Practical Implementation of Green Infrastructure Strategies

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Presentation to
CTS Infrastructure and Environment and Energy Councils
University of Minnesota
April 8, 2021

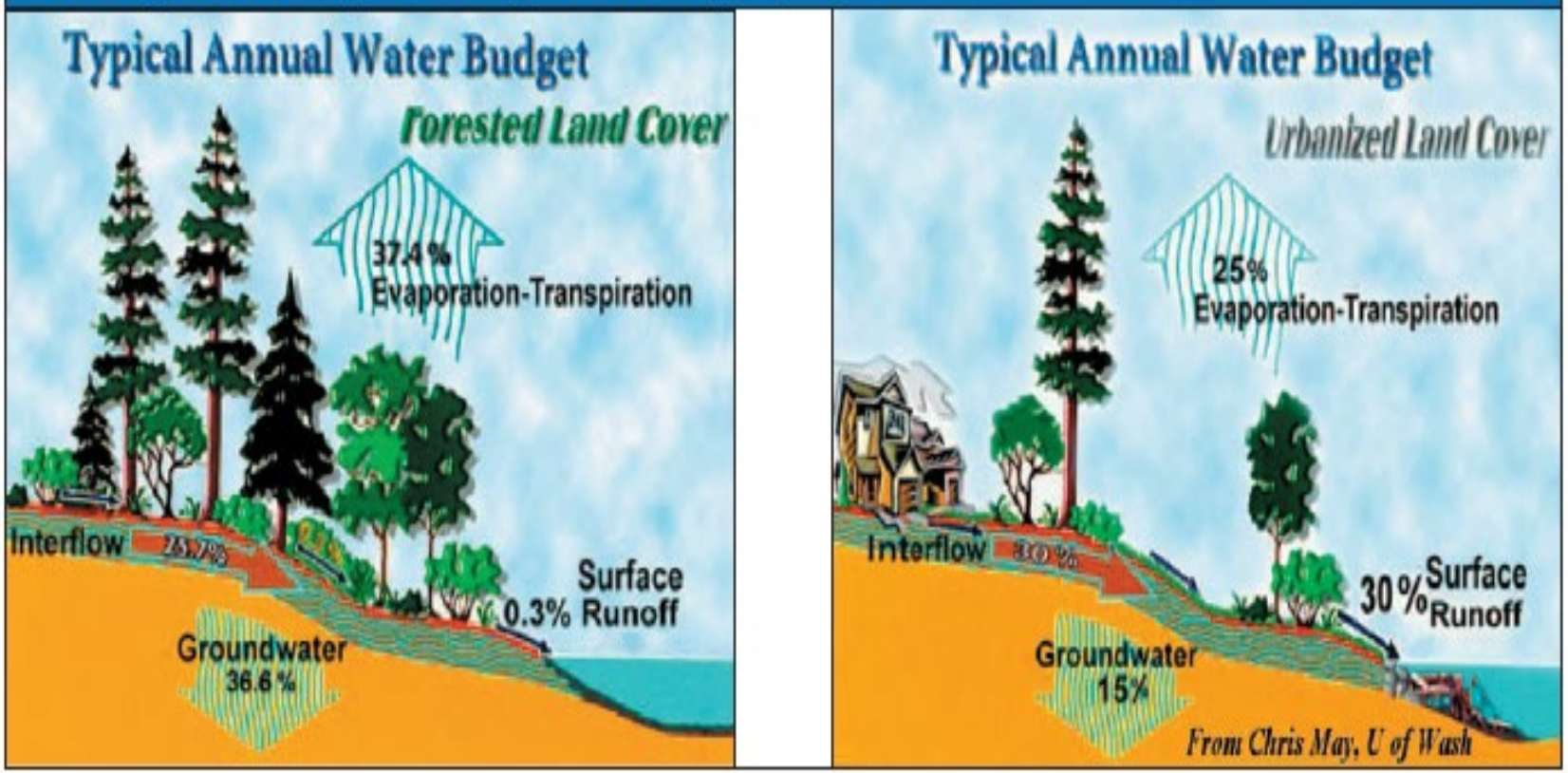
Agenda

- Impact of Impervious Runoff
- Evolution of Stormwater Terminology
- Definition(s) of Green Infrastructure
- Benefits, Challenges & Solutions of **Infiltration**
- Benefits, Challenges & Solutions of **Filtration**
- Benefits, Challenges & Risk Factors of **Pond Storage**
- Take Home Messages

Impact of Impervious Runoff

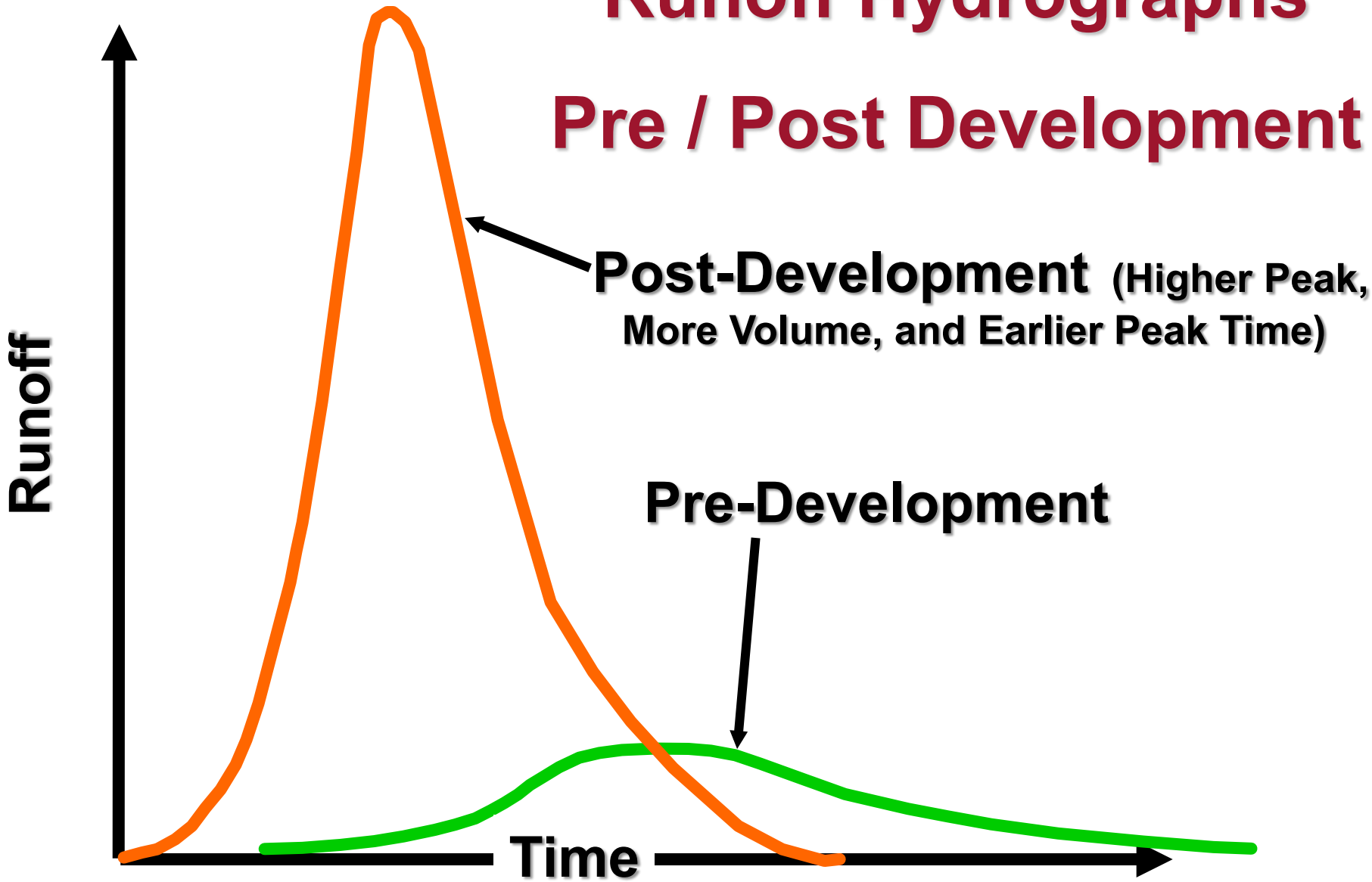
- Most urban runoff comes from impervious surfaces

