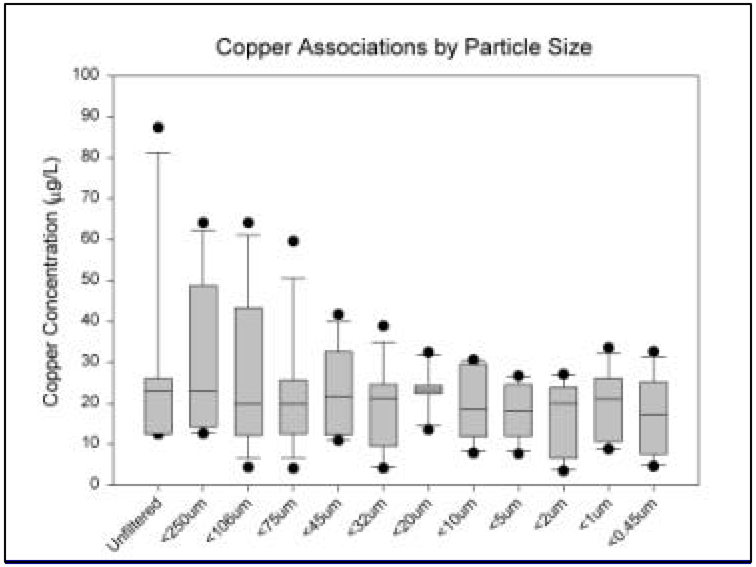
Automobile Service Area Samples

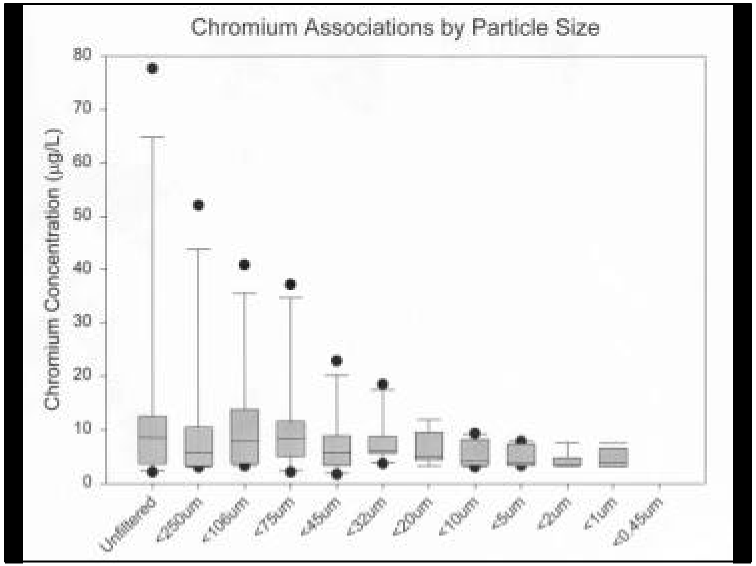


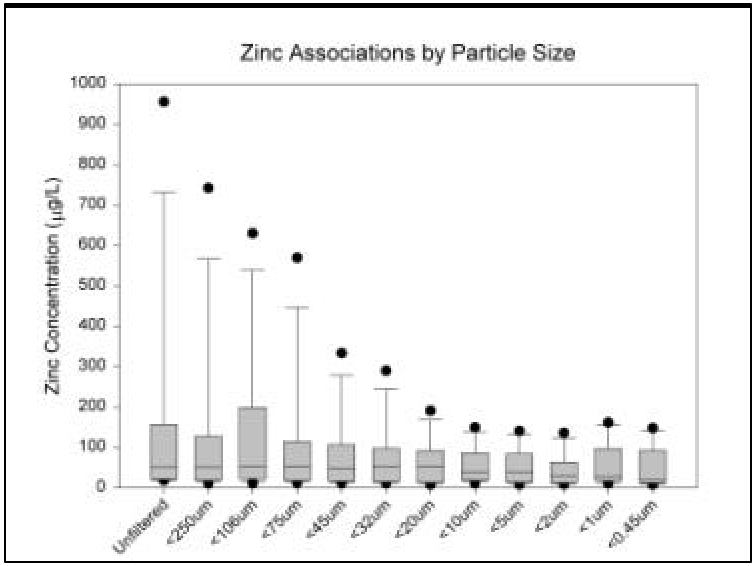
SIEVE ANALYSES

Industrial Loading and Parking Area Samples

Atomic Adsorption Spectrophotometer (AAS) With Graphite Furnace, Used for Ultra Low Level Measurements of Heavy Metals

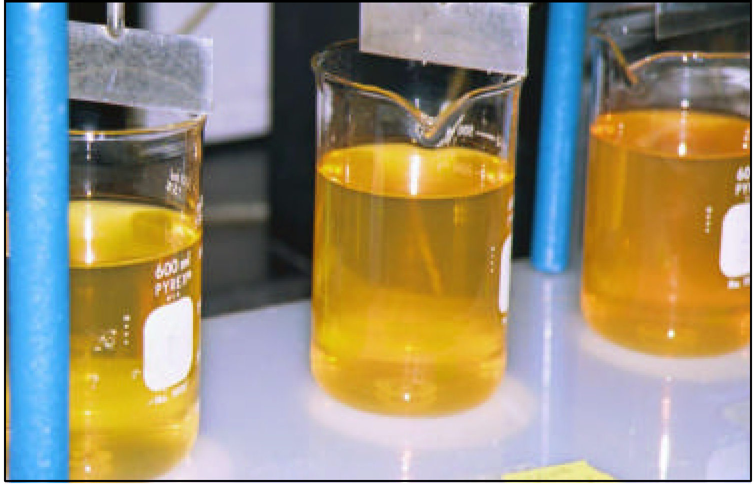






Gas Chromatograph/Mass Spectrophotometer (GC/MSD) used for Organic Toxicant Trace Analyses

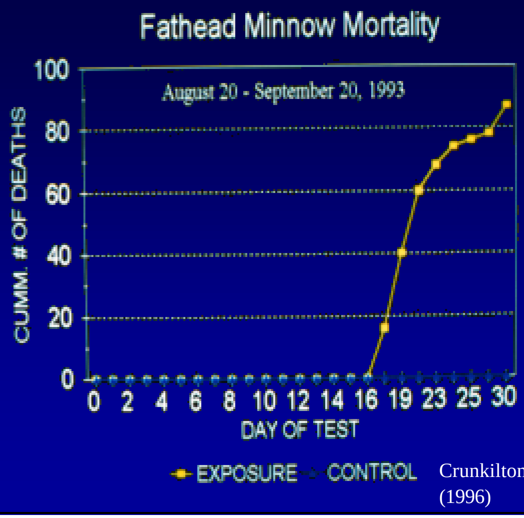
Simple Bench-Scale Chemical Treatment Tests



Pilot-Scale Treatment Tests using Filtration, Carbon Adsorption,UV Disinfection, and Aeration

Lincoln Creek Side-Stream Toxicity Tests
(UW Steven's Point, USGS, and WI DNR Tests)

Interior of Side -Stream Toxicity Test Facility



Crunkilton, *et al.* (1996)

Pilot-Scale Wet Detention Pond used at Lincoln Creek Side -Stream Toxicity Test Facility to Measure Reduction in Toxicity due to Removal of Stormwater Particulates

Stormwater Toxicant Control

- Toxicant removal mechanisms include sedimentation, biodegradation, volatilization, sorption onto soil particles, and chemical oxidation and hydrolysis
- These processes are available in many urban runoff controls, but modifications should be made in their designs to increase their toxicant removal efficiencies

Stormwater Toxicant Control, cont.

- The most effective treatment processes included:
- settling for at least 24 hours (40 to 90% reductions),
- screening through 40 micrometer sieves (20 to 70% reductions), and
- aeration and or photo-degradation for at least 24 hours (up to 80% reductions).

