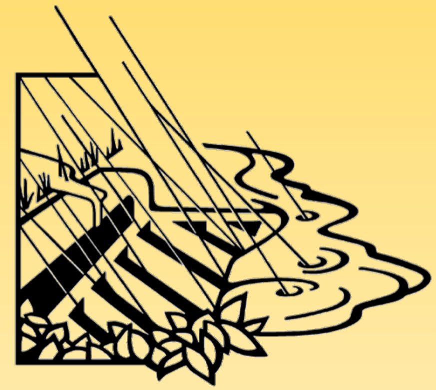
Treatment of Dissolved Compounds and BMP Costs

John S. Gulliver, Professor
Department of Civil Engineering
February 17, 2012
MIDS review



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Outline

- Urban Runoff Research at the U of MN
- Mitigation of Water Quality Impacts
- Dissolved Pollutants
- Dissolved Phosphorus Removal
- Applications of Dissolved Phosphorus Removal
- BMP Maintenance Costs
- Conclusions

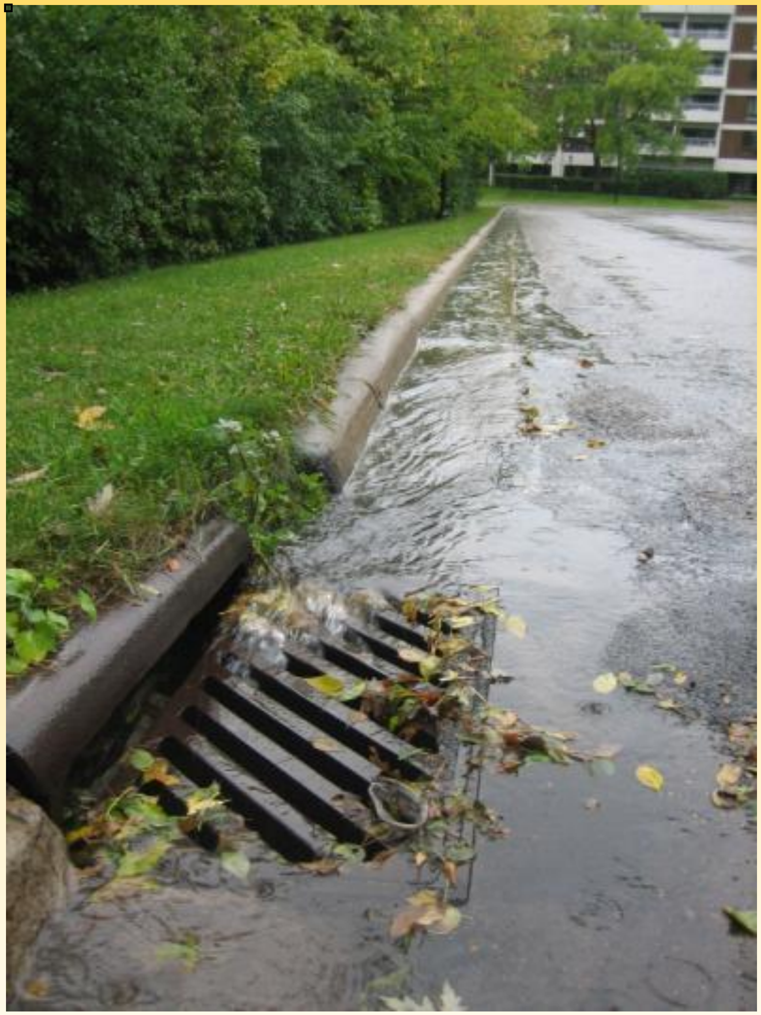
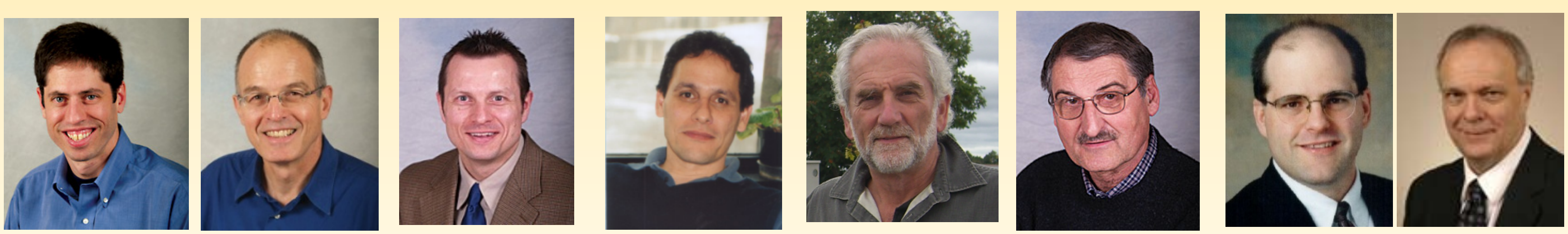


Photo Courtesy: A. Erickson

What are we doing about Urban Runoff at the U of MN?

- Education
  - Hydrologic Design, Capstone Design, Urban Hydrology and Land Development, Watershed Engineering, Hydrologic modeling of small watersheds, Ecological Engineering Design
  - ~27 MS/PhD Degrees, 21 current Graduate Students and 25 current and past Undergraduate Students on research
- Co-investigators
- Bill Arnold, John Gulliver, Raymond Hozalski, Omid Mohseni, John Nieber, Heinz Stefan, Pete Weiss, Bruce Wilson



  - Funding from MPCA, LRRB, MN/DOT, Met Council, MWMO/ MCWD, City of Prior Lake, RWMWD

Research in Urban Runoff
(selected list)

- Develop new treatment practices
  - Minnesota Filter
  - SAFL Baffle
- Assessment techniques for stormwater treatment
- Trout stream temperature prediction and stormwater remediation
- Salt impacts in runoff
- Particle size distribution in runoff
- Maintenance practice and costs
- Erosion from construction sites
- Cost and effectiveness of treatment practices
- Infiltration and GW-surface water interaction

How do we mitigate WQ impacts?

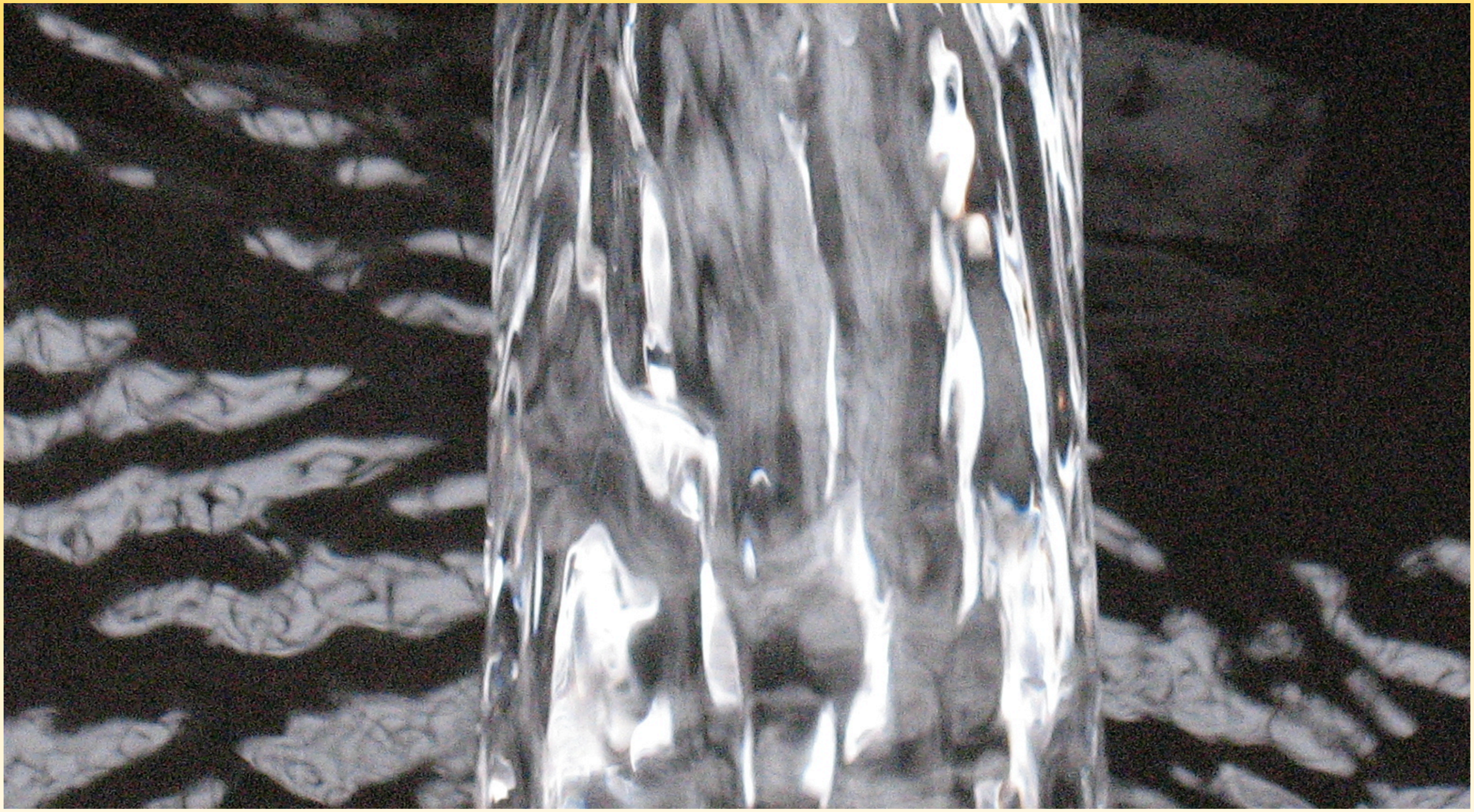
- Underground separators- Settle particles
- Wet ponds – Settle particles
- Dry ponds – Settle particles
- Constructed wetlands – Settle particles
- Filters – Filter particles

Low Impact Development Practices:

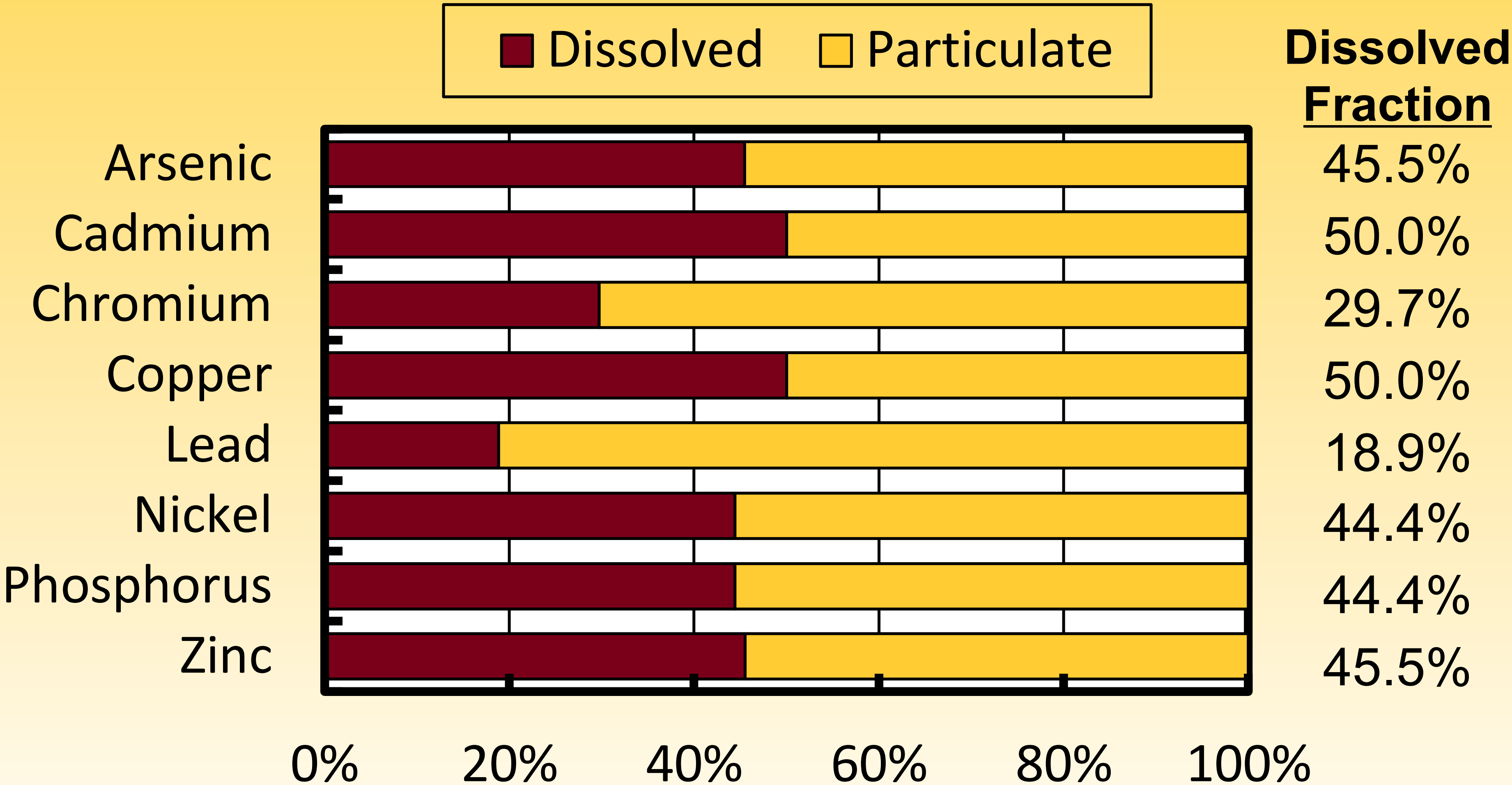
- Rain gardens – Settle and filter particles and infiltrate
- Infiltration basins - Settle and filter particles and infiltrate
- Swales - Settle and filter particles and infiltrate
- Green roofs- Minor water quality mitigation
- Source reduction- Full water quality mitigation

Dissolved Pollutants

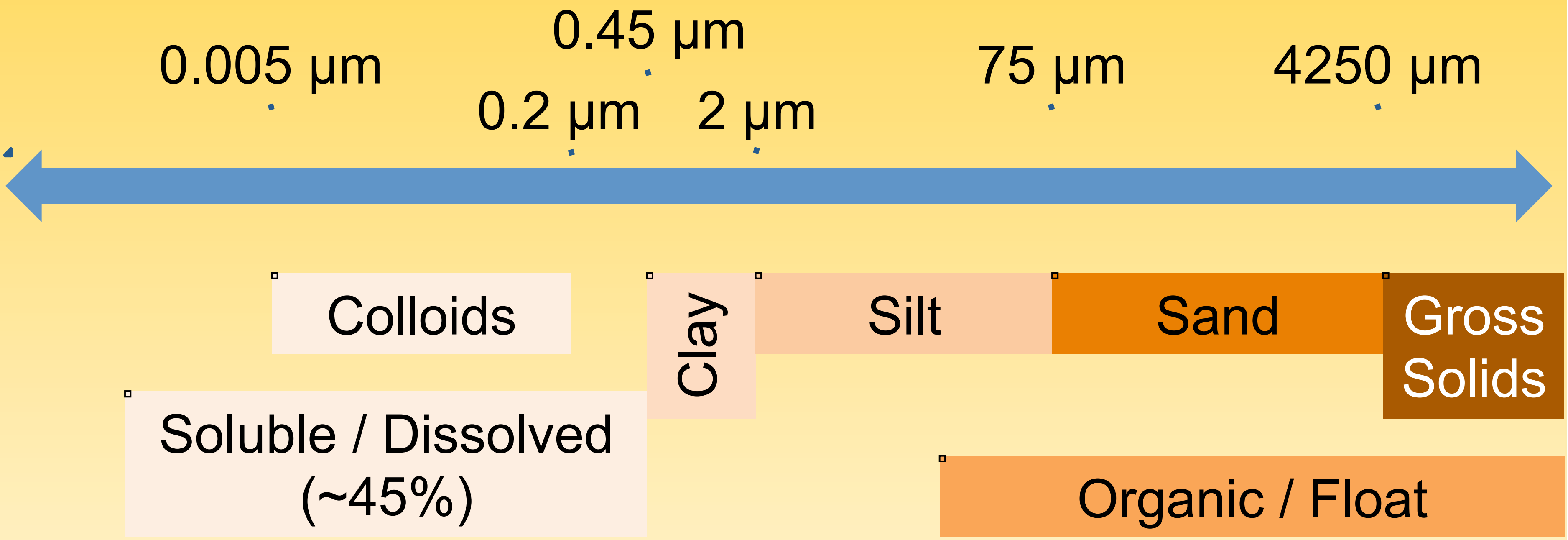
Dissolved Pollutants



Nationwide Data (Pitt et al., 2005)