Figure 2.1 Differences in Annual Water Budget from Natural Land Cover to Urbanized Land Cover (Source: May, University of Washington)



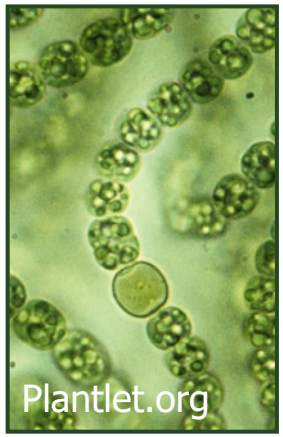
Runoff Hydrographs

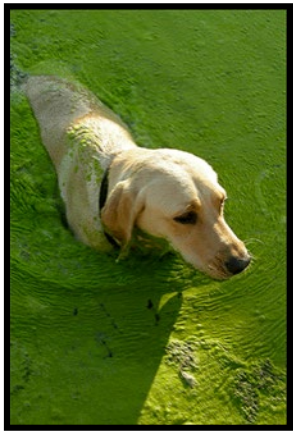
Pre / Post Development



Impact of Impervious Runoff

- Most urban runoff comes from impervious surfaces
- Runoff contains washoff pollutants
  - Nutrients from leaves, grass clippings, tree flowers, etc
  - Metals such as copper, zinc, chromium and lead
  - Petroleum Hydrocarbons

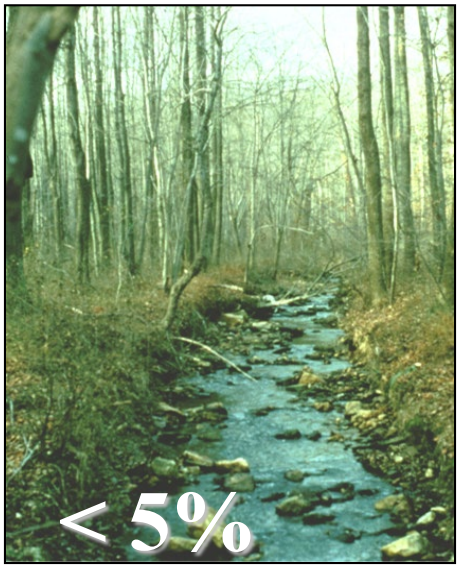


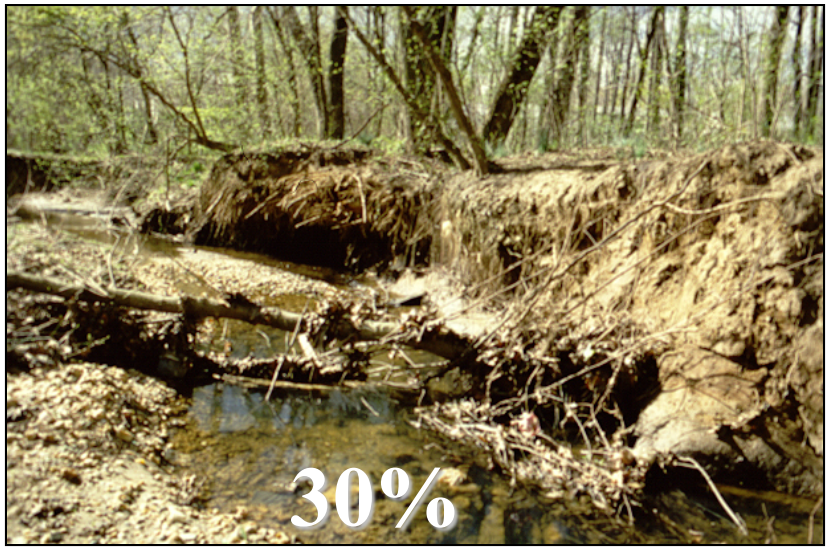


Impact of Impervious Runoff

- Most urban runoff comes from impervious surfaces
- Runoff contains washoff pollutants
- Increased stream bank erosion

Increasing
Impervious Cover =>





Impact of Impervious Runoff

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- Runoff contains washoff pollutants
- Increased stream bank erosion
- Combined sewer overflows

Impact of Impervious Runoff

- Most urban runoff comes from impervious surfaces
- Runoff contains washoff pollutants
- Increased stream bank erosion
- Combined sewer overflows
- Flooding during extreme events


Photo: Robert Dexter

Evolution of Stormwater Terminology (in the U.S.A.)

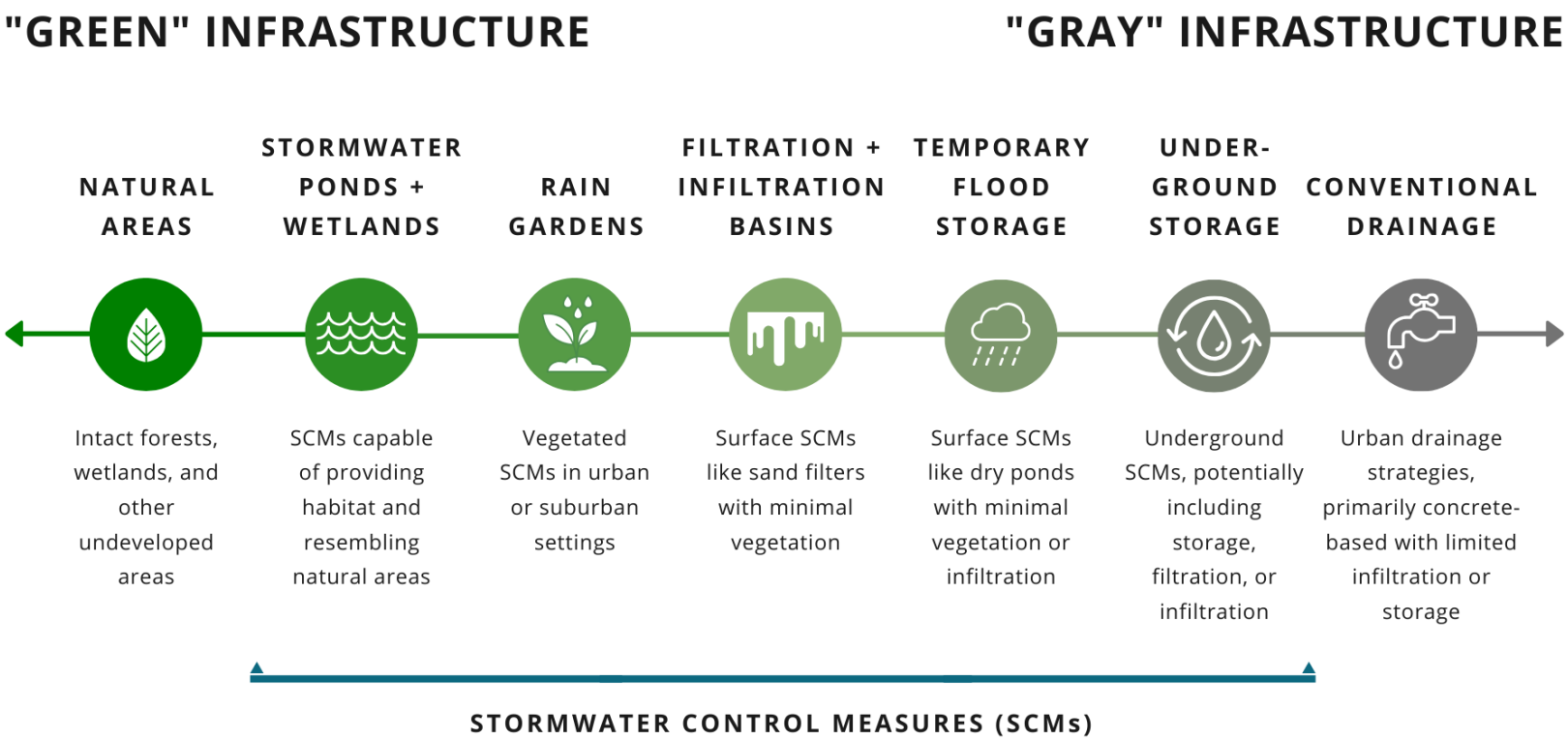
- Stormwater Best Management Practices (BMPs)
  - All infrastructure used to treat quantity and quality of stormwater
- Low Impact Development (LID)
  - Evapotranspiration and infiltration
- Stormwater Control Measures (SCMs)
  - SCMs = Stormwater BMPs
- Green Infrastructure (GI)
  - Started with stormwater but currently is an ecological framework for social, economic and environmental health
- Green Stormwater Infrastructure (GSI)