Design Modifications to Enhance Control of Toxicants in Wet Detention Ponds

- Settling of fine particulates
- Photo-degradation (enhanced vertical circulation, but not complete mixing that can scour sediments)
- Aeration
- Floatation (subsurface discharges) to increase trapping of floating litter

Common Stormwater Controls

- Public works practices (drainage systems, street and catchbasin cleaning)
- Sedimentation
- Infiltration/biofiltration
- Critical source area controls
- Public education

Goals of Storm Drainage Inlet Devices

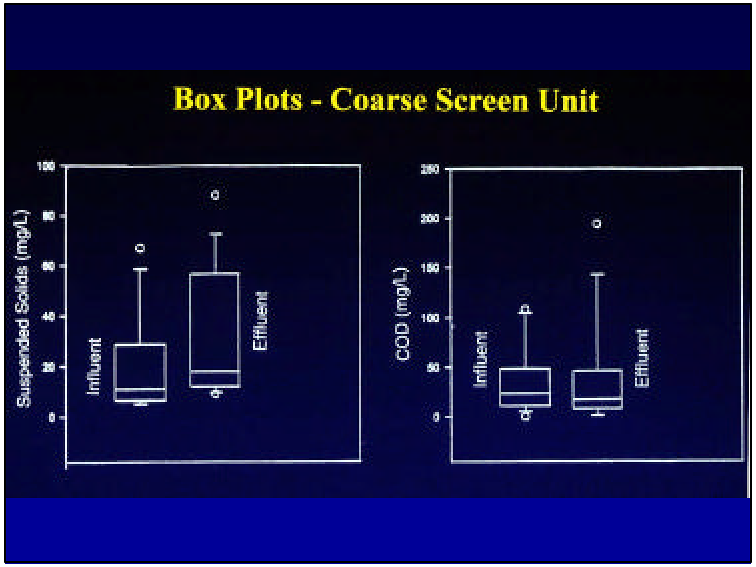
- Does not cause flooding when clogged with debris
- Does not force stormwater through the captured material
- Does not have adverse hydraulic head loss properties
- Maximizes pollutant reductions
- Requires inexpensive and infrequent maintenance

Drain Inserts

Caltrans, San Diego and Los Angeles, California

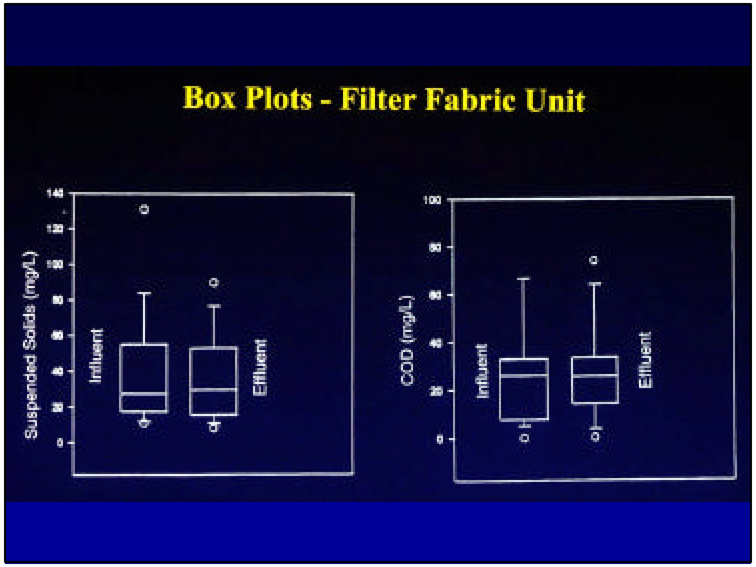
Typical German Inlet Strainer Basket

Coarse Screen Tested at Ocean County, NJ



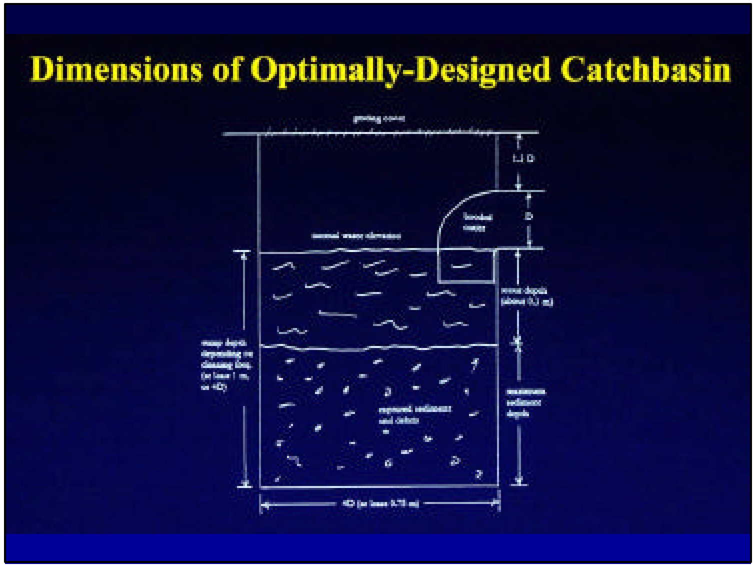
Box Plots - Coarse Screen Unit

Filter Fabric Inlet Insert Tested at Ocean County, NJ

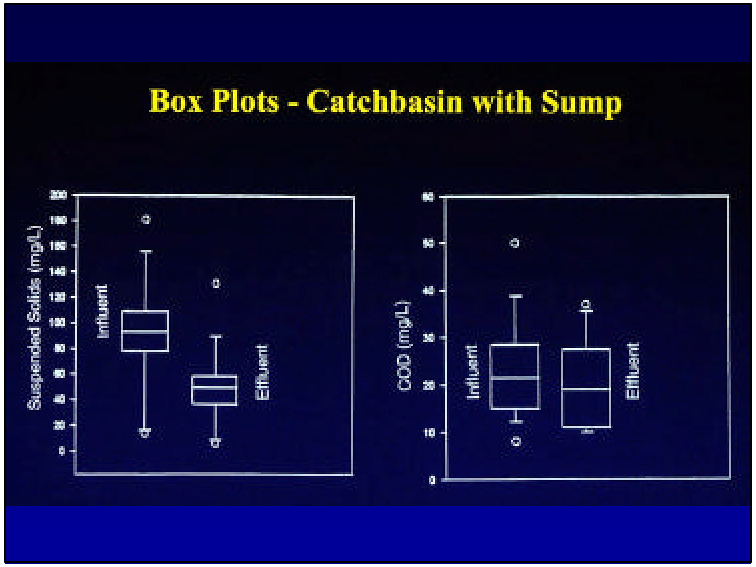


Box Plots - Filter Fabric Unit

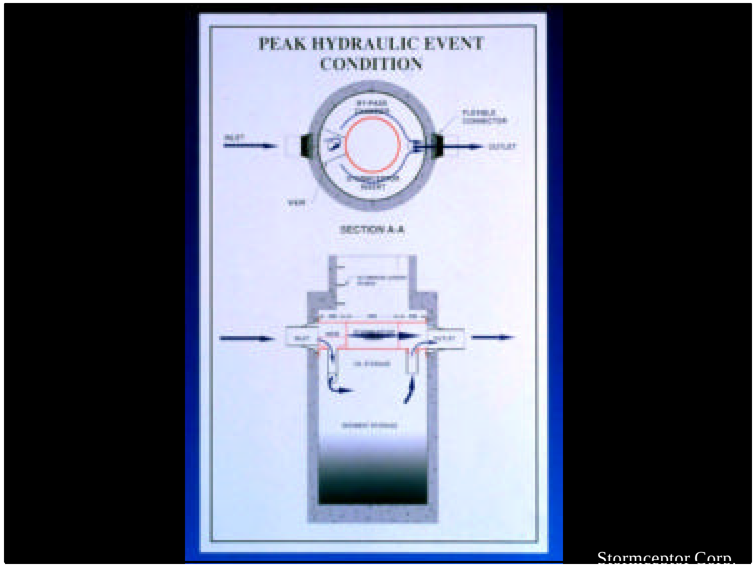
Retro-fitted Catchbasin with Sump Tested at Ocean County, NJ