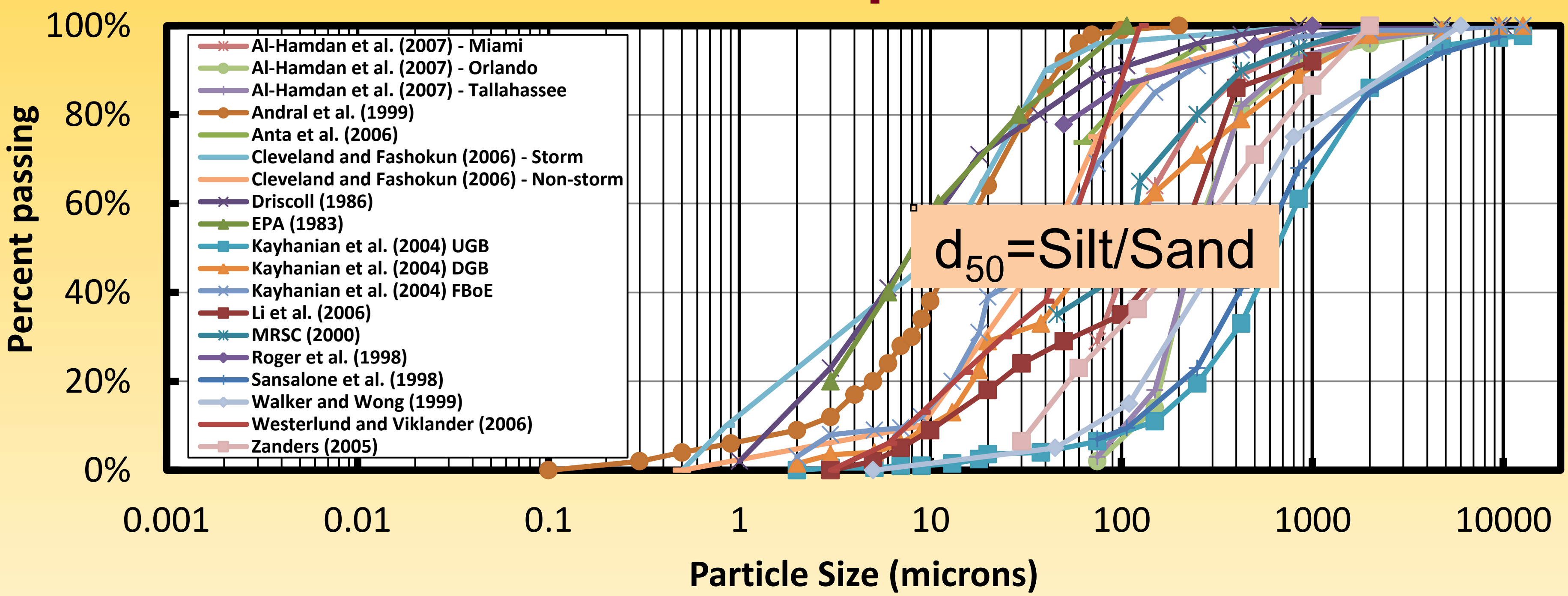


Pollutant Spectrum



- Varies by:
  - Pollutant
  - Location in management system

Pollutant Spectrum



Colloids

Clay

Silt

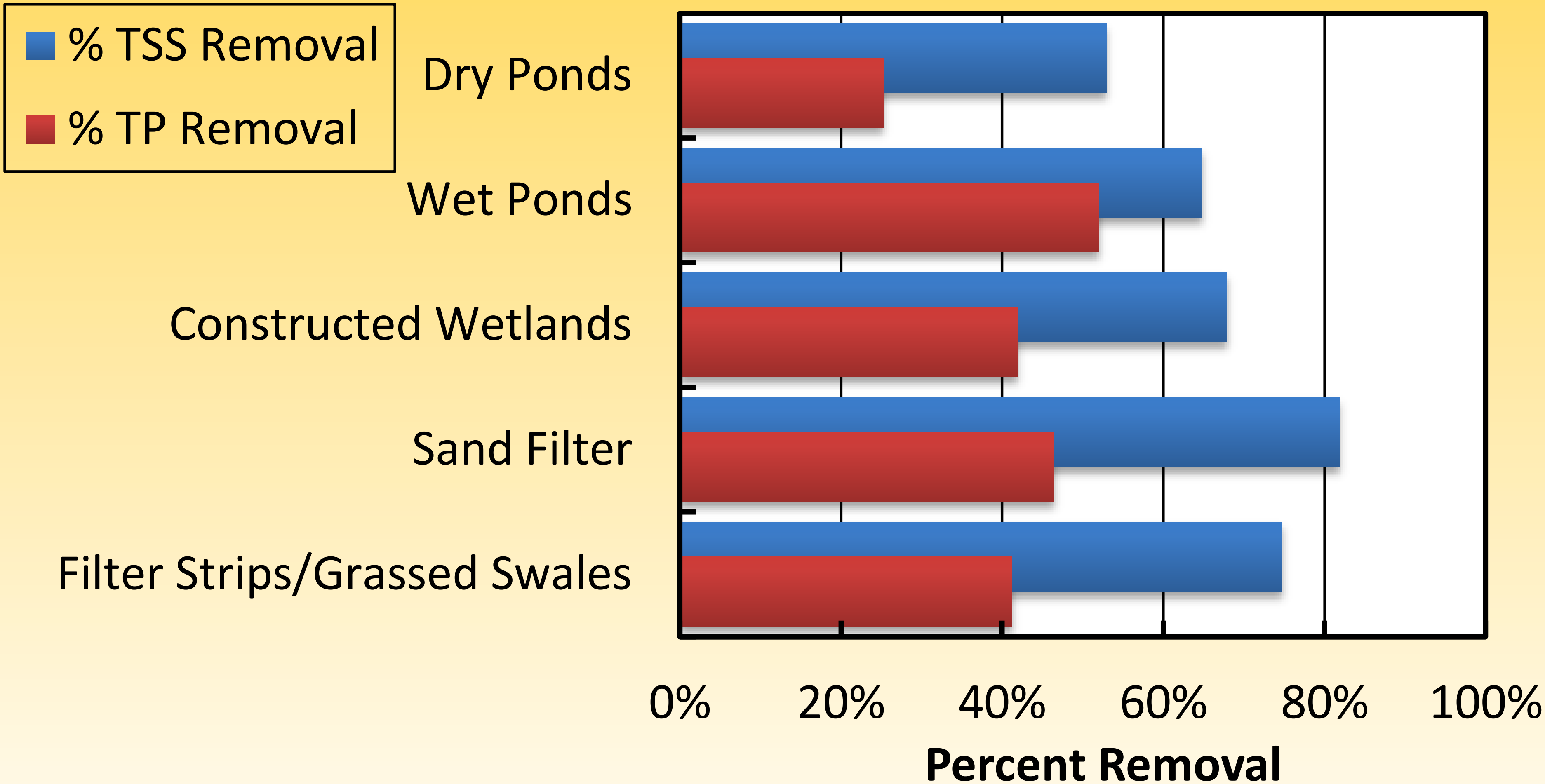
Sand

Gross Solids

Soluble / Dissolved (~45%)

Organic / Float

Current Treatment Practices

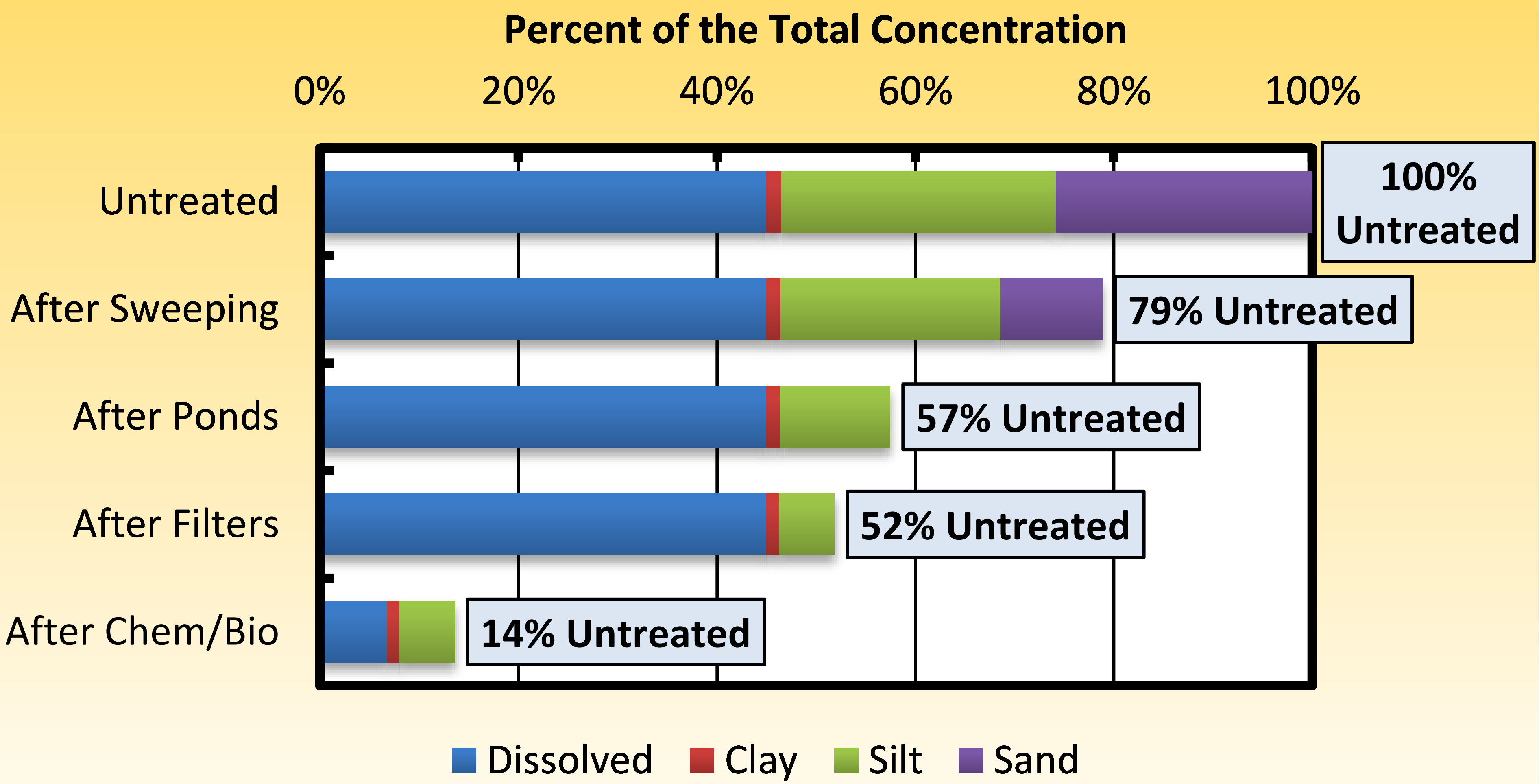


Source (adapted from): P.T. Weiss, A.J. Erickson and J.S. Gulliver. 2007. "Cost and pollutant removal of storm-water treatment practices," Journal of Water Resources Planning and Management,133(3),218-229, 2007.

Rationale

- Most urban watersheds need:
  - 80+% capture of solids ***and*** pollutants, including dissolved component
- We are currently treating for about half of the pollutants, without dissolved component.
- Precipitation, adsorption and ion exchange are three unit processes that have not been used much.

Treatment Train

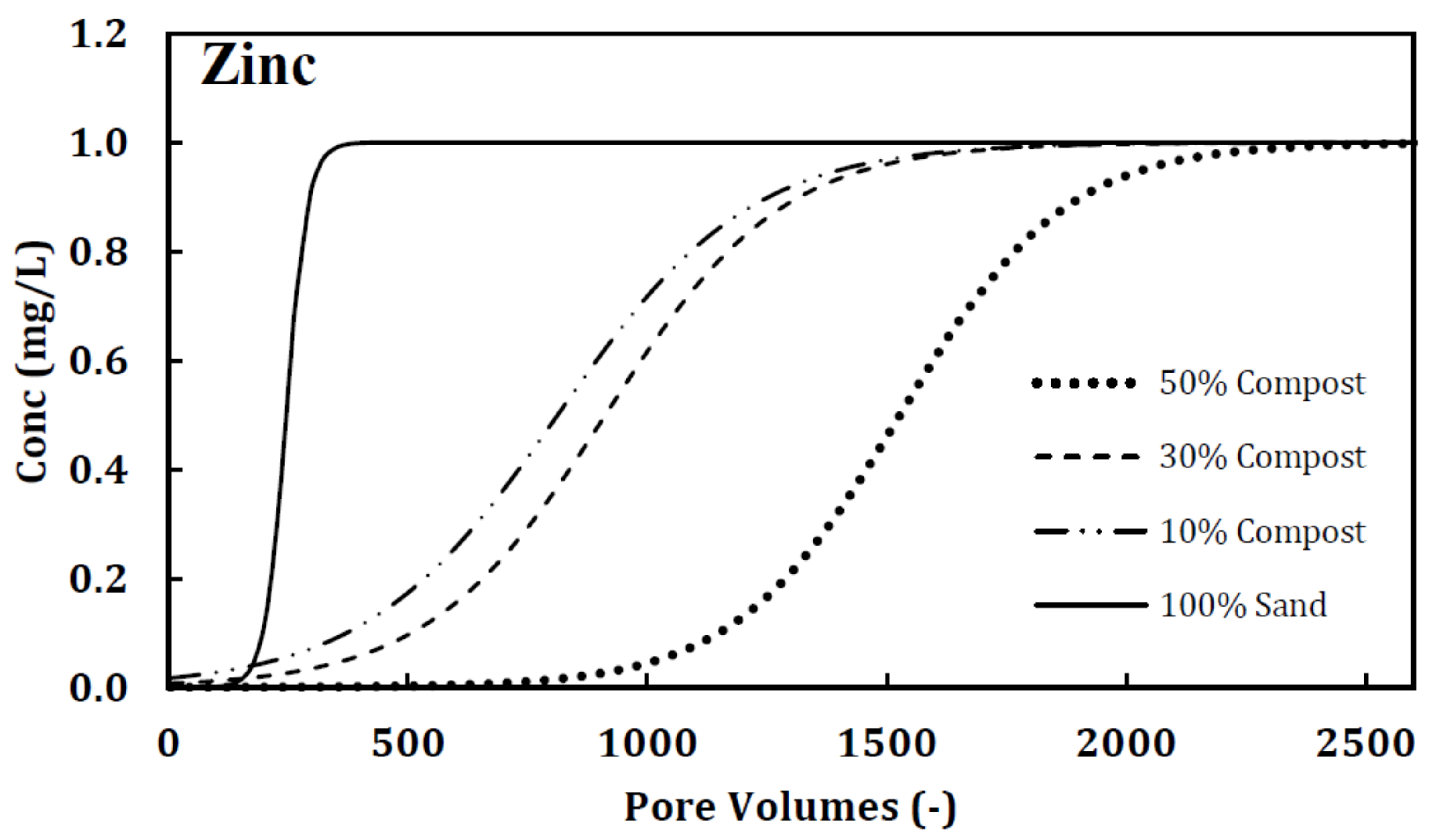


NOTE: Estimated Values.