U.S. EPA Definition of Green Infrastructure (November 2020)

- All about **Stormwater Volume Control**
  - Section 502 of the Clean Water Act defines green infrastructure as "...the range of measures that use **plant or soil systems**, permeable pavement or other **permeable surfaces** or substrates, **stormwater harvest and reuse**, or **landscaping** to **store**, **infiltrate**, or **evapotranspirate** stormwater and **reduce flows** to sewer systems or to surface waters."
- A portion of an ecological framework for **social, economic and environmental health**

Green to Gray Continuum in Stormwater Infrastructure

(Vinicius Taguchi, et al. 2020)



SCMs ≅ Stormwater BMPs

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- Benefits, Challenges & Solutions of **Infiltration**
- Benefits, Challenges & Solutions of **Filtration**
- Benefits, Challenges & Risk Factors of **Pond Storage**
- Take Home Messages

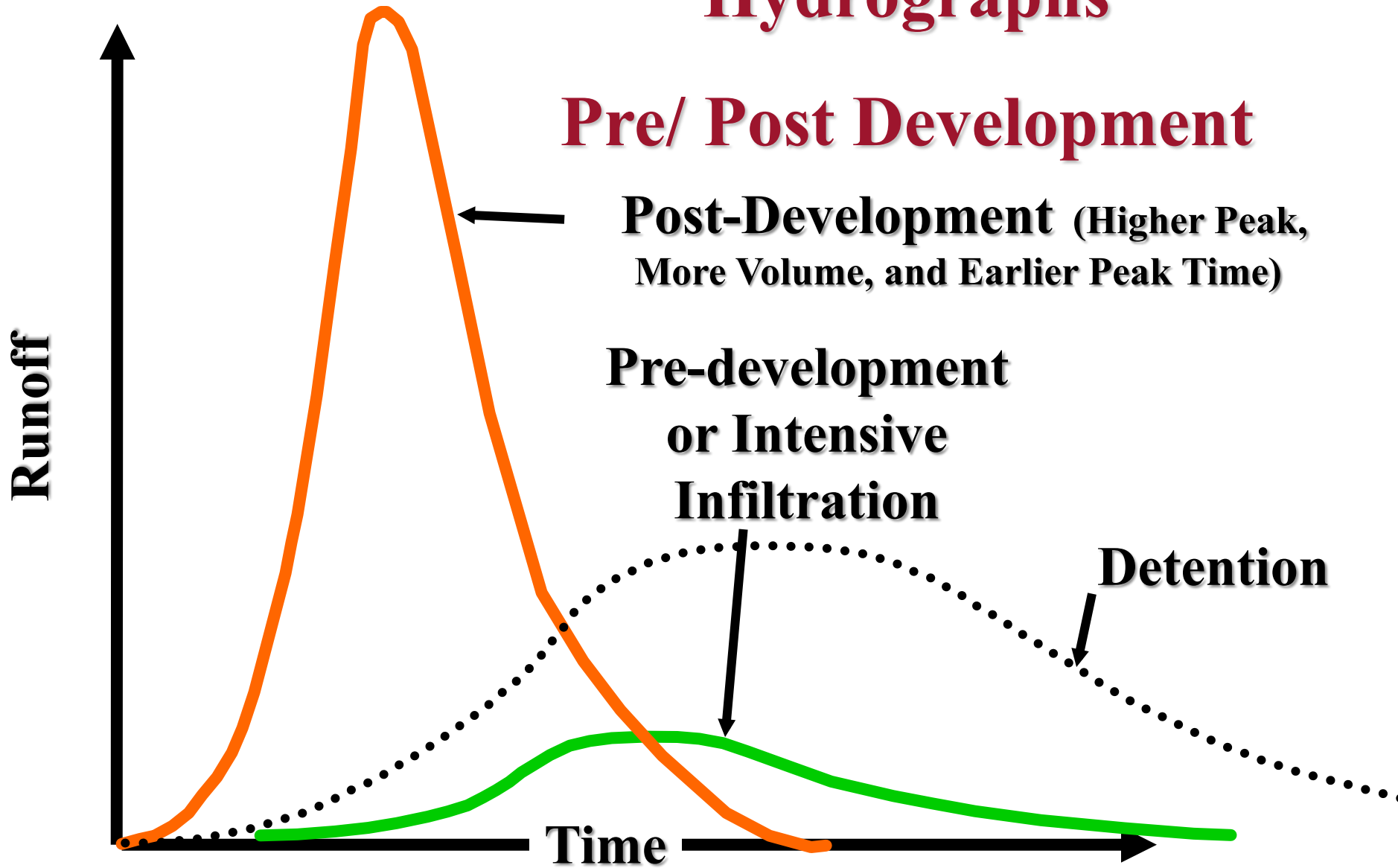
Benefits of Infiltration

- Volume Reduction – a high % of the WQ storm and smaller can be infiltrated.
- Reduced Peak Flow
- Filtration through soil – remove solids, bacteria and phosphorus and metals associated with solids.
- Temperature control through GW recharge – important for trout streams
- Increase base flow in streams