Dimensions of Optimally-Designed Catchbasin

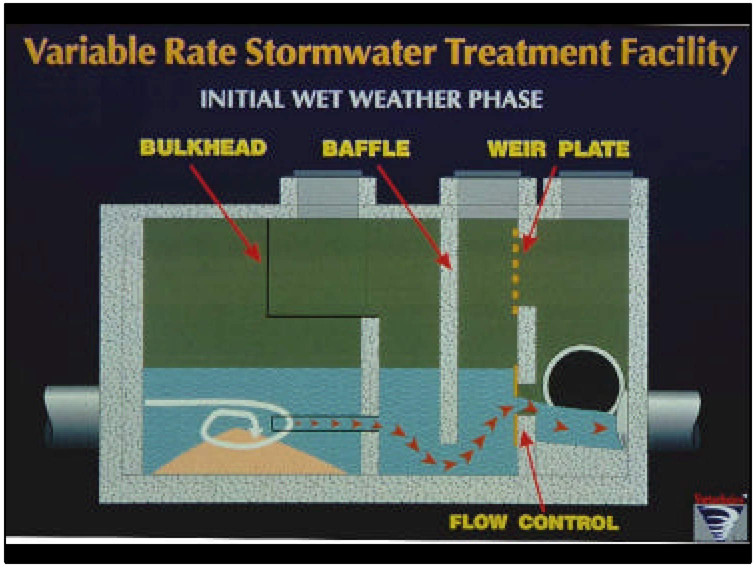


Box Plots - Catchbasin with Sump



Stormceptor Corp.

USGS and WI DNR Monitoring Facility for Stormceptor Tests, Madison, WI



Variable Rate Stormwater Treatment Facility

INITIAL WET WEATHER PHASE

Sedimentation

- Dry detention ponds
- Wet detention ponds
- Wetlands

Wet Basins

Caltrans, San Diego, California

Extended Detention Ponds

Caltrans, San Diego and Los Angeles, California

Wet Detention Pond Advantages

- Very good control of particulate pollutants
- Opportunity to utilize biological processes
  - Protozoa as bacteria predators
  - Aquatic plants enable higher levels of nutrient removal
- Outfall ponds capture and treat all storm sewer discharges
  - Wet weather stormwater runoff
  - Dry weather baseflows
  - Snowmelt
  - Industrial spills
  - Illegal discharges

Typical Dry Detention Pond, with Pilot Channel

Unusual Dry Detention Pond Located on Hillside to Meet Peak Flow Rate Criterion

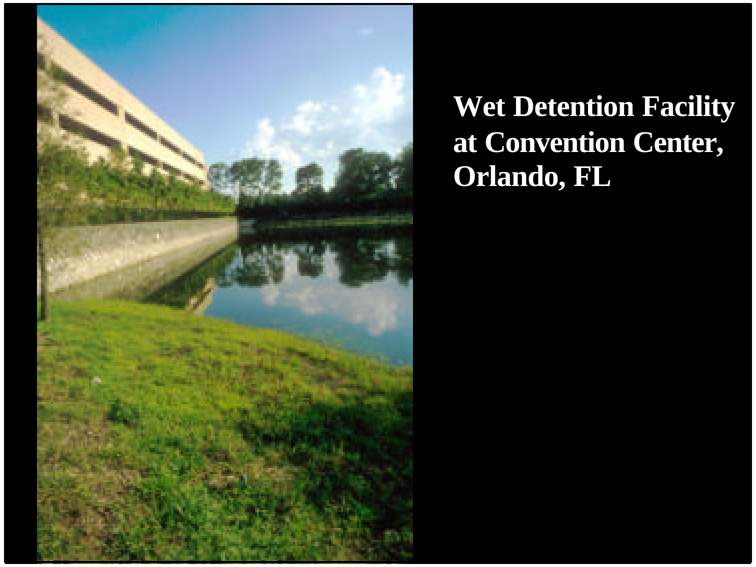
Dry Detention Pond Forebay for Stormwater Pump Station, Los Angeles, CA

Scour and Sediment Transport in Dry Detention Ponds

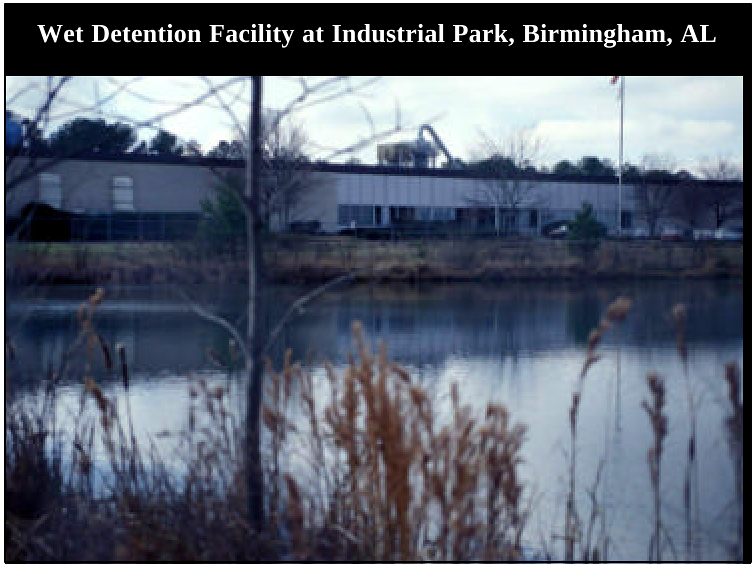
Large Corrugated Pipes used for Underground Detention Below Parking Area

Wet Detention Facility at Shopping Center, Birmingham, AL

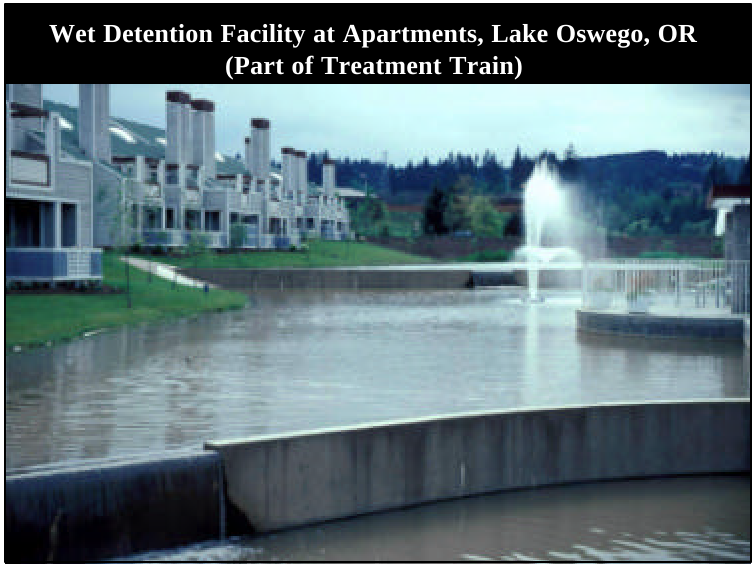
Wet Detention Facility at Shopping Center, Dayton, OH



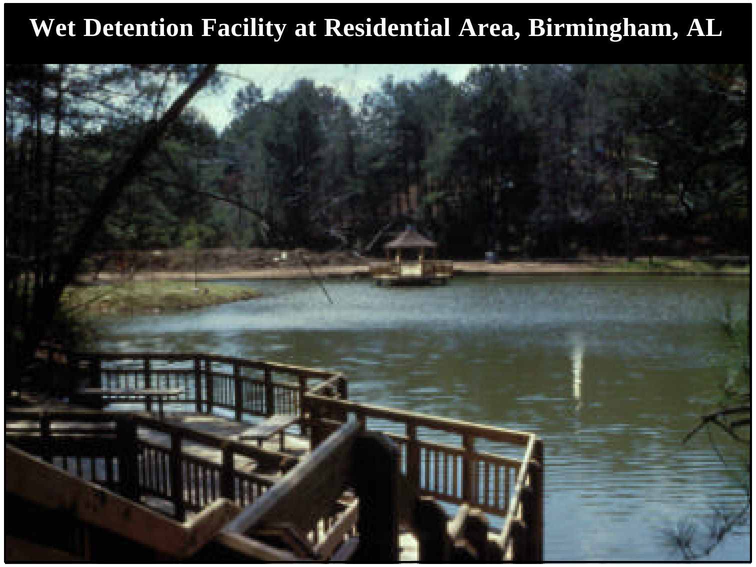
Wet Detention Facility at Convention Center, Orlando, FL