Dissolved Pollutant Removal Processes

- **Sorption**: surface sorption or complexation to capture dissolved pollutants
- **Biodegradation**: bacteria conversion of nitrates to nitrogen gas or petroleum hydrocarbons to carbon dioxide
- **Vegetative processes**: plant uptake and rhizospheric activity (microbes, etc.) that use and convert dissolved pollutants

Metals sorption to Compost



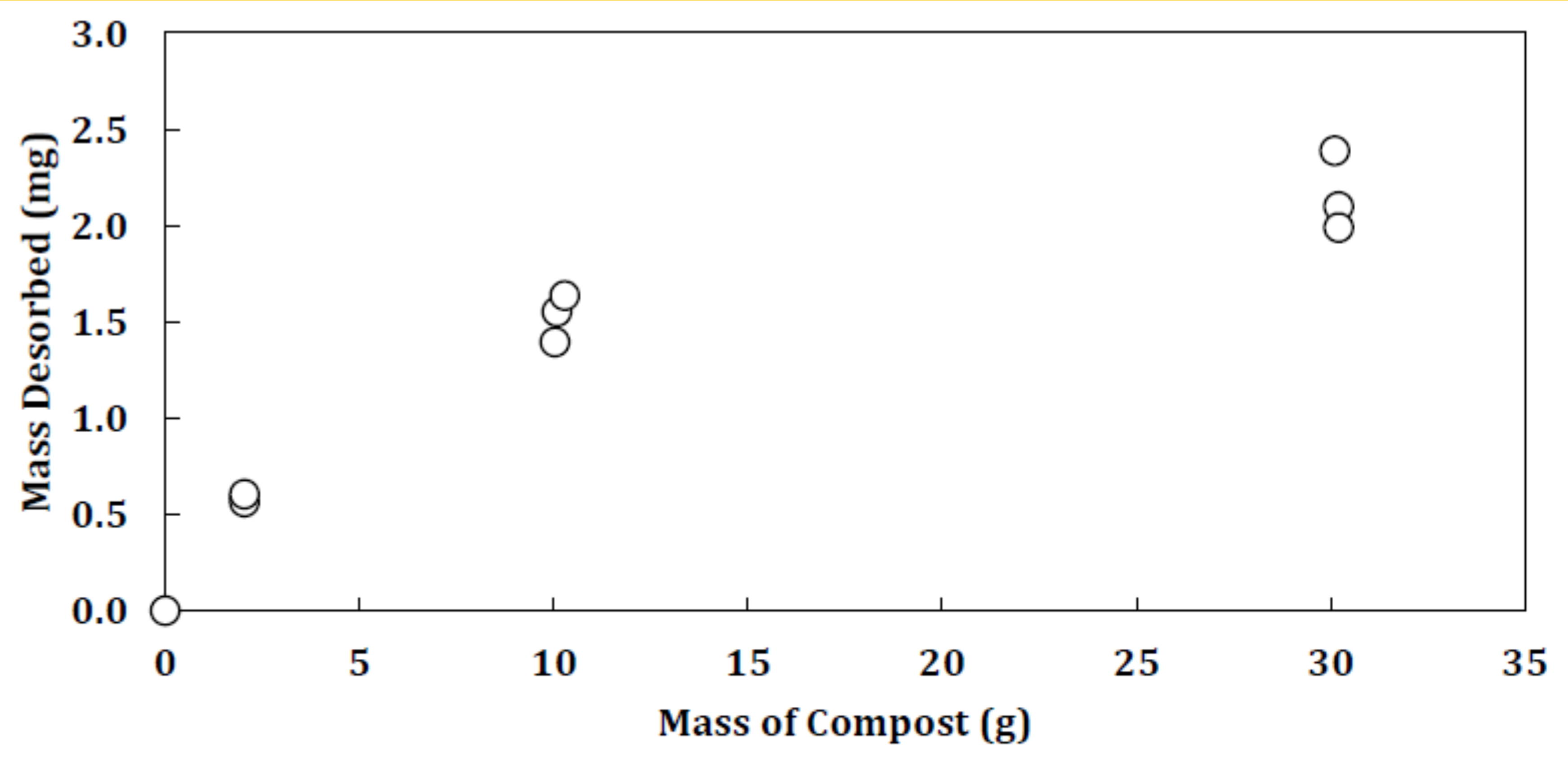
Source: Morgan, J. G., Paus, K. A., Hozalski, R. M., and Gulliver , J. S. (2011). "Sorption and Release of Dissolved Pollutants Via Bioretention Media." Project Report 559. St. Anthony Falls Laboratory, University of Minnesota, Minneapolis, MN.

Biodegradation of petroleum hydrocarbons

- Petroleum Hydrocarbons are captured in rain gardens through sorption and biodegradation
- Biodegradation prevents accumulation of petroleum hydrocarbons
- Rain gardens are an effective option for sustainably treating petroleum hydrocarbons in stormwater

Source: LeFevre, G.H., Hozalski, R.M., and Novak, P.J. (2012, in press). "The Role of Biodegradation in Limiting the Accumulation of Petroleum Hydrocarbons in Raingarden Soils." Water Research.

Phosphorus Leaching from Compost



Source: Morgan, J. G., Paus, K. A., Hozalski, R. M., and Gulliver , J. S. (2011). "Sorption and Release of Dissolved Pollutants Via Bioretention Media." Project Report 559. St. Anthony Falls Laboratory, University of Minnesota, Minneapolis, MN.

Designing for Metals and Petroleum Hydrocarbon capture with Rain Gardens

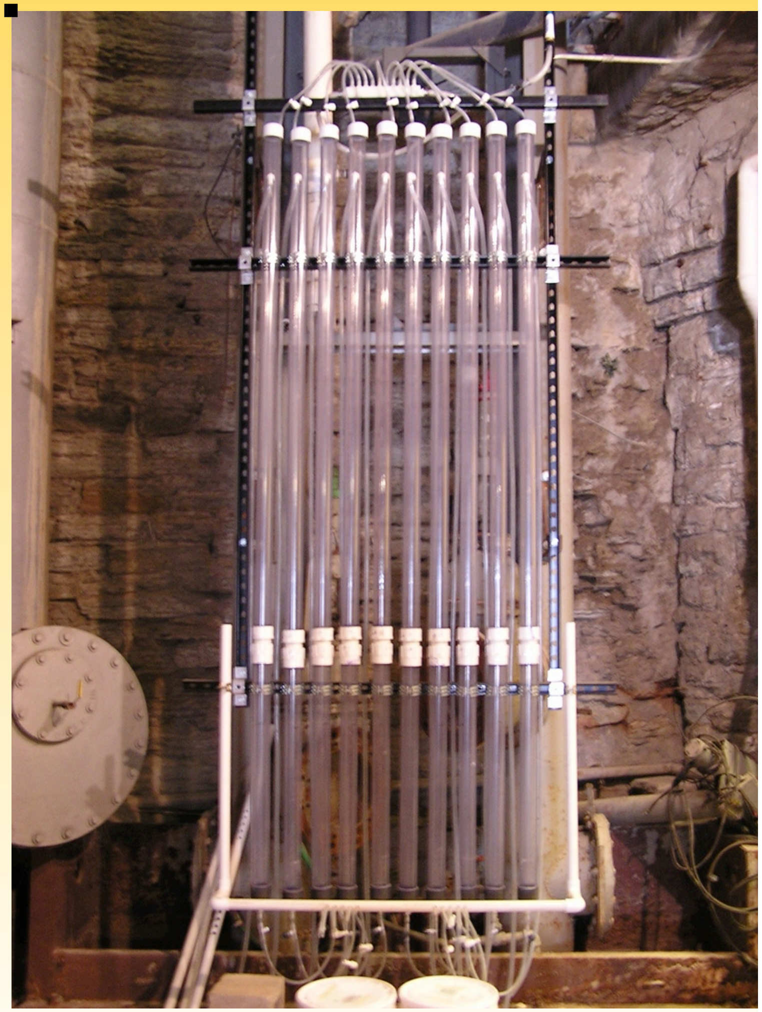
- Compost can capture metals and petroleum hydrocarbons but can release phosphorus, therefore:
  - Incorporate compost in treatment practices to capture metals and hydrocarbons
  - Ensure aerobic conditions to promote biodegradation
  - Incorporate another process to capture dissolved phosphorus

Dissolved Phosphorus Removal Experiments and Model

- Batch Studies for Adsorption and Precipitation
  - Calcareous sand
  - Limestone
  - Aluminum oxide
  - Steel wool
  - Iron Filings
  - Steel industry byproducts

Experiments and Model

- Column Studies
  – Sand
  – Calcareous sand
  – Limestone
  – Steel Wool
  – Iron Filings



Experimental Setup

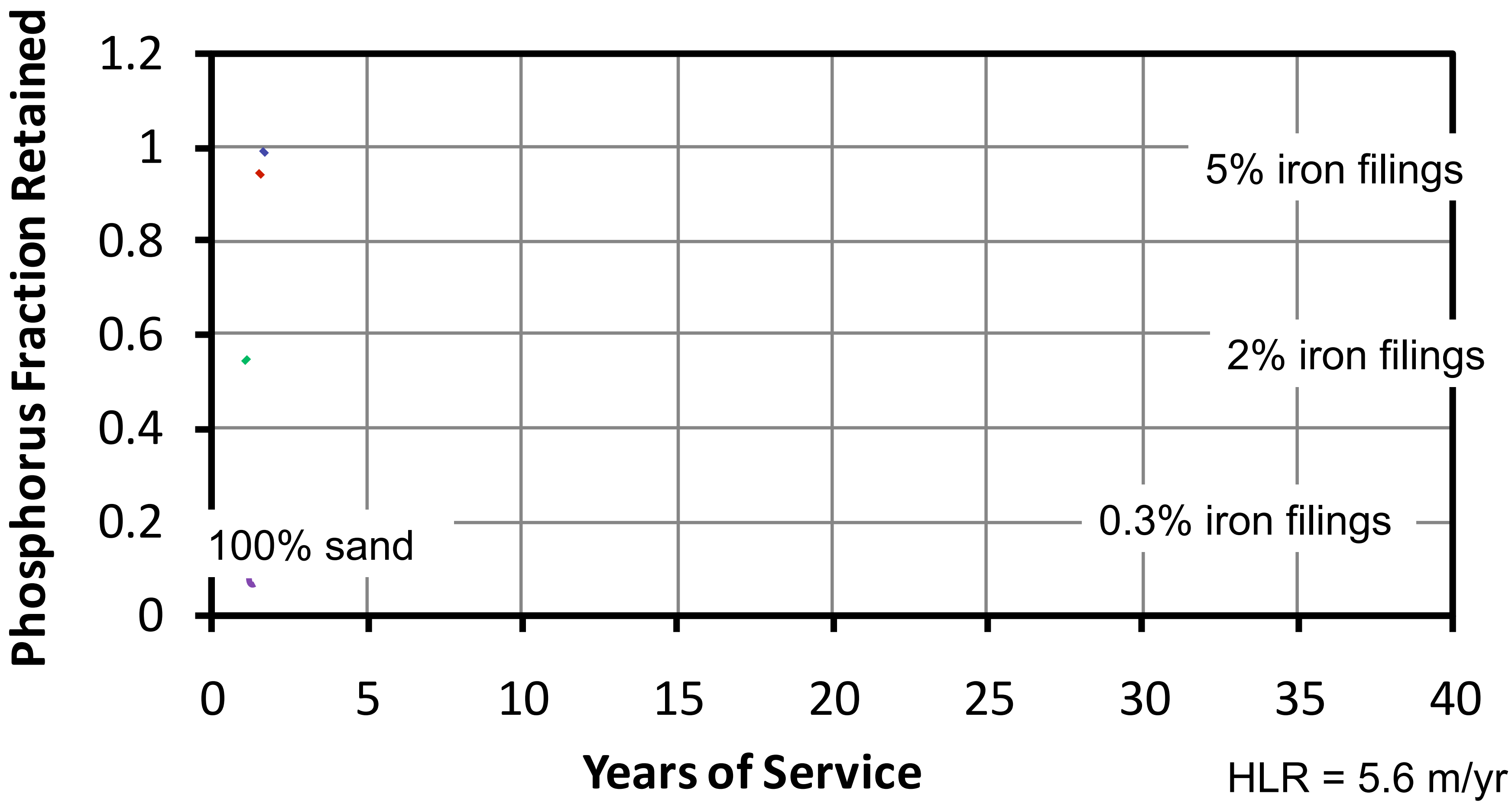
- Column Study (10)
  - 5% iron (3) – A,B,C
  - 2% iron (3) – D,E,F
  - 0.3% iron (3) – G,H,I
  - 100% sand (1) – J
- Reservoir mixed with dissolved phosphorus
- Mass balance model