- The MPCA recommends infiltration when reasonable

Hydrographs

Pre/ Post Development



Infiltration Practices

- Infiltration Basins
- Underground Infiltration Chambers
- Infiltration Trenches
- Swales
- Filter Strips
- Bio-infiltration Practices
- Tree Trenches
- Permeable Pavement


http://dnr.wi.gov


www.estormwater.com

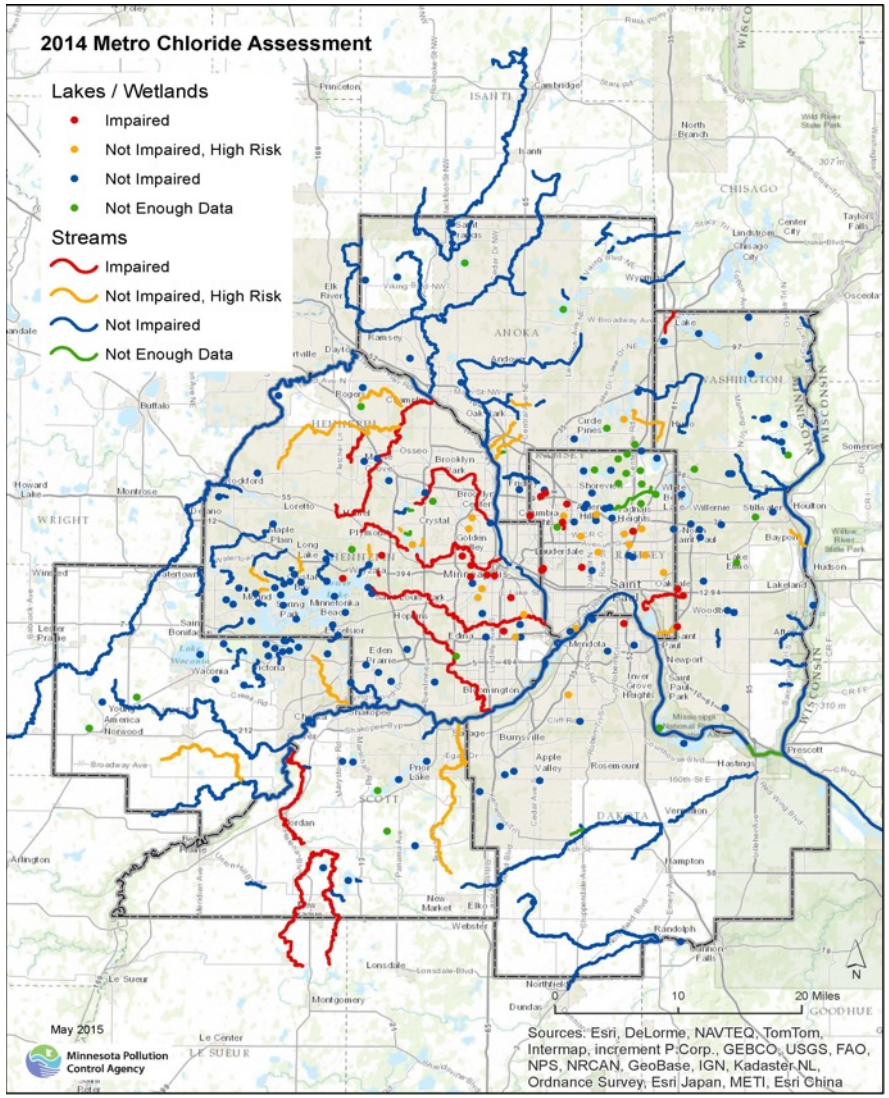

bluegreenbldg.org


Photo: Brooke Asleson

Challenges to Infiltration

- Can pollute Groundwater
  - Cl^-
  - NO_3^{-2}

Photo: MnDOT



Challenges to Infiltration

- Can pollute Groundwater
- Failure to Infiltrate (~30% of practices)
  - High spatial variability
  - Need expertise in soil profiling
  - Different kind of excavation and grading


Photo: John Gulliver


Photo: Brooke Asleson


Photo: Brooke asleson

Challenges to Infiltration

- Can pollute Groundwater
- Failure to Infiltrate (~30% of practices)
- Clogging of Pores
  - Important when plants are not present
    - Permeable pavement
    - Underground infiltration chambers

A Partial Solution to Failure to Infiltrate

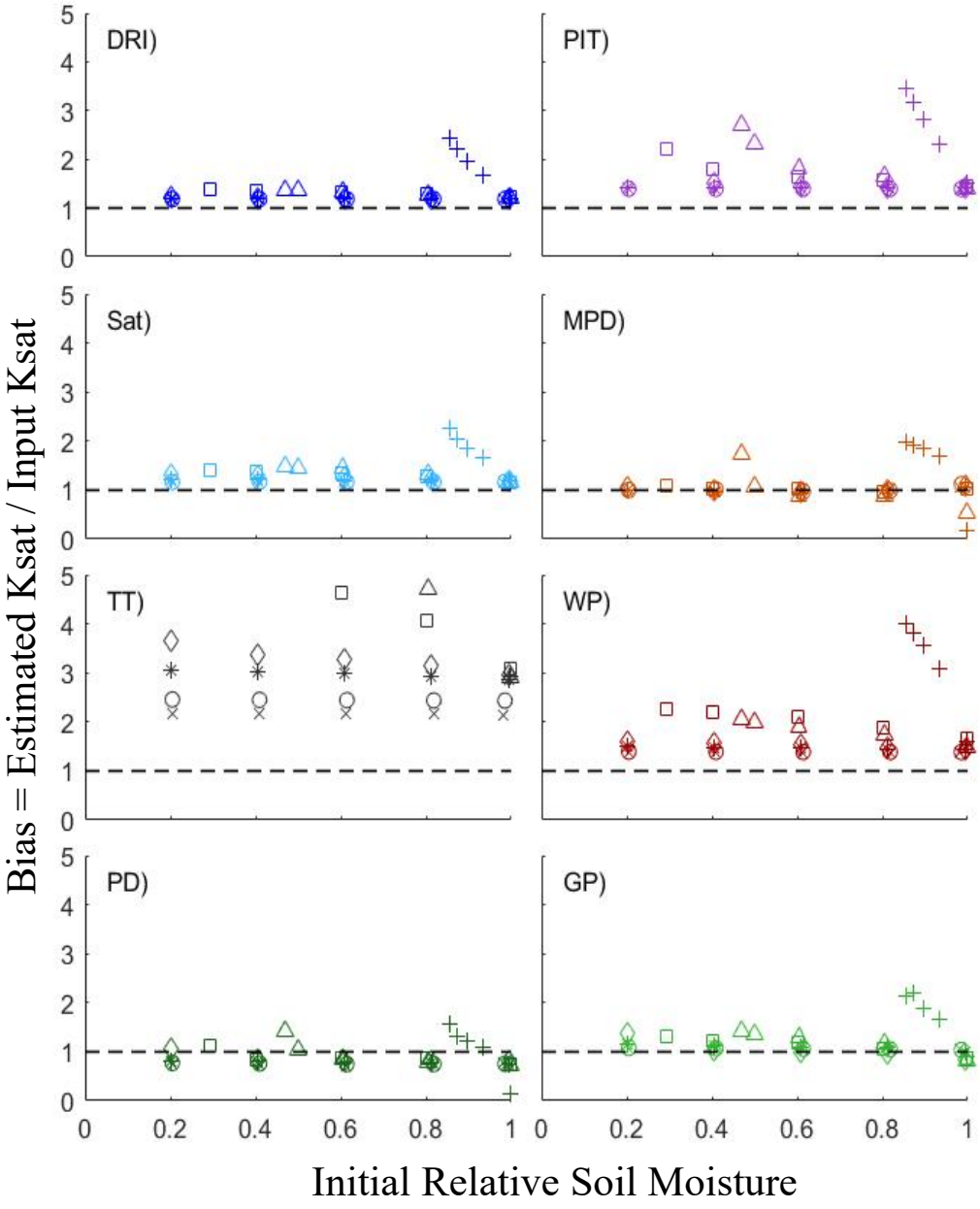
Spatial Variability in Infiltration Rates