Wet Detention Facility at Industrial Park, Birmingham, AL



Wet Detention Facility at Apartments, Lake Oswego, OR (Part of Treatment Train)



Wet Detention Facility at Residential Area, Birmingham, AL

Advertising for New Wet Ponds, Austin, TX

Wetlands for Stormwater Control

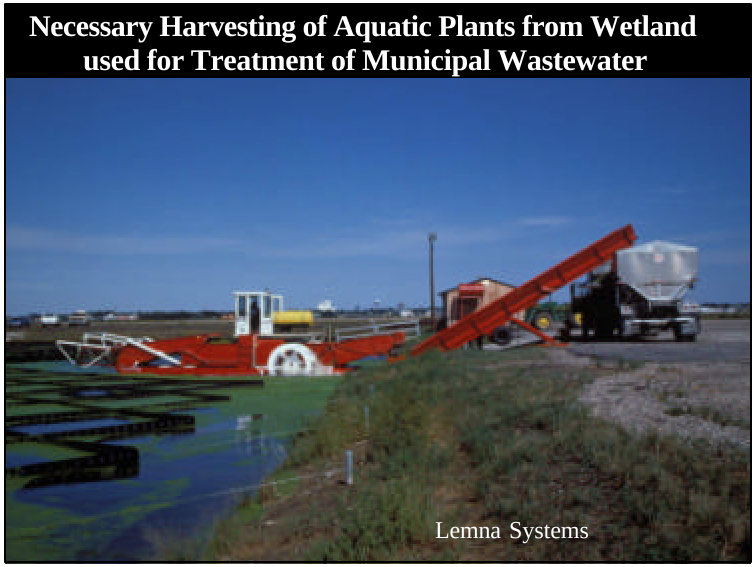
Wetlands in Malmo, Sweden (under construction and mature)

Inlet for Wetland in Malmo. Sweden for Treatment of CSOs and Stormwater

Mature Wetlands and Wet Detention Pond Facility, Malmo, Sweden

New Wetlands being Planted by Volunteers, Malmo, Sweden

New Wetlands being Planted by Volunteers, Malmo, Sweden



Necessary Harvesting of Aquatic Plants from Wetland used for Treatment of Municipal Wastewater

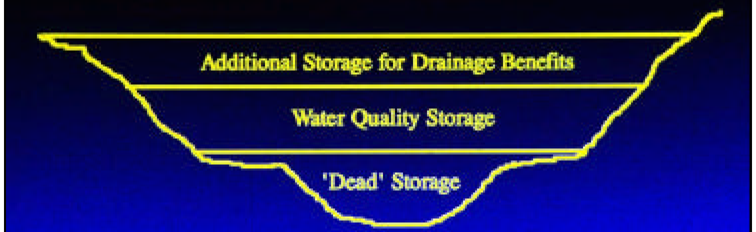
Lemna Systems

Observed Wet Pond Performance (when constructed and operated according to best guidance)

- Suspended solids: 70 to 95%
- COD: 60 to 70%
- BOD_5: 35 to 70%
- Total Kjeldahl nitrogen: 25 to 60%
- Total phosphorus: 35 to 85%
- Bacteria: 50 to 95%
- Copper: 60 to 95%
- Lead: 60 to 95%
- Zinc: 60 to 95%

Wet Pond Design Criteria for Water Quality

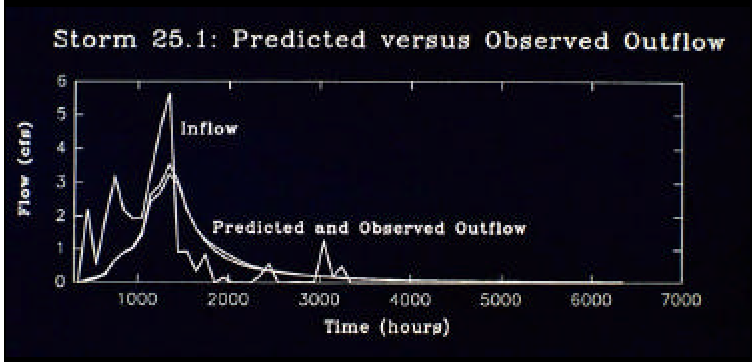
- Surface area should have a minimum area based on land use and desired pollutant control
- Pond freeboard storage equal to runoff associated with 1.25 inches of rain for the land use and development
- Select outlet device to obtain desired pollutant control for all pond stages
- Incorporate special features for harsh winters and snowmelt loads, if needed



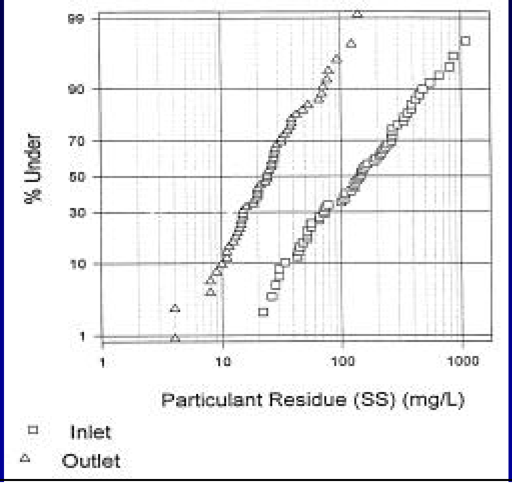
MUST PROVIDE EMERGENCY SPILLWAY

Pond Area as a Percentage of Drainage Area

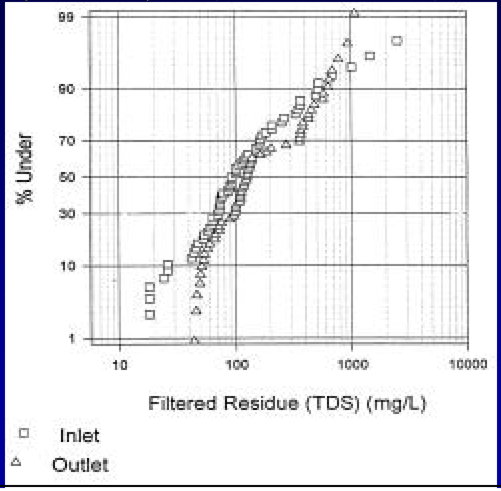
	5 micrometer	20 micrometer
Totally paved	2.8	1.0
Industrial	2.0	0.8
Commercial	1.7	0.6
Institutional	1.7	0.6
Residential	0.8	0.3
Open space	0.6	0.2
Construction	1.5	0.5



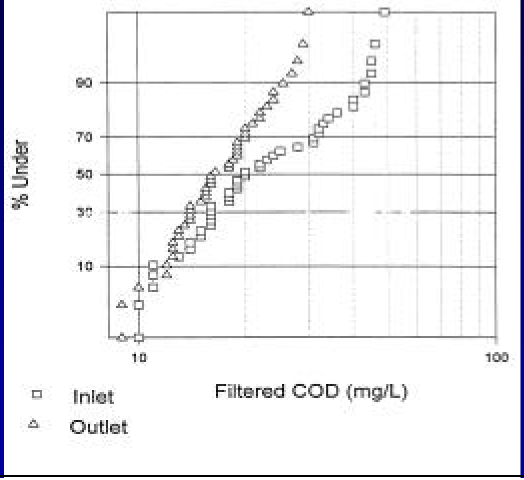
Suspended Solids Control at Monroe St. Detention Pond, Madison, WI (USGS and WI DNR data)



Total Dissolved Solids Control at Monroe St. Detention Pond, Madison, WI (USGS and WI DNR data)