Photo Courtesy: A. Erickson

Model Developed to Design Treatment Systems

- Model Attributes:
  - Mass balance model between iron and phosphorus in water
  - Predict phosphorus capture of iron-enhanced sand filtration
  - Data observed in column experiments
  - Function of contact time (t_c) and total mass of adsorbed phosphorus (SM)

Experimental Results (iron)



Designing for Phosphorus Capture with Iron

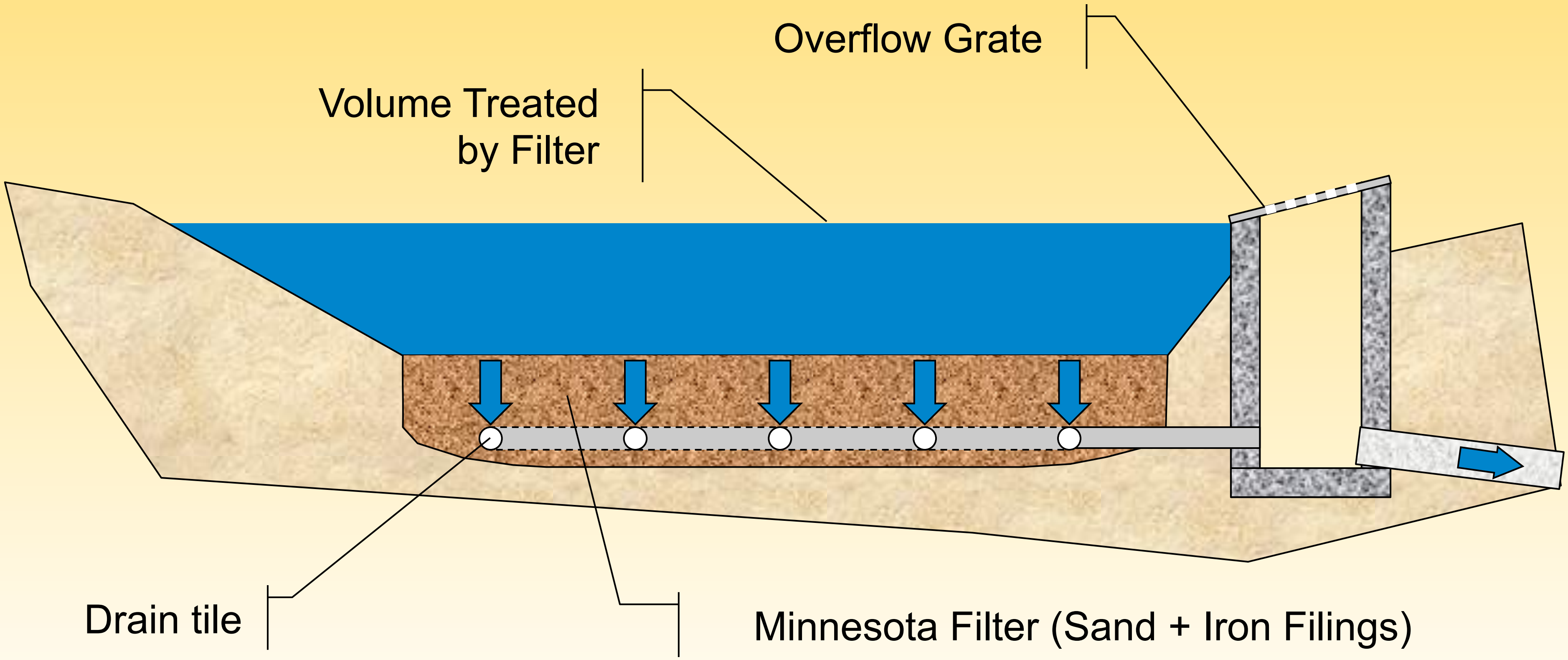
- As iron rusts, sorption sites for phosphorus are created, therefore:
  - Design Minnesota Filter (iron + sand filtration) systems for watersheds with significant dissolved phosphorus fraction
  - Ensure the system is oxygenated to ensure iron oxides remain aerobic
  - Design systems with 8% or less iron by weight to prevent clogging

Applications: "Minnesota Filter" (e.g., sand with 5% iron filings, Maplewood, MN)

Photo Courtesy: A. Erickson

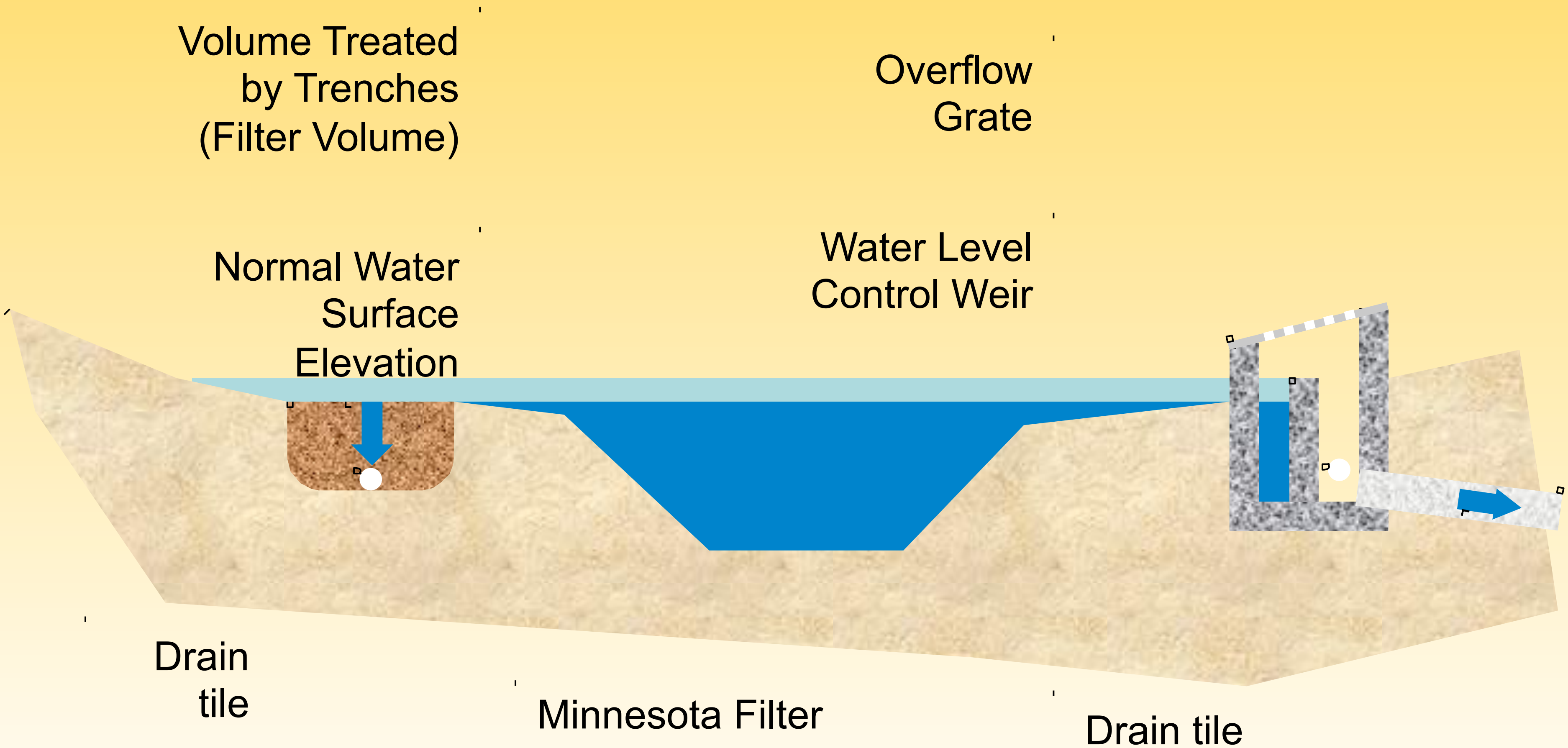
“Minnesota Filter” (e.g., sand with 5% iron filings, Maplewood, MN)