Collaborators: Co-PI John Nieber, Rebecca Nestigen, Brooke Asleson

- Need multiple infiltration measurements
  - To characterize infiltration rate
  - 10 – 20 measurements
- Modified Phillip-Dunne Infiltrometer (2007)
  - Relatively quick
  - Requires less water
  - Easy to install
- Licensed to Upstream Technologies

Infiltrometer Accuracy

(Nick Tecca)



DRI = Double ring infiltrometer
PIT = Pilot infiltration test
SAT = Saturo
MPD = Modified Phillip-Dunne
TT = Turf-Tec
WP = USBR 7300-89 Well Permeameter
PD = Philip-Dunne Permeameter
GP = Guelph permeameter

X	Sand
O	Loamy Sand
*	Sandy Loam
Diamond	Sandy Clay Loam
Square	Silt Loam
Triangle	Sandy Clay
+	Silty Clay

Compact Soil in Rain Gardens (Bioinfiltration practices)

Collaborators: Dr. John Nieber, Brooke Asleson and Rebecca Nestingen

Funding: Metropolitan Council

- What we don't want: ----------→

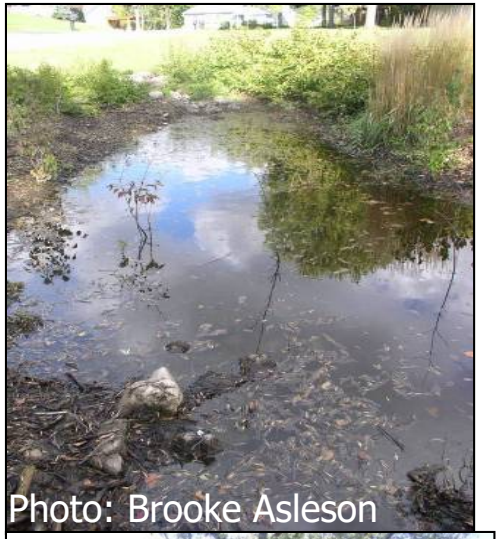
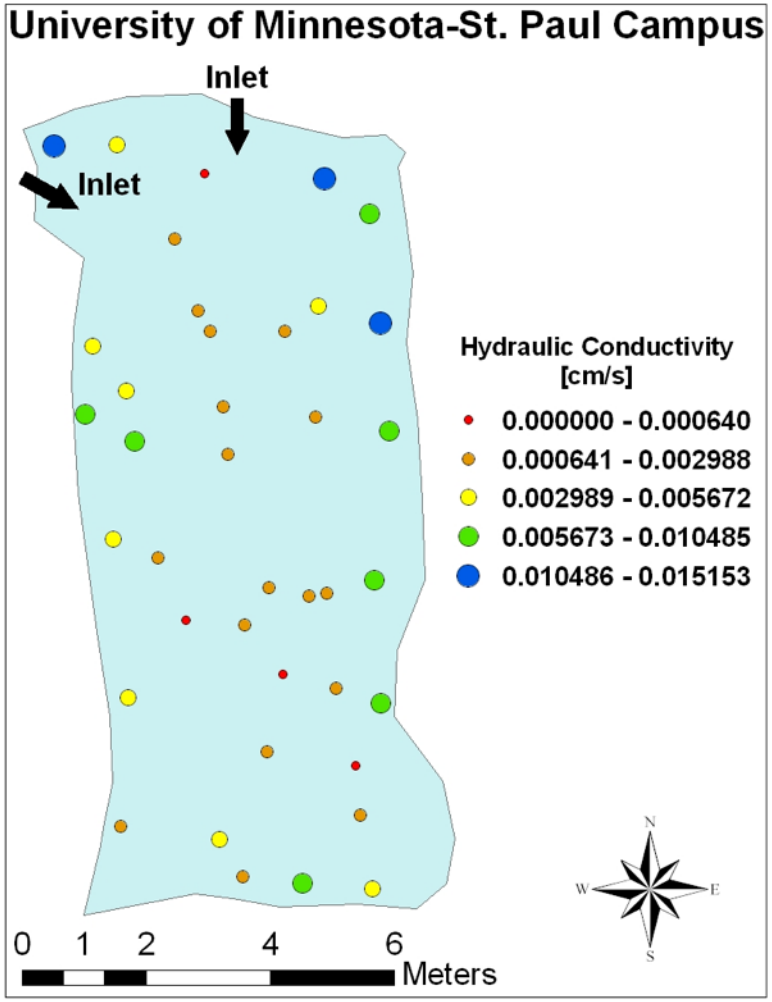


Photo: Brooke Asleson

- What we do want: ----------→

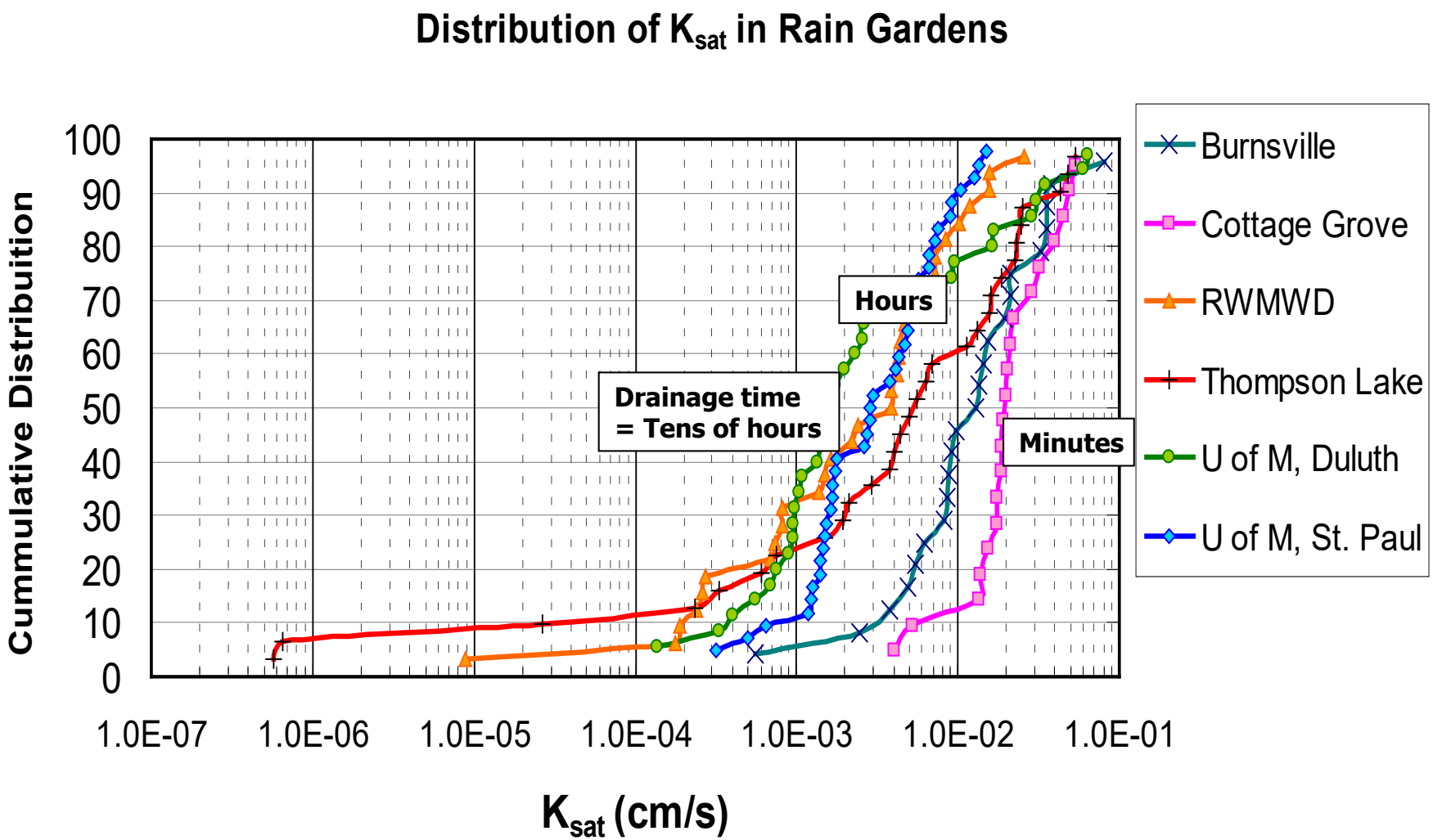
Photo: Brooke Asleson

Variation of Infiltration Rates



Mean (cm/s) =	4.28E-03
Median (cm/s) =	2.88E-03
Cv =	0.88
Min. (cm/s) =	0.00E+00
Max. (cm/s) =	1.52E-02