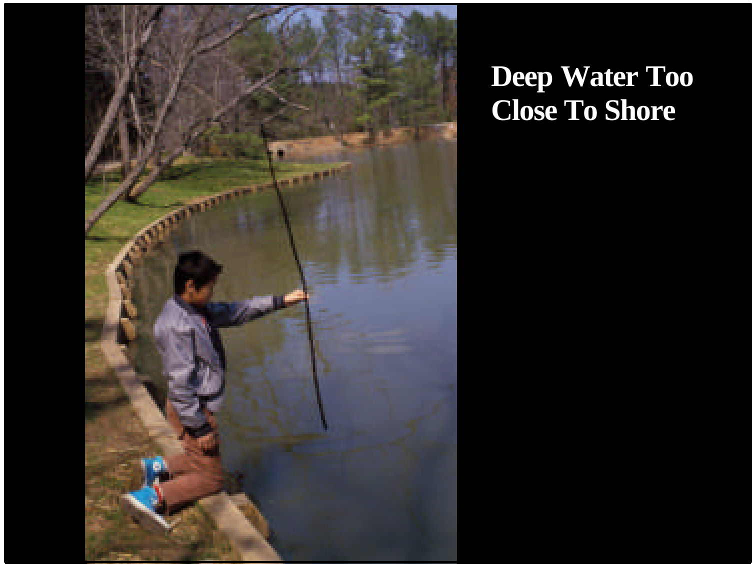


COD Control at Monroe St. Detention Pond, Madison, WI (USGS and WI DNR data)



Pond Problems

- Safety
- Nuisance conditions
- Maintenance
- Poorly known site conditions
- Critters



Deep Water Too Close To Shore

Thin Ice Near Shore

Steve Auger photo

Children are Attracted to Urban Waters

Wisconsin DNR

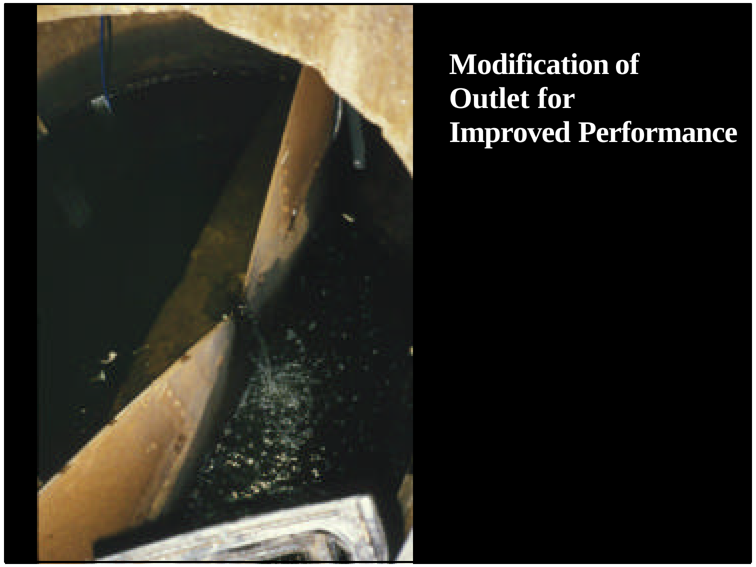
Frequent Maintenance and Adjustments to Outlets may be Needed

Wet Ponds Located in Areas of Karst Geology may have Sinkholes

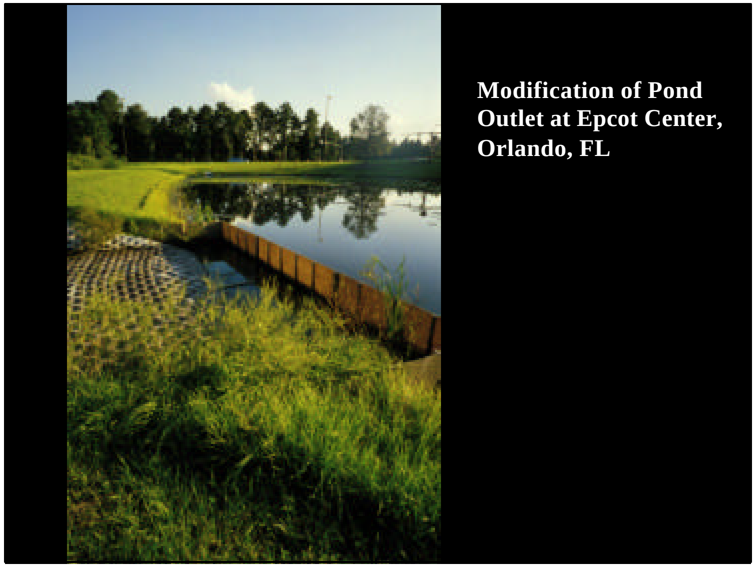
Bob Kort photo

Existing Ponds can be Modified for Improved Performance

- Change outlet device
- Reshape pond
- Add extra effluent controls
- Add internal berms to prevent short-circuiting

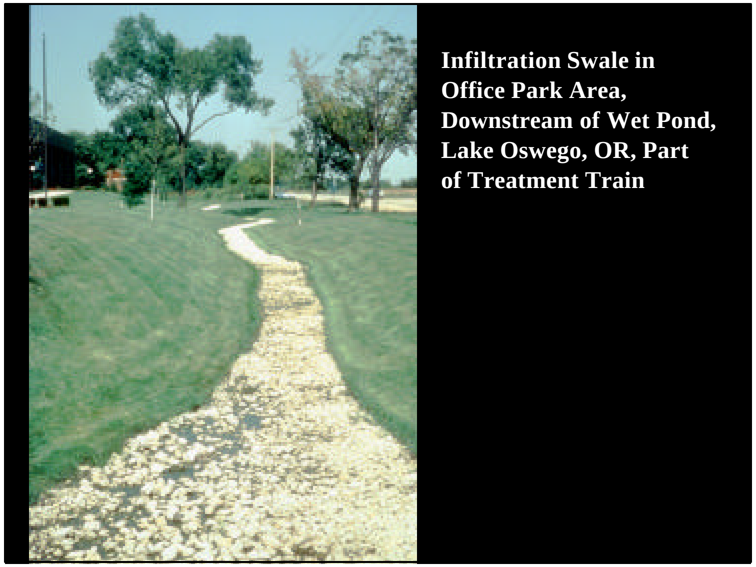


Modification of Outlet for Improved Performance



Modification of Pond Outlet at Epcot Center, Orlando, FL

Re-building Pond (Re-shaping and Dredging), Moscow, Russia



Infiltration Swale in Office Park Area, Downstream of Wet Pond, Lake Oswego, OR, Part of Treatment Train

Berm Located in Pond to Minimize Short-Circuiting, Gulfport, MS

Design Suggestions to Enhance Pollutant Control and to Minimize Problems

Composite list from literature and experience

- Locate and size ponds to minimize hydraulic interferences.
- Keep pond shape simple to minimize short-circuiting.
- Slope ground leading to pond between 5 and 25%.
- Use shallow perimeter shelf as a safety ledge.
- Plant dense emergent vegetation on shelf.
- Plant thick vegetation barrier around pond perimeter.
- Provide at least 3 ft. of permanent pool depth for scour protection.
- Provide at least 2 more feet as sacrificial storage.

Design Suggestions (cont.)

- Use sub-surface outlets to minimize clogging and to retain floatables.
- Discourage water contact recreation and consumptive fishing.
- Stock mosquito eating fish.
- Minimize water level fluctuations to reduce mosquito problems.
- Place rocks at inlet and outlet areas to minimize scour.
- Use anti-seep collars around outlet pipes to minimize piping.
- Provide trash and safety racks, plus baffles on outlets.
- Provide emergency spillway.

Use of Sedimentation in Conjunction with other Controls

- Sedimentation is a common pre-treatment option for filtration and chemical treatment
- Sedimentation can better handle large flows and serves to protect downstream more “fragile” devices, such as wetlands or infiltration areas.