Field Results: Removal/retention to below detection limits

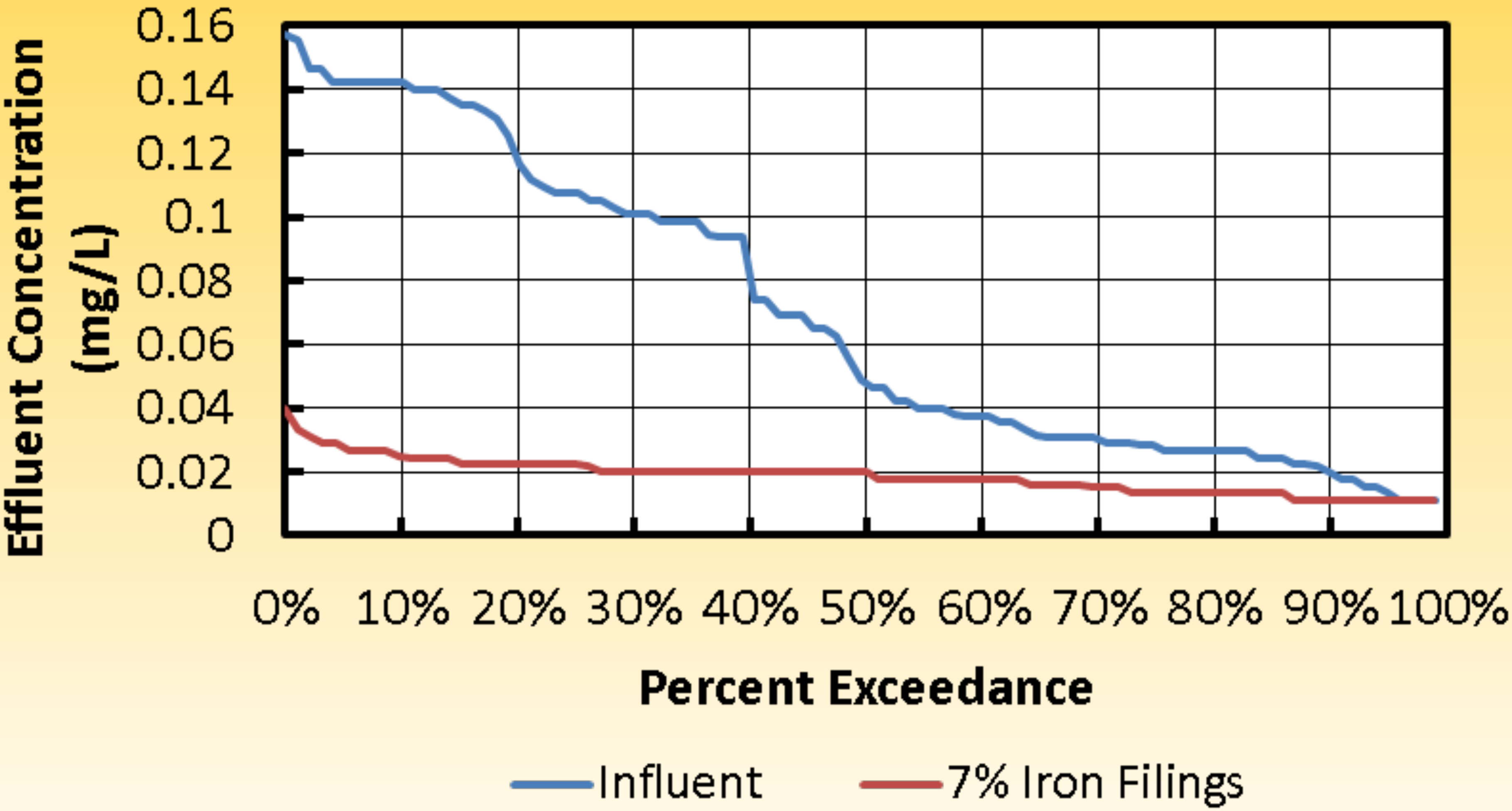


Filter Trenches around wet detention ponds (Prior Lake, MN)

Minnesota Filter Trenches around wet detention ponds



Field Testing Results (trenches)



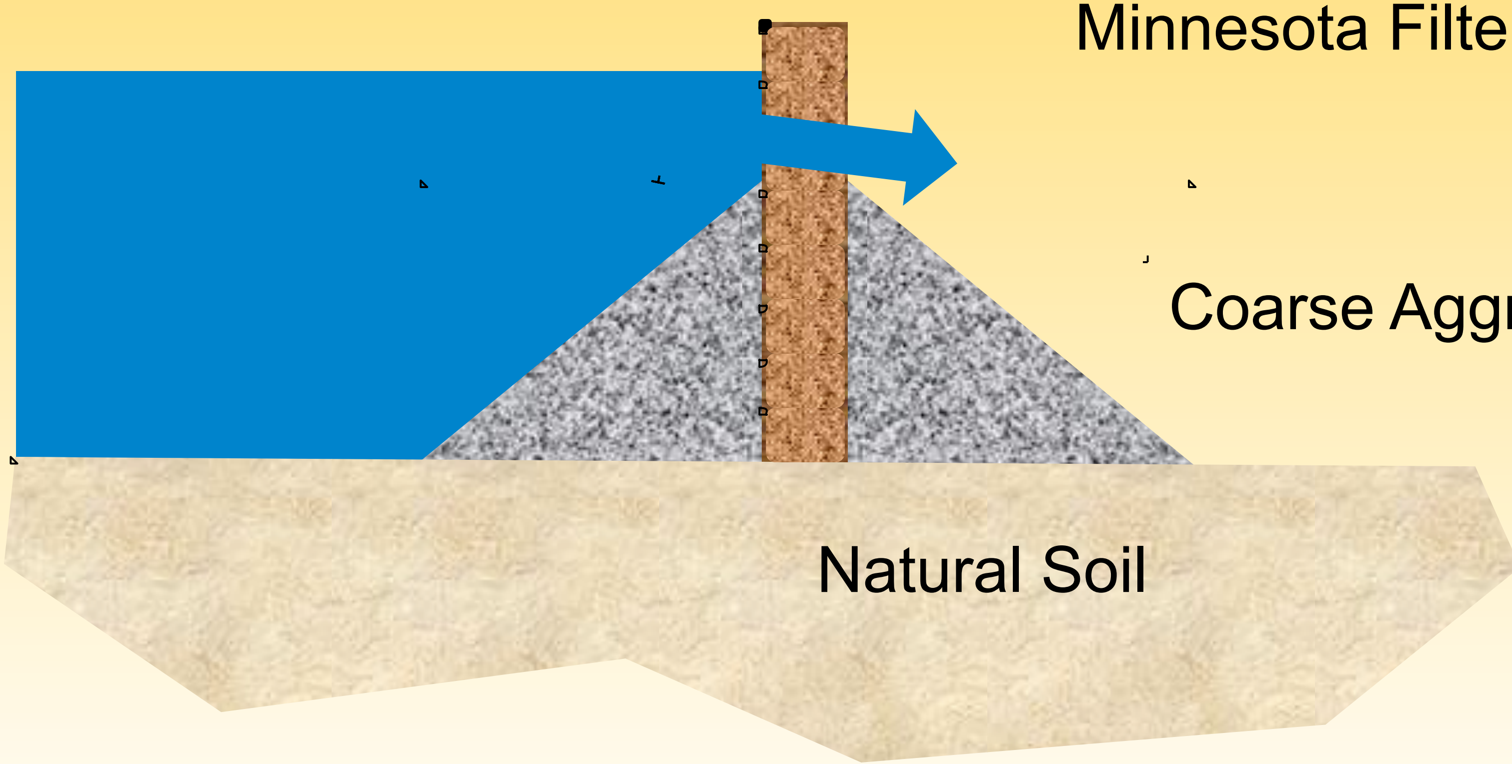
Source: Erickson, A. J., and Gulliver, J. S. (2010). "Performance Assessment of an Iron-Enhanced Sand Filtration Trench for Capturing Dissolved Phosphorus." St. Anthony Falls Laboratory Project Report #549, Prepared for the City of Prior Lake. University of Minnesota, Minneapolis, MN.

Minnesota Filter Permeable Weir

Photo Courtesy: VLAWMO and EOR

Minnesota Filter Permeable Weir

- Permeable Weir:

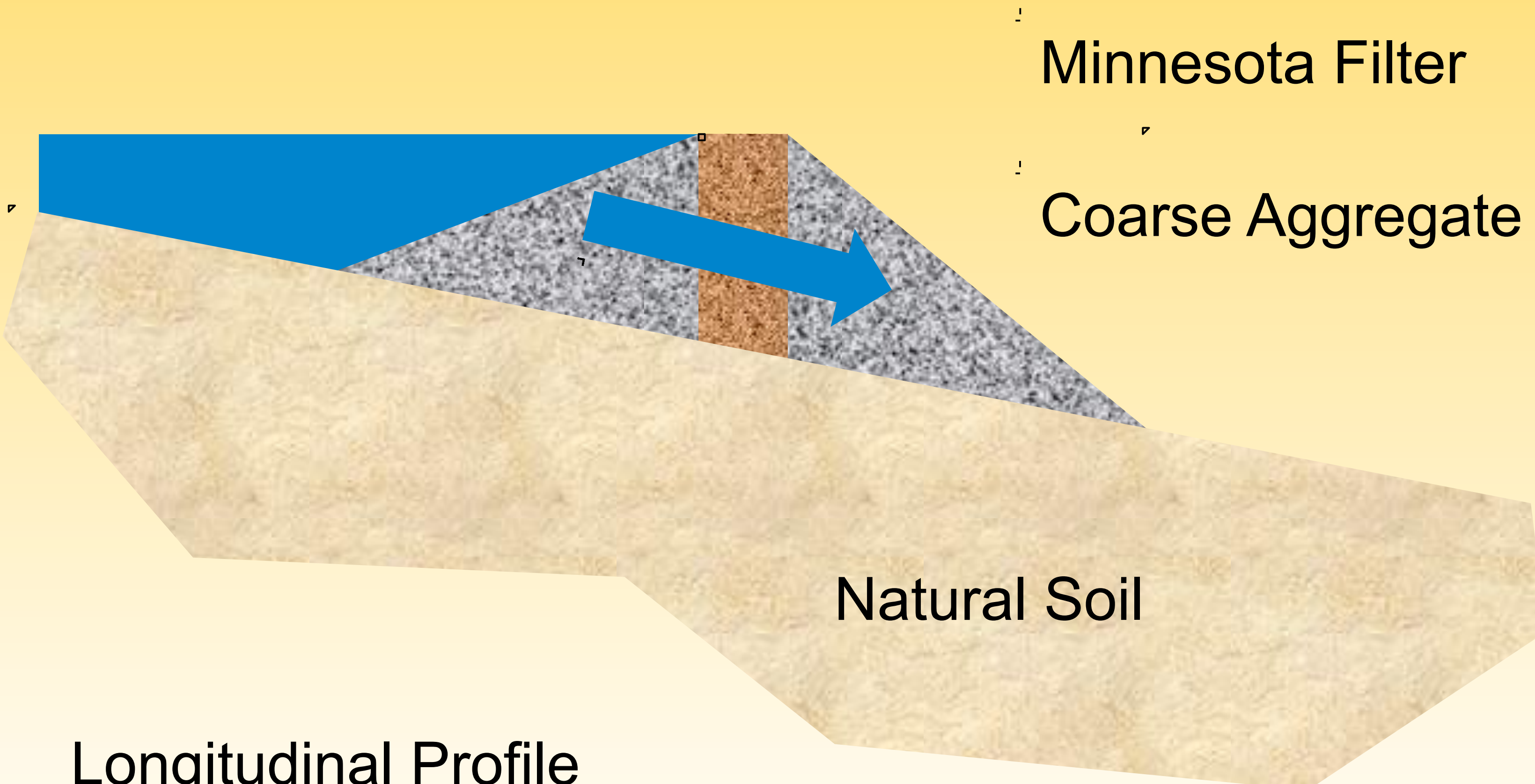


Minnesota Filter Ditch Check Dams (under development)

http://www.cpluhna.nau.edu/Change/waterdevelopment2.htm

http://www.dfr.state.nc.us/water_quality/wqglossary.htm

Minnesota Filter Ditch Check Dams (under development for LRRB)