Infiltration Capacity Test Results



Infiltration in MnDOT Drainage Ditches => Grassed Swales

Collaborators: Dr. John Nieber, Farzana Ahmed, Maria Garcia-Serrana and Nicholas Tecca

Funding: MnDOT and Local Road Research Board

- Detailed design specifications:
  - 12 in. of top soil with ~20% grade 2 compost.
  - Allow for plant growth
    - Deep rooted grasses

Photo courtesy Maria Garcia-Serrana

Infiltration in MnDOT Swales

- Successful at infiltrating
  - Except where groundwater is high
  - Plants are the reason (macropores)
- Minimal maintenance

Photo Courtesy Maria Garcia-Serrana


Photo: John Gulliver

Infiltration in MnDOT Swales

(HSG = NCRS Hydrologic Soil Group (A → D))

	Soil Texture	HSG based on Soil Texture	Ksat (cm/h) from field meas. (CV)	HSG based on Ksat	Porosity (%)
Hwy 51	Loam / Sandy Loam	A / B	3.5 (1.4)	A	56
Hwy 77	Loamy Sand	A	5.7 (0.9)	A	56
Hwy 47	Loamy Sand / Sandy Loam	A	3.5 (1.3)	A	54
Hwy 13	Loam / Sandy Clay Loam	B / C	4.1 (1.9)	A	58

Influence of plants

Benefits of Filtration Practices

- Filter water to improve water quality by filtering particles

Challenges:

- Does not have the multiple benefits of infiltration
  - Small reduction in Peak Flow
  - No volume reduction
  - Minimal temperature control
  - Base flow in streams is not increased
- Does not remove dissolved contaminants like phosphate
  - ~45% of pollutants


Photo courtesy Andy Erickson

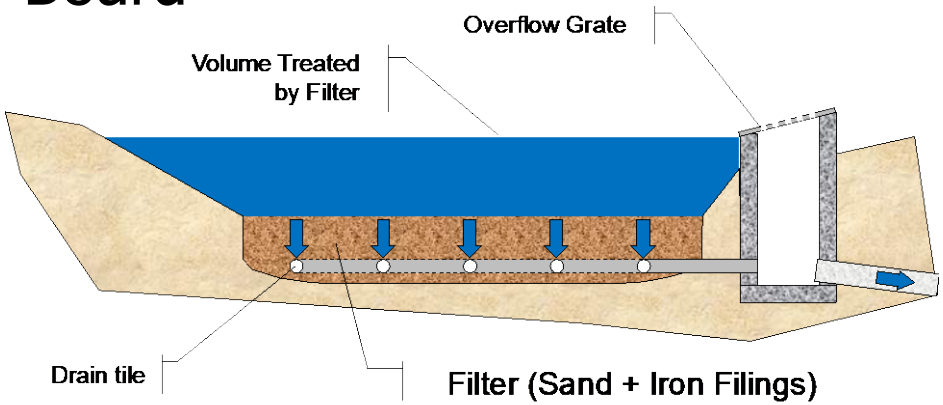
Phosphate is the primary cause of harmful algae blooms

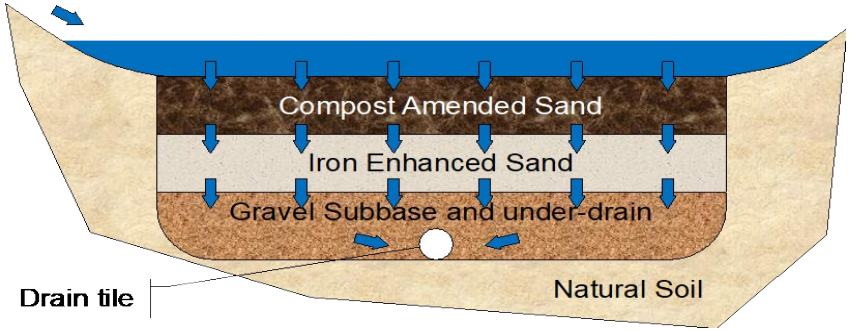
A Partial Solution
(Phosphate Retention)

- **Iron Enhanced Sand Filter** to remove phosphate
  - 5 - 10% iron filings
  - 95 - 90% sand
  - Oxidized iron filings capture phosphate
  - Retention of 70 - 90%of phosphate when designed and maintained properly

Collaborators: Pete Weiss and Andy Erickson

Funding: Local Road Research Board





Example IESF Applications


Photo courtesy Ross Bintner


Photo: Courtesy Andy Erickson


Photo courtesy Pete Weiss

~170 IESF Installations

Benefits of Stormwater Ponds

- Settle particulates and associated pollutants
- Convert phosphate to particulate phosphorus
- Provide wildlife habitat
- Amenity in urban neighborhoods