Wet Pond after Oil and Grease Trap and Step Aerator, Austin, TX

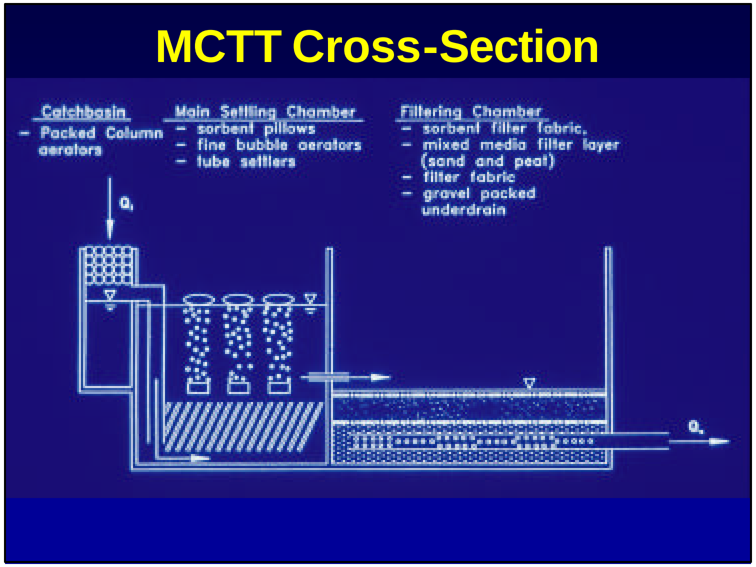
Settling Pond after Alum Injection, Orlando, FL

Dry Pond to Equalize Flows before Sand Filter, Austin, TX

Equalizing Dry Pond to Control SSO Problems, Moody, AL

Multi-Chambered Treatment Trains (MCTT)

Caltrans, Los Angeles, California

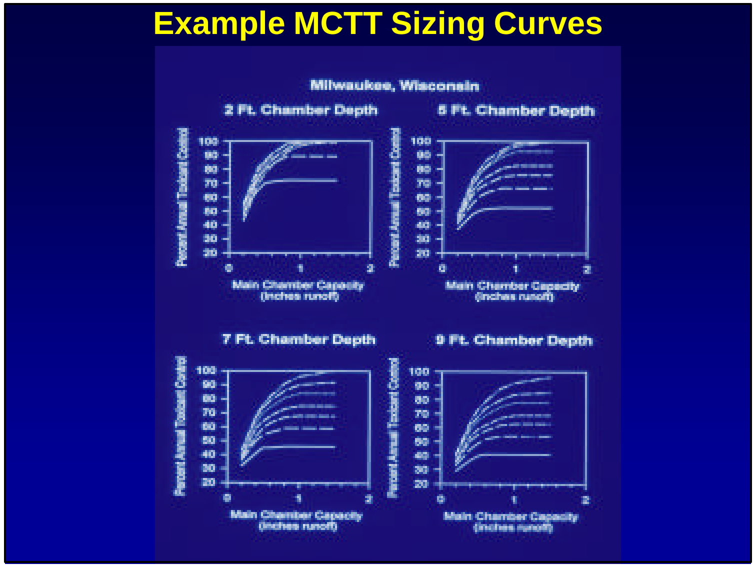


MCTT Cross-Section

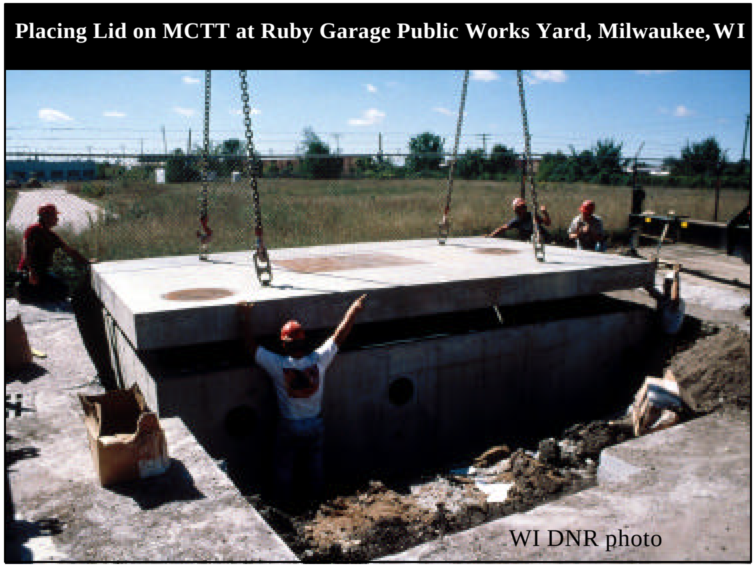
Catchbasin
- Packed Column aerators

Main Settling Chamber
- sorbent pillows
- fine bubble aerators
- tube settlers

Filtering Chamber
- sorbent filter fabric,
- mixed media filter layer (sand and peat)
- filter fabric
- gravel packed underdrain



Example MCTT Sizing Curves



Placing Lid on MCTT at Ruby Garage Public Works Yard, Milwaukee, WI

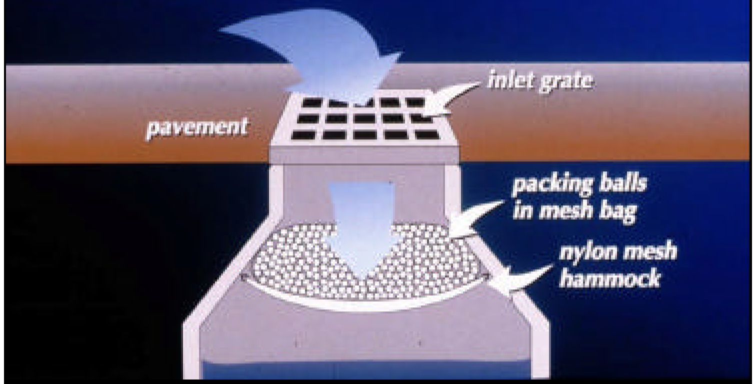
WI DNR photo

Backfilling MCTT at Minocqua, WI

WI DNR photo

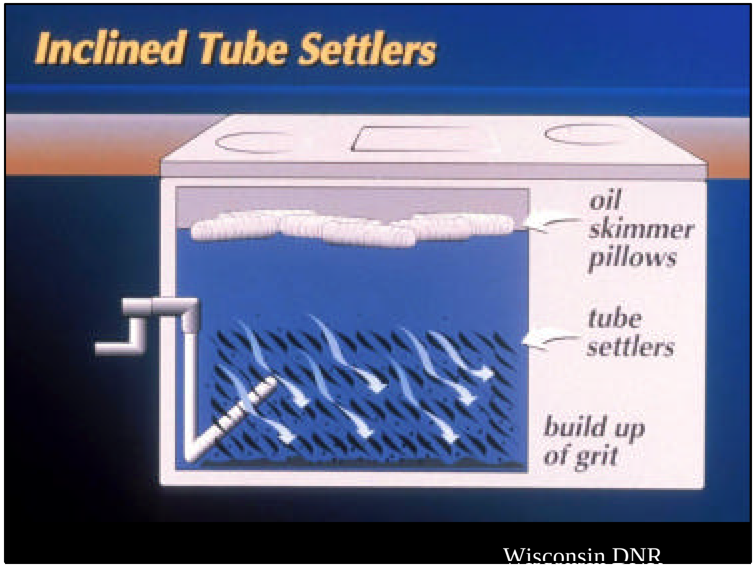
MCTT Filter Chamber at Park and Ride Facility, Los Angeles, CA