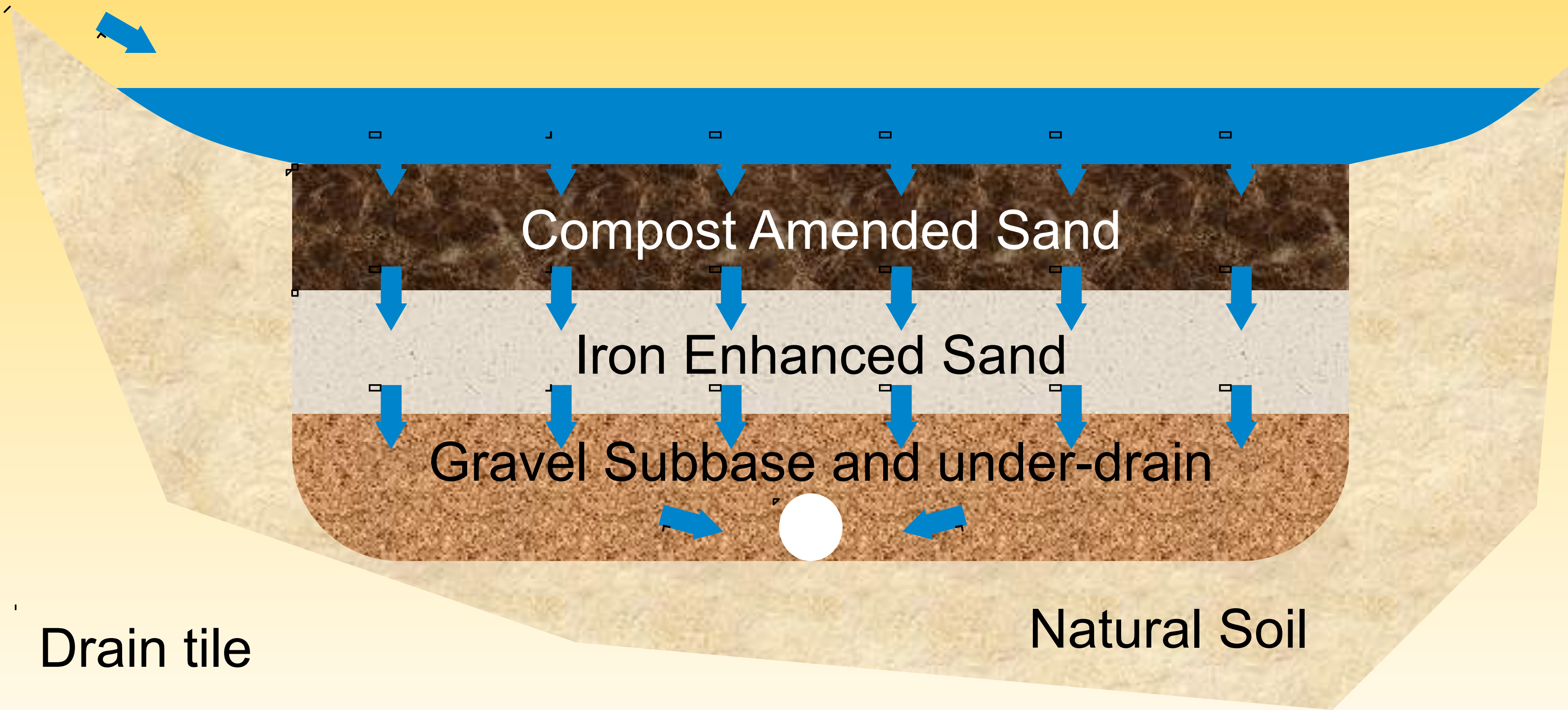


Longitudinal Profile

Bioretention Facilities

- Compost is great at removing hydrocarbons (LeFevre, et al, 2012)
- Compost is great at removing dissolved metals (Morgan, et al., 2012)
- Compost releases dissolved phosphorus (Morgan, et al. 2012)

Minnesota Filter with Bioretention



Conclusions on Treatment for Dissolved Pollutants

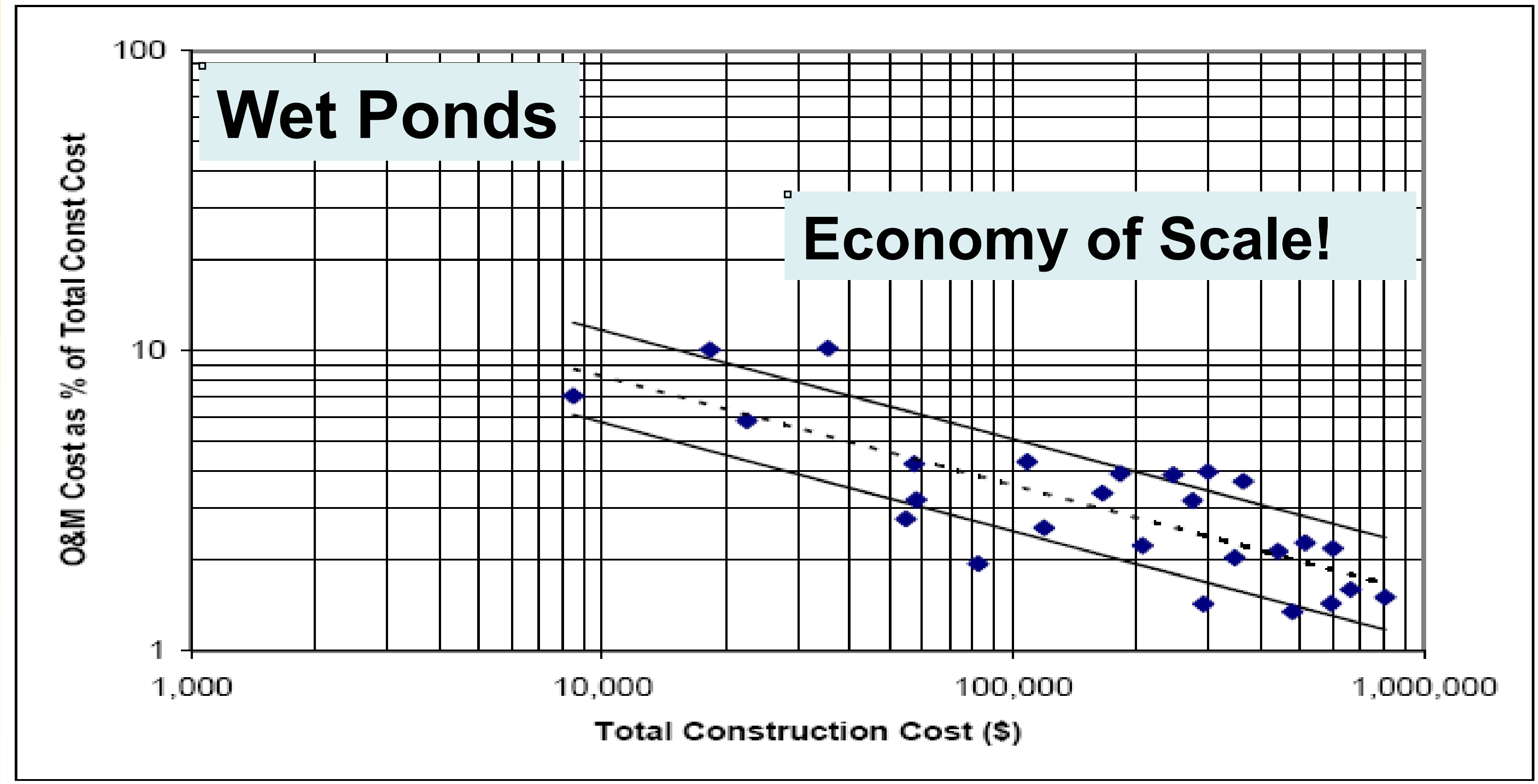
- Dissolved Stormwater Pollutants are important
  - Approx. 45% of total concentration is dissolved
- Physical methods are not enough
  - Chemical and biological mechanisms can be used to capture dissolved fractions
- There are solutions!
  - Minnesota Filter (iron-enhanced sand) → phosphorus
  - Compost-amended bioretention → metals and hydrocarbons

Maintenance Costs of Stormwater Management Practices

Outline

- Cost of Maintenance
- Overall cost of BMPs
- Summary and Conclusions

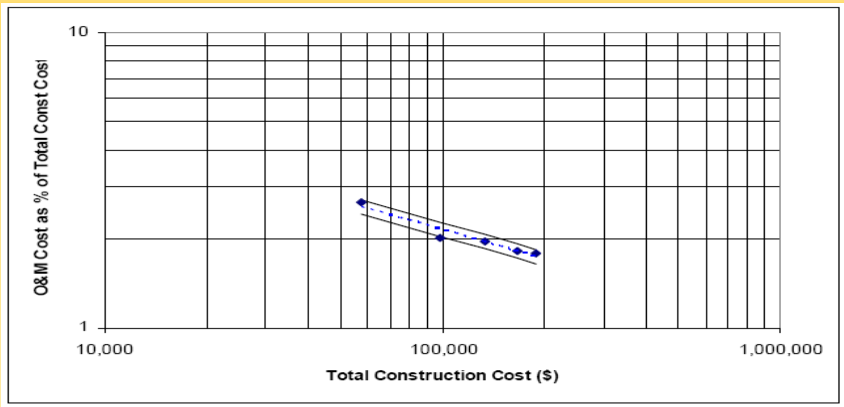
Annual O&M Costs for Stormwater Ponds (Weiss et al., 2005, 2007)



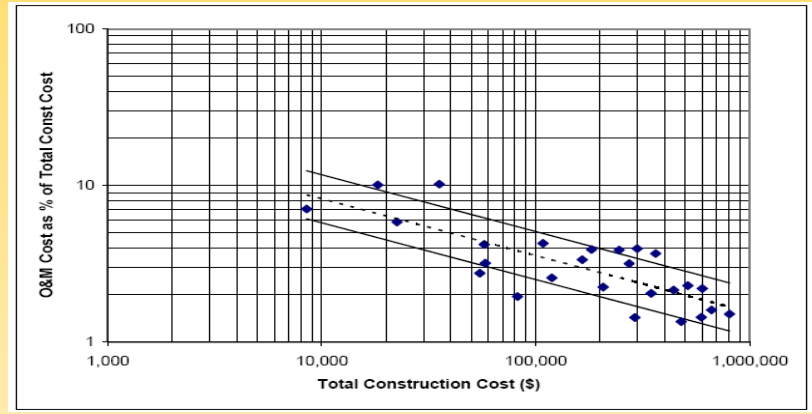
Weiss, P.T., J. S. Gulliver and A. J. Erickson, (2005). "The Cost and Effectiveness of Stormwater Management Practices," Minnesota Department of Transportation Report 2005-23

Annual O&M Costs for Stormwater Ponds (Weiss et al., 2005)