Challenges

- Need maintenance
- Expensive to dredge

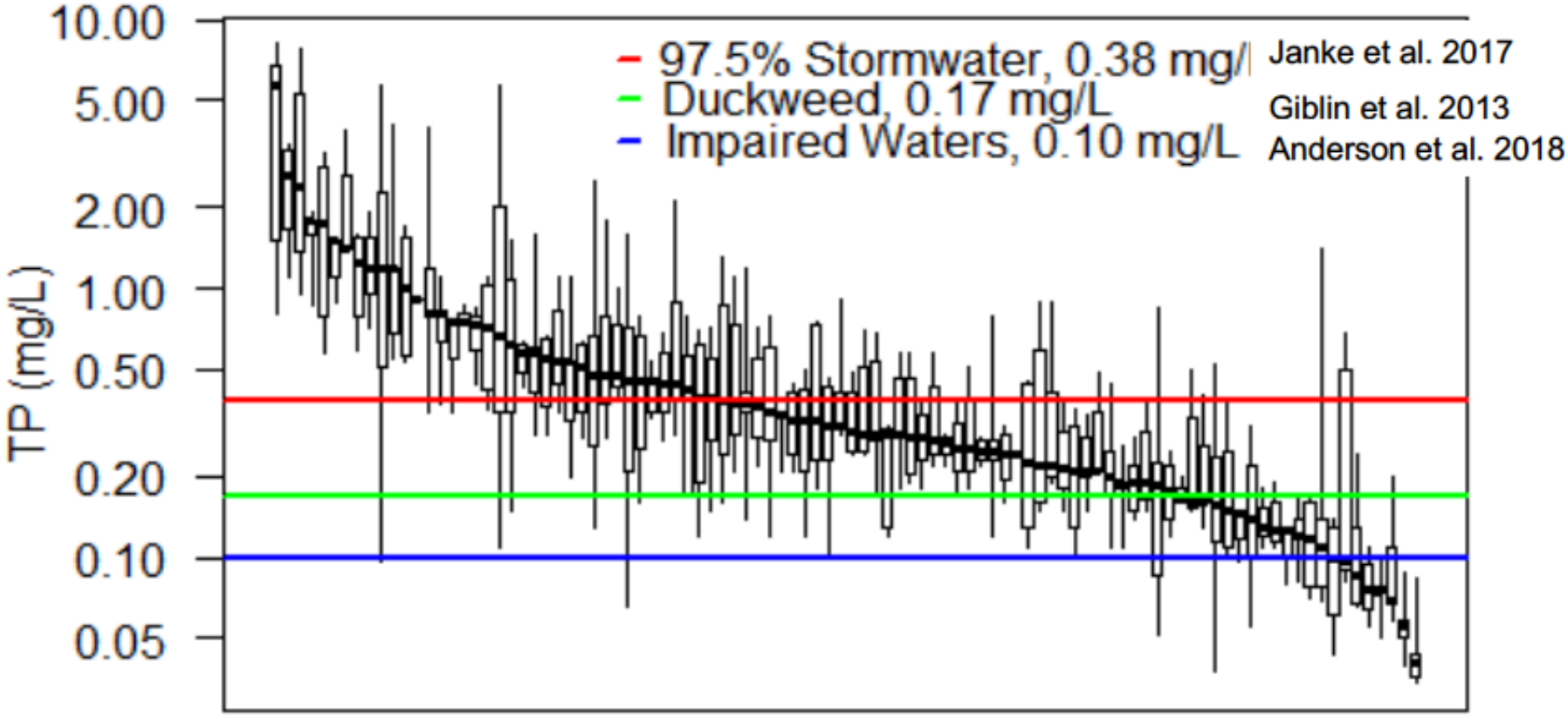





High Phosphorus Concentration in Ponds

Riley Purgatory Bluff Creek Watershed District

98 Ponds – 32% had total phosphorus above 97.5% of inflow concentrations



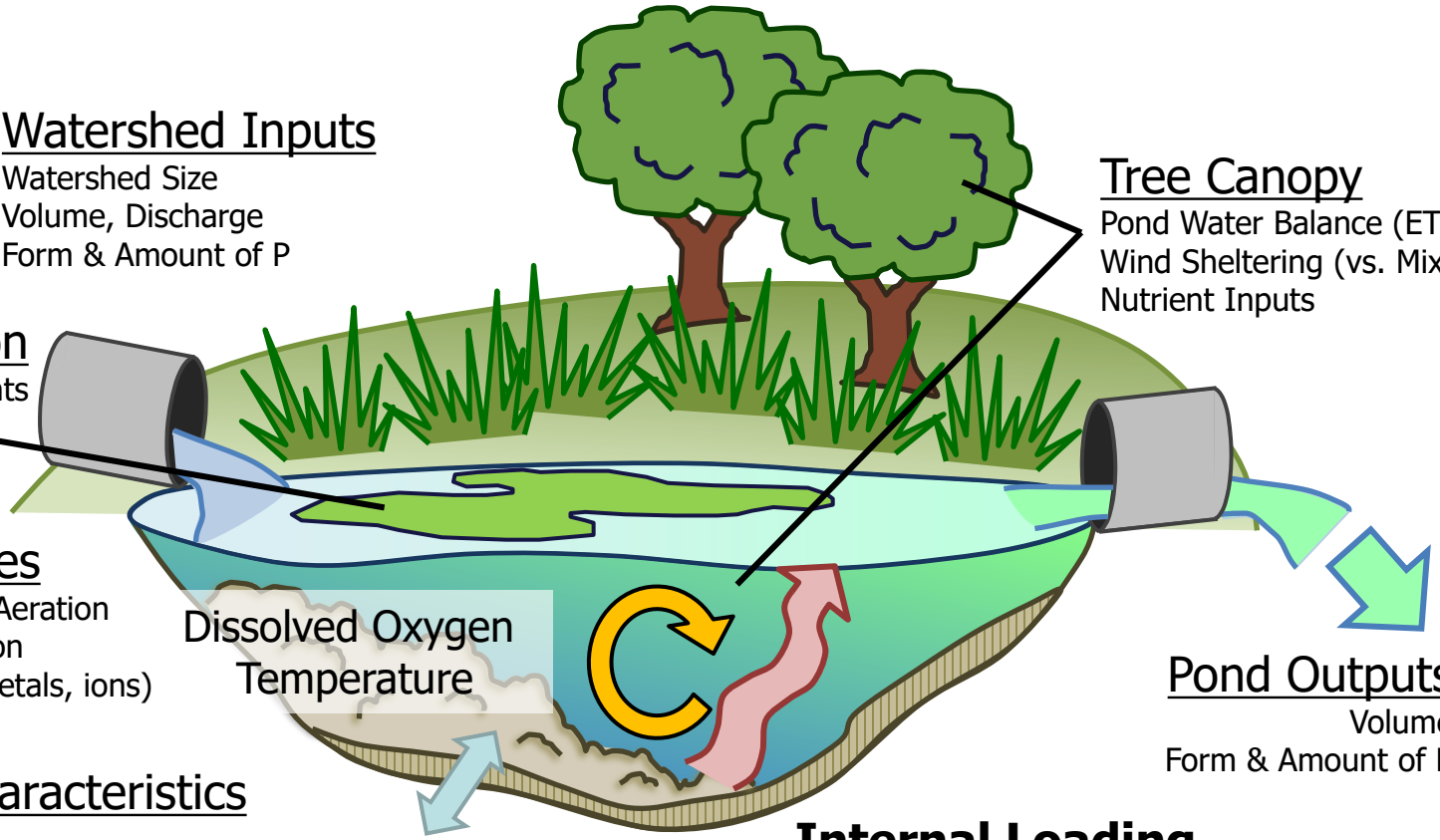
98 Ponds

Processes that Affect Phosphorus Retention are Complex

Watershed Inputs
Watershed Size
Volume, Discharge
Form & Amount of P

Tree Canopy
Pond Water Balance (ET)
Wind Sheltering (vs. Mixing)
Nutrient Inputs

Aquatic Vegetation
Uptake/Release of Nutrients
Shading/Sheltering



Internal Processes
Stratification vs. Mixing/Aeration
Settling and Resuspension
Sediment Interaction (metals, ions)

Pond Outputs
Volume
Form & Amount of P

Sediment Characteristics
Phosphorus Forms
Organic Matter
Oxygen Demand

Groundwater Interaction
Gain or loss of P?
Pond water balance

Internal Loading
DO ⇩
Soluble P ? ⇧

Research Discoveries

MINNESOTA POLLUTION CONTROL AGENCY

LRRB

Collaborators: Co-PI Jacques Finlay, Ben Janke, Poornima Natarajan, Vini Taguchi, Paliza Shrestha

Funding: MPCA, Minnesota Stormwater Research Council, RPBCWD, RWMWD, LRRB

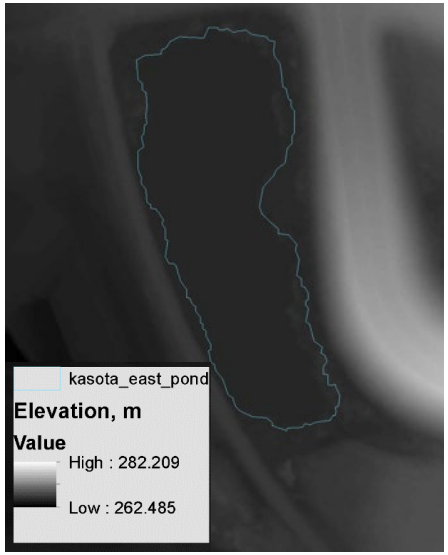
1. **Ponds are highly stratified, low oxygen systems**
2. **Duckweed has major impacts**
3. **Low oxygen results in sediment phosphate release**
4. **Pond hydrology affects P retention**