Packing Balls



Wisconsin DNR

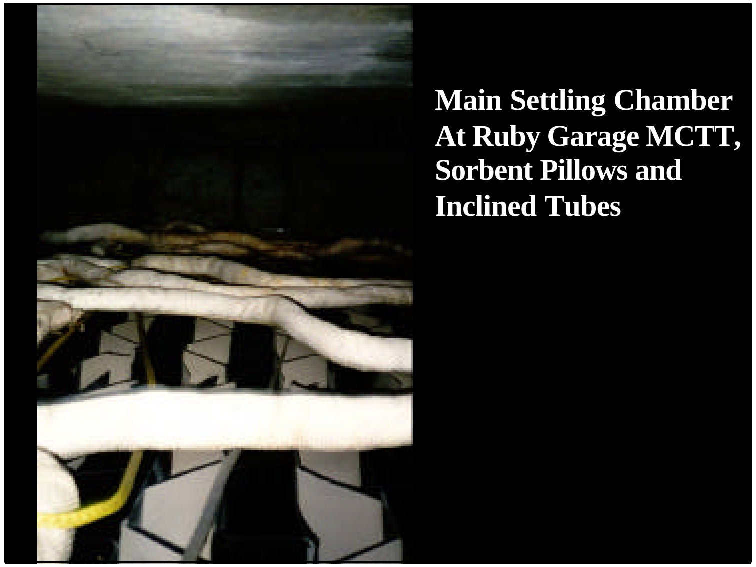
Inlet Chamber for MCTT at Ruby Garage Public Works Yard, Milwaukee, WI



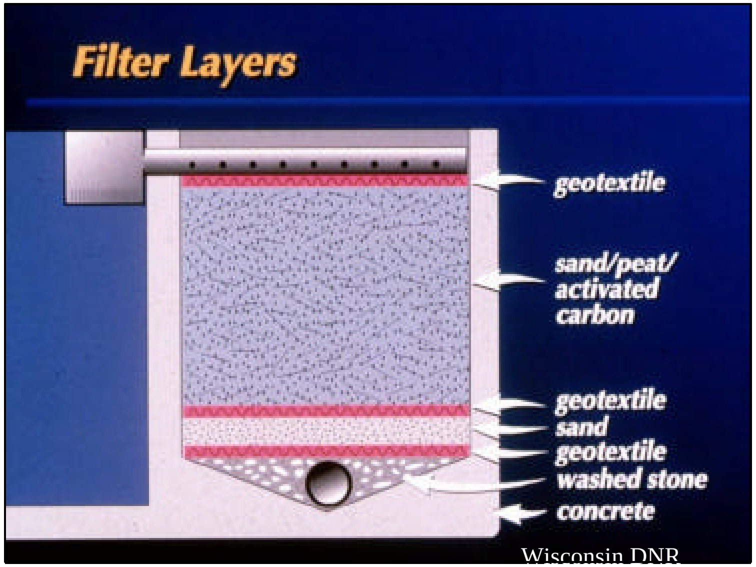
Inclined Tube Settlers

Wisconsin DNR

MCTT Main Settling Chamber at Minocqua, WI



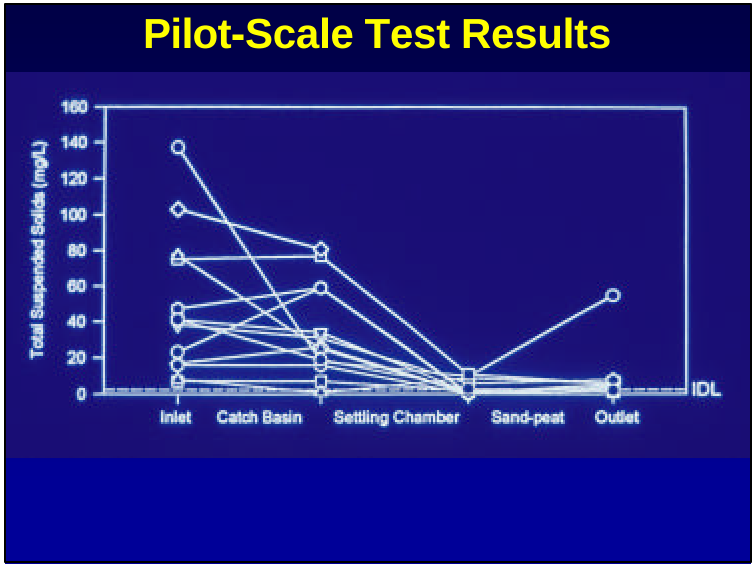
Main Settling Chamber At Ruby Garage MCTT, Sorbent Pillows and Inclined Tubes



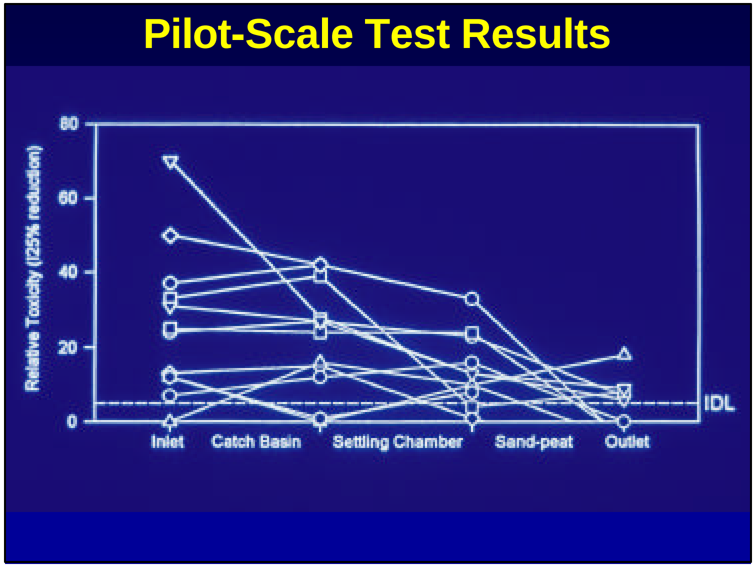
Filter Layers

Wisconsin DNR

MCTT Filter Chamber
At Ruby Garage,
Showing
Filter Fabric for Flow
Distribution and Ballast



Pilot-Scale Test Results



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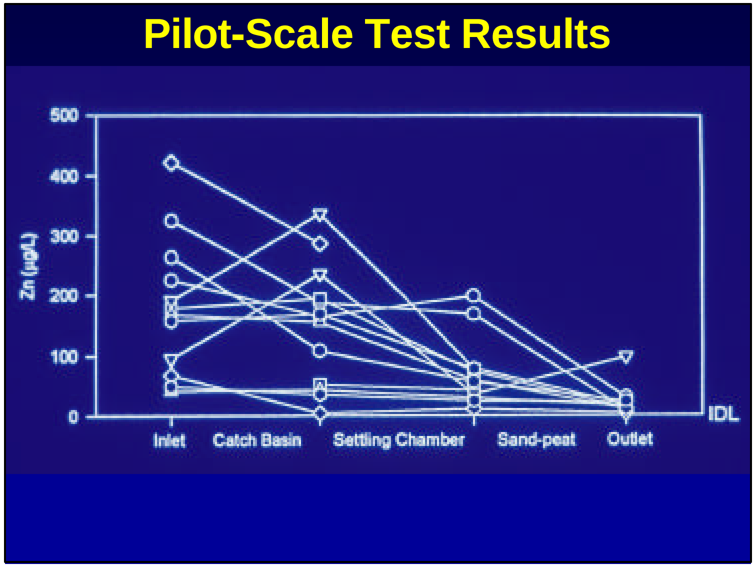

Pilot-Scale Test Results

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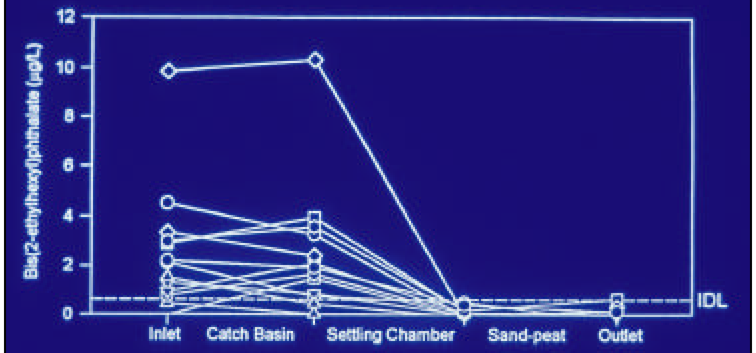