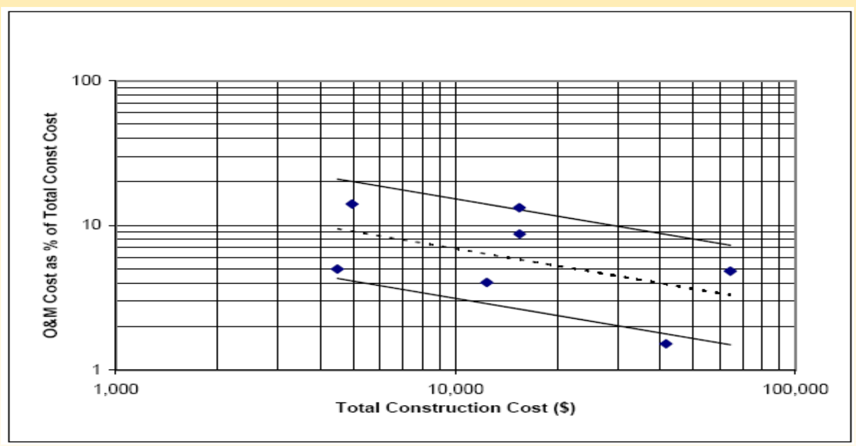
Dry Ponds



Wet Ponds



Wetlands

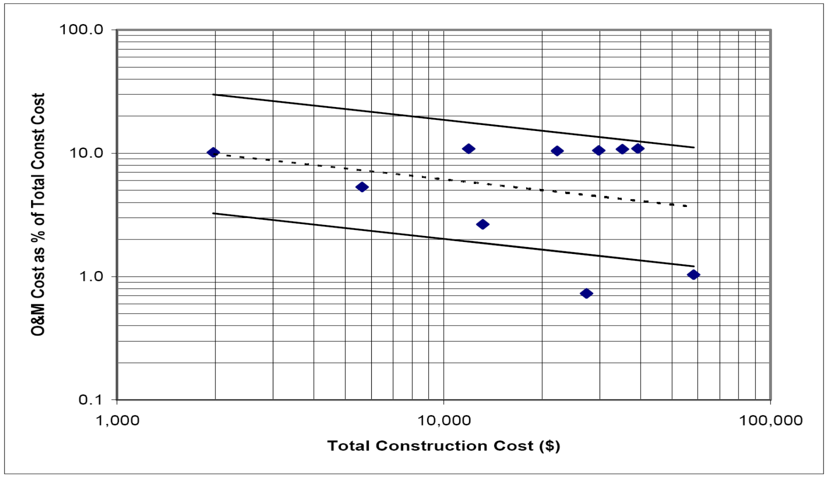


Economy of Scale!

Data from SWRPC, 1991; Landphair, *et al*, 2000, Wossink and Hunt, 2003

Annual O&M Costs for Distributed Practices (Weiss, et al., 2005)

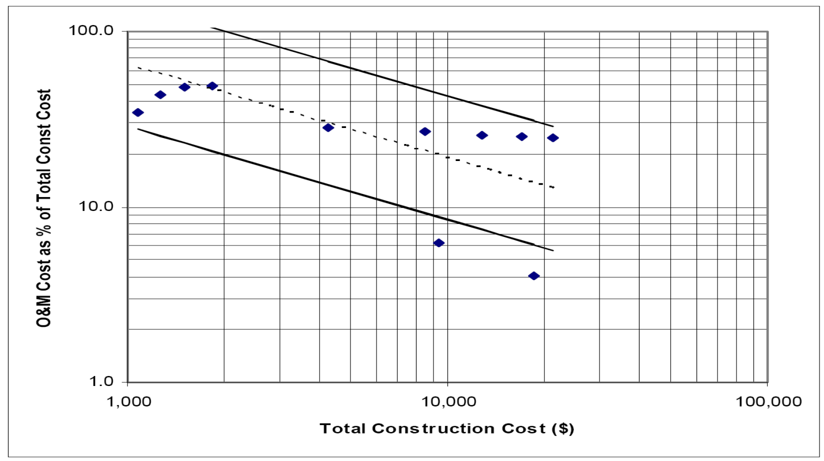
Bioretention Practices



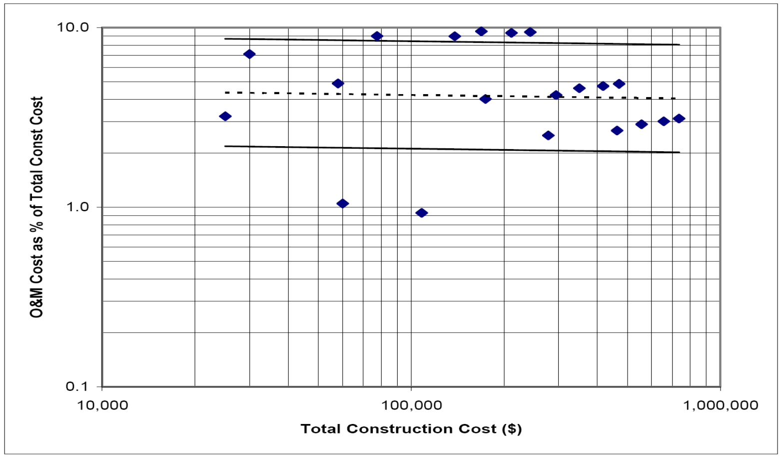
Less Economy of Scale

Data from SWRPC, 1991; Landphair, *et al*, 2000, Wossink and Hunt, 2003

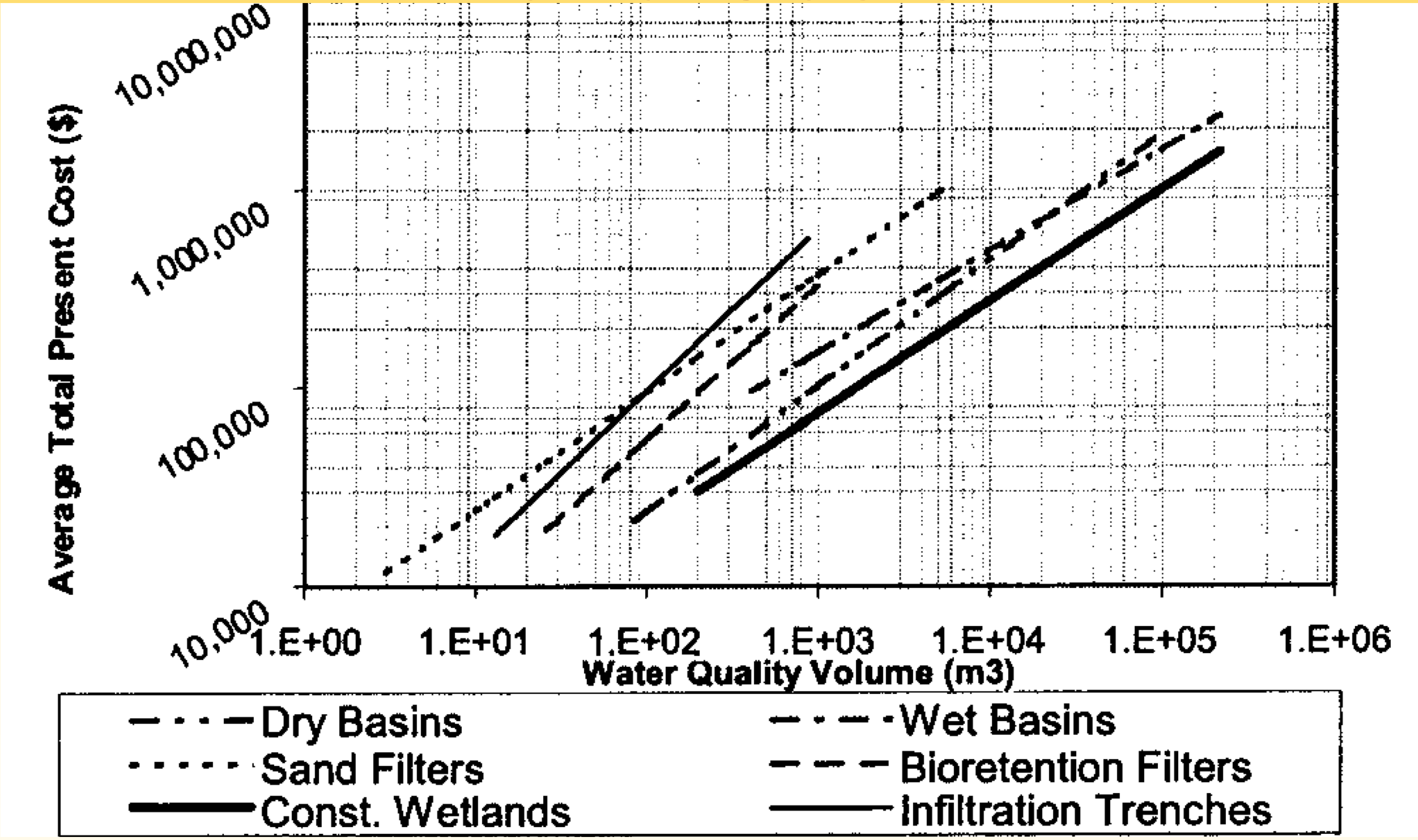
Swales



Sand Filters



Total Present Cost minus Land Costs



Conclusions on Maintenance: Rule of Thumb

- Maintenance costs are important to consider.
  - Maintenance cost = construction cost after **10 years** for a **$10,000 installation**
  - Maintenance cost = construction cost after **20 years** for a **$100,000 installation**

Weiss, P.T., J. S. Gulliver and A. J. Erickson, (2005). "The Cost and Effectiveness of Stormwater Management Practices," Minnesota Department of Transportation Report 2005-23. http://www.cts.umn.edu/Publications/ResearchReports/reportdetail.html?id=1023

Weiss, P.T., Gulliver, J.S., and Erickson, A.J. (2007). "Cost and pollutant removal of stormwater treatment practices." Journal of Water Resources Planning and Management, 133(3).

Data collected from SWRPC 1991; Landphair et al. 2000; Caltrans 2004; Moran and Hunt 2004

Stormwater Treatment: Assessment and Maintenance

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Stormwater Assessment and Maintenance
UPDATES

August 2011 (Volume 6 - Issue 7)

Welcome Andy!

Thank you for reading our newsletter! Our purpose is to create opportunities for partnerships which are crucial to our quest for improving the methods for assessment and maintenance of stormwater treatment practices.

For past newsletters, publications, presentations and more information, please visit our website.

If you have any questions, please contact Andy Erickson.

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Restoration of critical sediment source areas in th[e] Lower Poplar River

Contributed by John L. Nieber and Brad Hansen (Department of Bioproducts and Biosystems Engineering, University of Minnesota)

The Poplar River, located along the north shore of Lake Superior at Lutsen, is one of Minnesota's prized north shore streams. The lower part of the river consists of steep channel slopes, large cobble and boulder channels, and slumping bluffs consisting of glacial till. Analysis of monitoring data led to the designation of the low[er] portion of the Poplar River on the MPCA's impaired waters l[ist] in 2004 for violation of the aquatic life turbidity limit of 10 NTUs. A study in 2009 conducted by the University of Minnesota, Department of Bioproducts and Biosystems Engineering, along with previous studies, has led to the identification of critical areas for sediment source reduction. The Cook County Soil and Water Conservation District and t[he] Poplar River Management Board have collaborated to deve[lop] design plans for engineered practices that when implemente[d] the landscape will significantly reduce sediment production f[rom] these critical areas. *(read more)*

Past Articles

- July 2011 : Techniques for Determining Effective (Connected) Impervious Area
- June 2011: Celebrating 10 Years of Stormwater Training
- April 2011: Soil Remediation with Compost

Events Calendar

NOTE: Participant travel paid for by the University of Minnesota.