Risk Factors of Reduced P Retention in Ponds

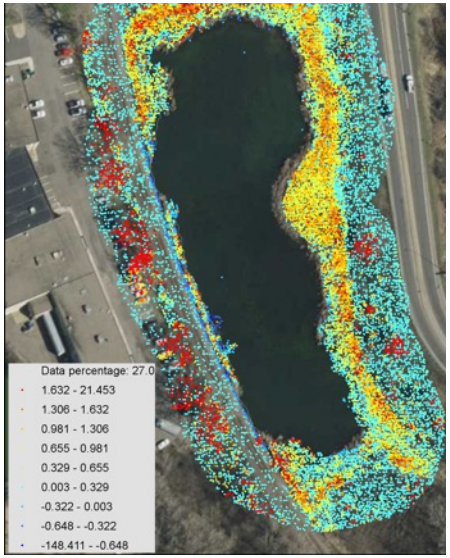
Importance of Wind Sheltering

VS

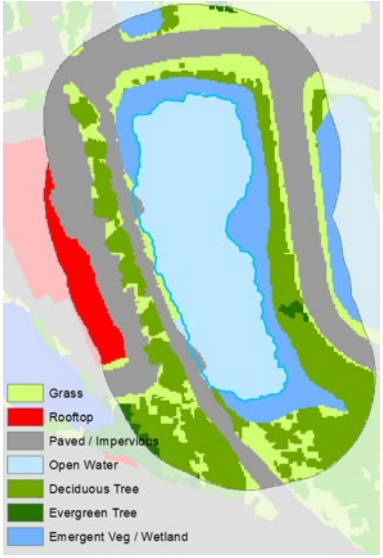
Topography

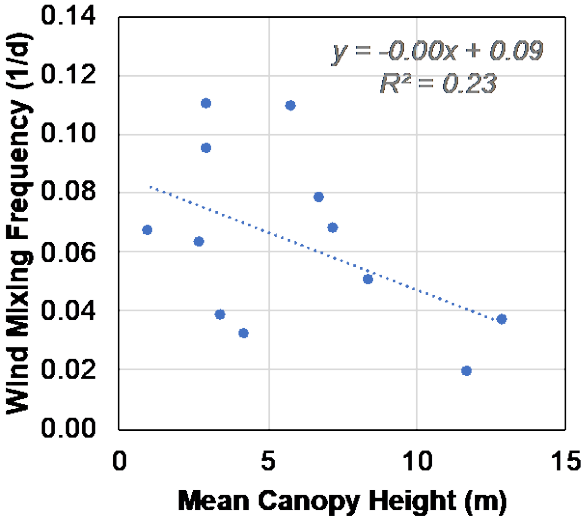


Canopy Height, Density



Canopy Extent





Risk Factors of Reduced P Retention in Ponds

- Importance of wind sheltering
- Duckweed coverage during summer months
  - Stratification => Low DO near sediments

Risk Factors of Reduced P Retention in Ponds

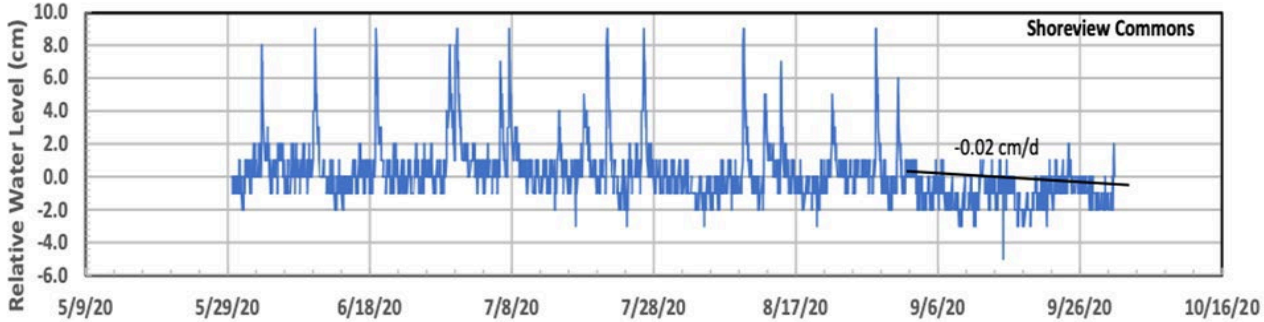
- Wind sheltering (How much sheltering is sufficient?)
- Duckweed coverage during summer months
- Documented phosphate release due to low DO near the bottom

Risk Factors of Reduced P Retention in Ponds (Volume Released)

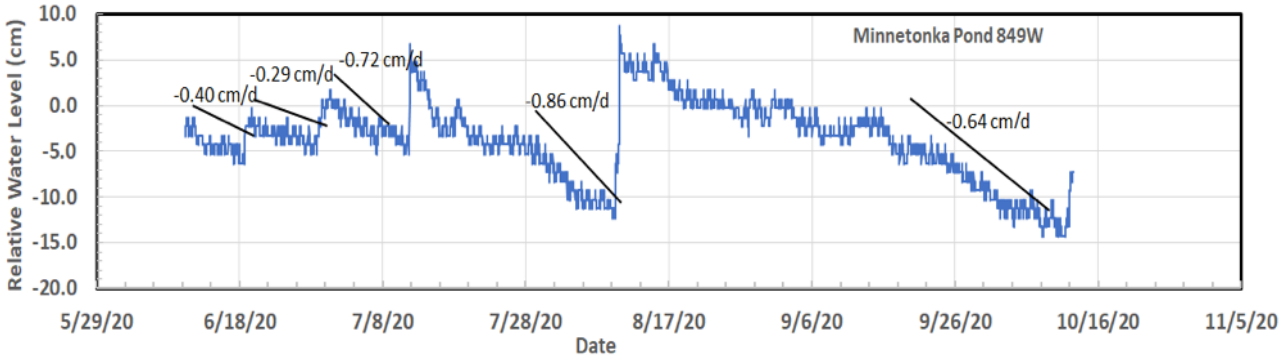
How rapidly / how far does water level decrease during dry periods?

Water Level Relative to Elevation at Which Discharge Begins (d=0)

Low Retention = High Risk



High Retention =Low Risk



Take Home Messages

- Infiltration has many benefits
  - Volume Reduction – a high % of the WQ storm and smaller can be infiltrated.
  - Reduced Peak Flow
  - Filtration through soil – remove solids, bacteria and nutrients and metals associated with solids.
  - Temperature control through GW recharge – important for trout streams
  - Increase base flow in streams
- Challenges of infiltration
  - Can pollute Groundwater
  - Failure to Infiltrate
    - Need expertise in soil profiling
    - Different kind of excavation and grading
- Plants will help infiltrate and reduce maintenance

Take Home Messages

- Filtration is very good at retaining particulates
  - Plants help reduce clogging (biofiltration facilities)
  - Do not retain dissolved contaminants
  - Additives like iron filings can help
- Need to look after our stormwater ponds
  - Many are stratified and releasing phosphate
  - Wind sheltering => more stratified days
  - Solutions are currently being researched
  - These systems are complex – solutions will take time and effort

Questions?