Wisconsin Full-Scale MCTT Test Results

(median % reductions and median effluent quality)	Milwaukee (15 events)	Minocqua (7 events)
Suspended Solids	98 (<5 mg/L)	85 (10 mg/L)
Phosphorus	88 (0.02 mg/L)	>80 (<0.1 mg/L)
Copper	90 (3 µg/L)	65 (15 µg/L)
Lead	96 (1.8 µg/L)	nd (<3 µg/L)
Zinc	91 (<20 µg/L)	90 (15 µg/L)
Benzo (b) fluoranthene	>95 (<0.1 µg/L)	>75 <0.1 µg/L)
Phenanthrene	99 (<0.05 µg/L)	>65 (<0.2 µg/L)
Pyrene	98 (<0.05 µg/L)	>75 (<0.2 µg/L)

Caltrans Full-Scale MCTT Test Results

	Mean % reductions and mean effluent quality
Suspended solids	80 (6 mg/L)
TKN	35 (0.82 mg/L)
Total Phosphorus	39 (0.11 mg/L)
Copper	38 (5 µg/L)
Lead	50 (3 µg/L)
Zinc	85 (13 µg/L)
Total petroleum hydrocarbons	85 (210 µg/L)
Fecal coliforms	82 (171 MPN/100 mL)

Controls During Development (“Low Impact Development”)

- Minimize pavement area and disconnect roof/paved area drainage
- Use porous pavement for temporary access roads and overflow parking
- Use grass roadside drainage
- Use non-pollution building materials
- Minimize stream disturbance
- Provide substantial stream buffers and allow large organic debris accumulations in streams

Construction Site Erosion Control

- Diversion of upslope drainage away from disturbed area
- Protect on-site disturbed areas if long delays
- Downslope controls
- Good housekeeping practices

Filter Fabric at Construction Site Showing Maximum Water Depth

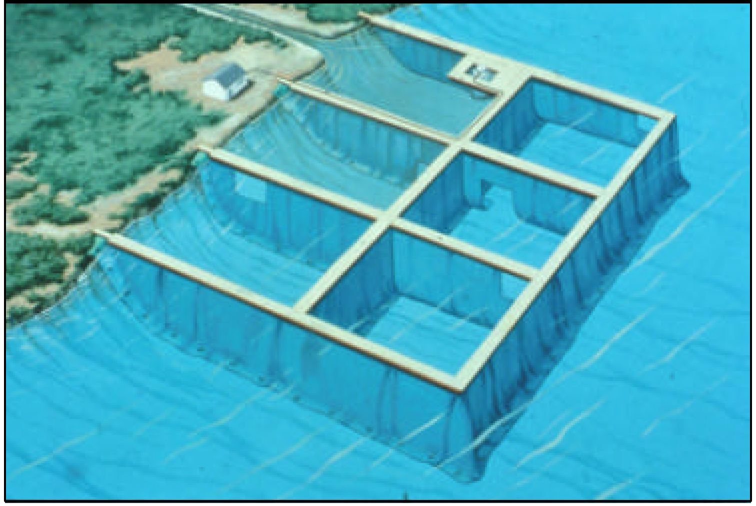
Filter Fabric at Construction Site Showing Maximum Water Depth

Small Wet Pond At Construction Site With Perforated Riser

Flow-Balancing Method (FBM)

- Developed by Karl Dunkers, Taby, Sweden
- Sedimentation facility placed directly in water.
- Usually for pumpback systems to treatment facilities

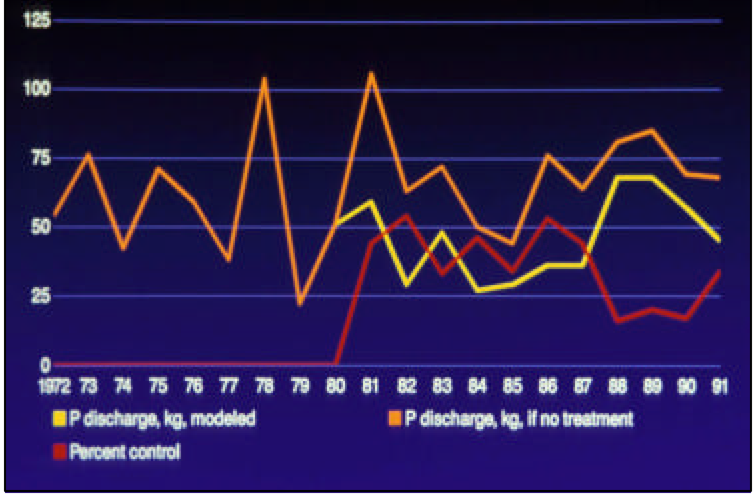
Drawing of FBM in Place (Karl Dunker, Taby, Sweden)



FBM Chamber at Lake Ronningesjon, Taby Sweden (Karl Dunker)

Ferric Chloride Treatment Unit at Lake Ronningesjon, Taby Sweden (Karl Dunker)

Lake Phosphorus Discharge Trends



Percolation Ponds

- Can incorporate sedimentation with infiltration
- Usually in areas of shallow groundwater
- Concern about possible groundwater contamination, especially in industrial areas

Watertable Percolation Pond, Berlin, Germany

Watertable Percolation Pond, Madison, WI

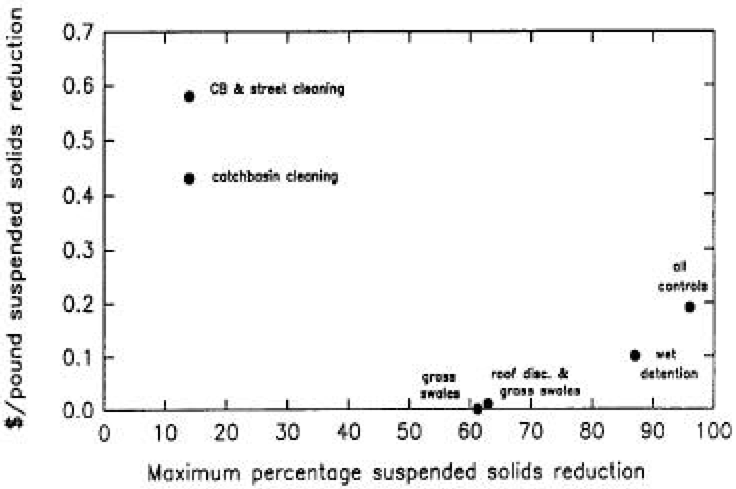
Special Stormwater Control Considerations in Areas having Harsh Winters

- Snowmelt can contribute the majority of the annual pollutant loads from urban areas
- Summer runoff is typically only considered in the design of stormwater controls
- Cold weather hinders all stormwater control processes (such as infiltration, settling, and plant uptake)
- Deicing salts are a special threat to urban groundwater quality

Stormwater Design Considerations for Cold Climates

- “Oversize” wet ponds to accommodate reduced settling rates (can be one-half of the summer rates)
- Protect sediment from scour during snowmelt
- “Oversize” infiltration areas due to reduced soil infiltration rates, but substantial infiltration does occur under snowpacks during long winters
- Divert snowmelt from infiltration areas
- Do not rely on wetlands and other controls utilizing plants during long dormant season
- Follow good snow removal practices
- Reduce the use of deicing salts
- Prevention is especially important in design of land development

Cost-Benefit Analysis for Various Stormwater Controls, SLAMM



Appropriate Combinations of Controls

- No single control is adequate for all problems
- Only infiltration reduces water flows, along with soluble and particulate pollutants. Only applicable in conditions having minimal groundwater contamination potential.
- Wet detention ponds reduce particulate pollutants and may help control dry weather flows. They do not consistently reduce concentrations of soluble pollutants, nor do they generally solve regional drainage and flooding problems.
- A combination of biofiltration and sedimentation practices is usually needed, at both critical source areas and at critical outfalls.

Conclusions – relative effectiveness of controls

	Cost	**Effectiveness**
Inappropriate discharge	**Low**	**High**
Erosion control	**Low to mod.**	**Low to moderate**
Floatable and litter control	**Low to mod.**	**Low to high**
Oil&water separators	**Moderate**	**Very low**
Critical source control	**High**	**Low to high**
Low impact development	**Low to mod.**	**Moderate to high**
Public education	**Low to mod.**	**?????**