Groundwater Impacts from Stormwater Infiltration: a potpourri of known unknowns?

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There are concerns within both the stormwater and groundwater communities about groundwater impacts from stormwater.

Are those concerns warranted?

Outline

- Stormwater infiltration 101
- Potential impacts to groundwater
  - Water quality
  - Water quantity/hydrology
- What next?

NOTE: this presentation focuses on stormwater control practices, not regional infiltration practices

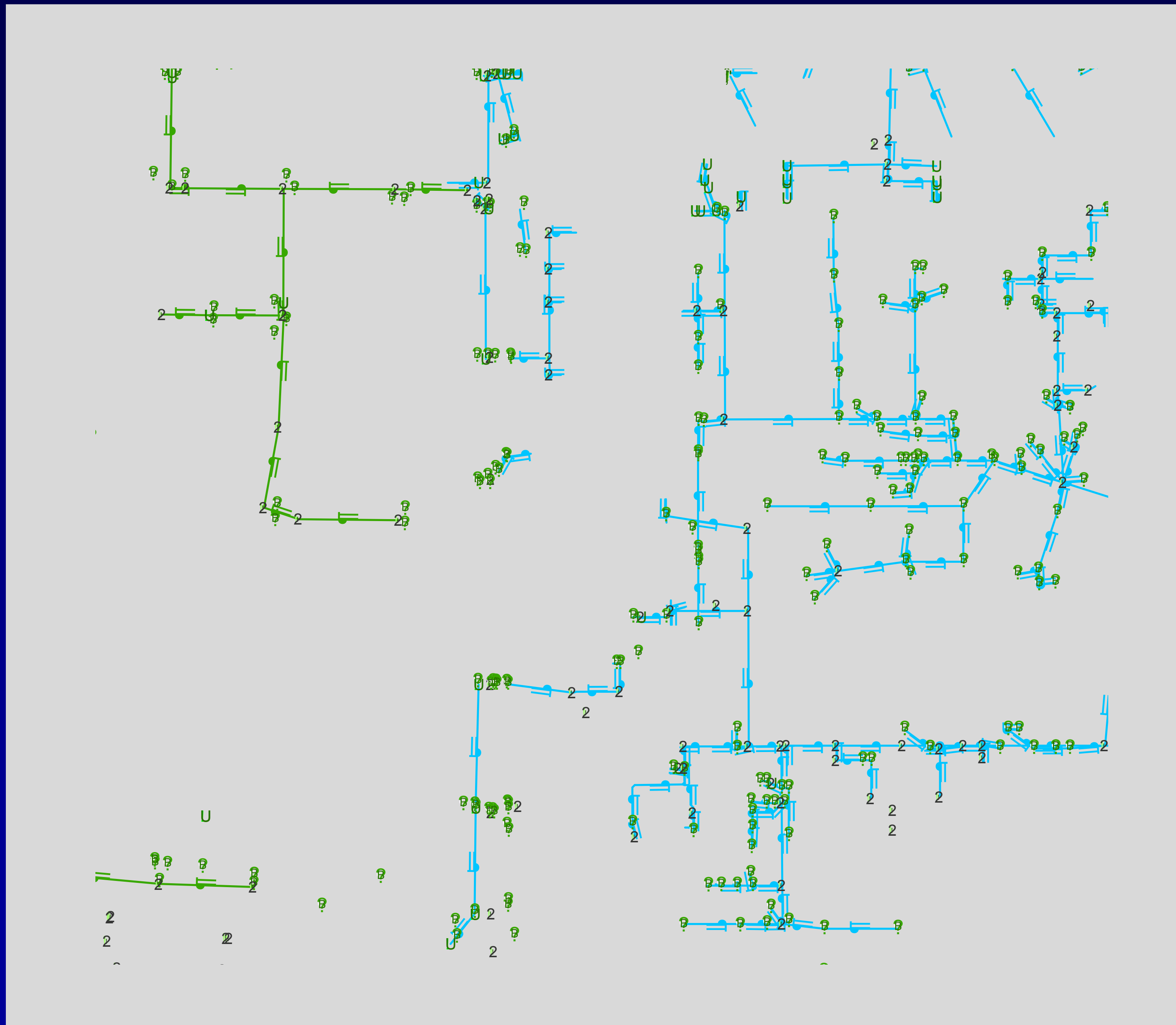
Stormwater runoff

- Precipitation or snowmelt that does not percolate or evaporate and flows over land
- Runoff accumulates debris, chemicals, sediment
- Primary method to control stormwater discharges is the use of BMPs

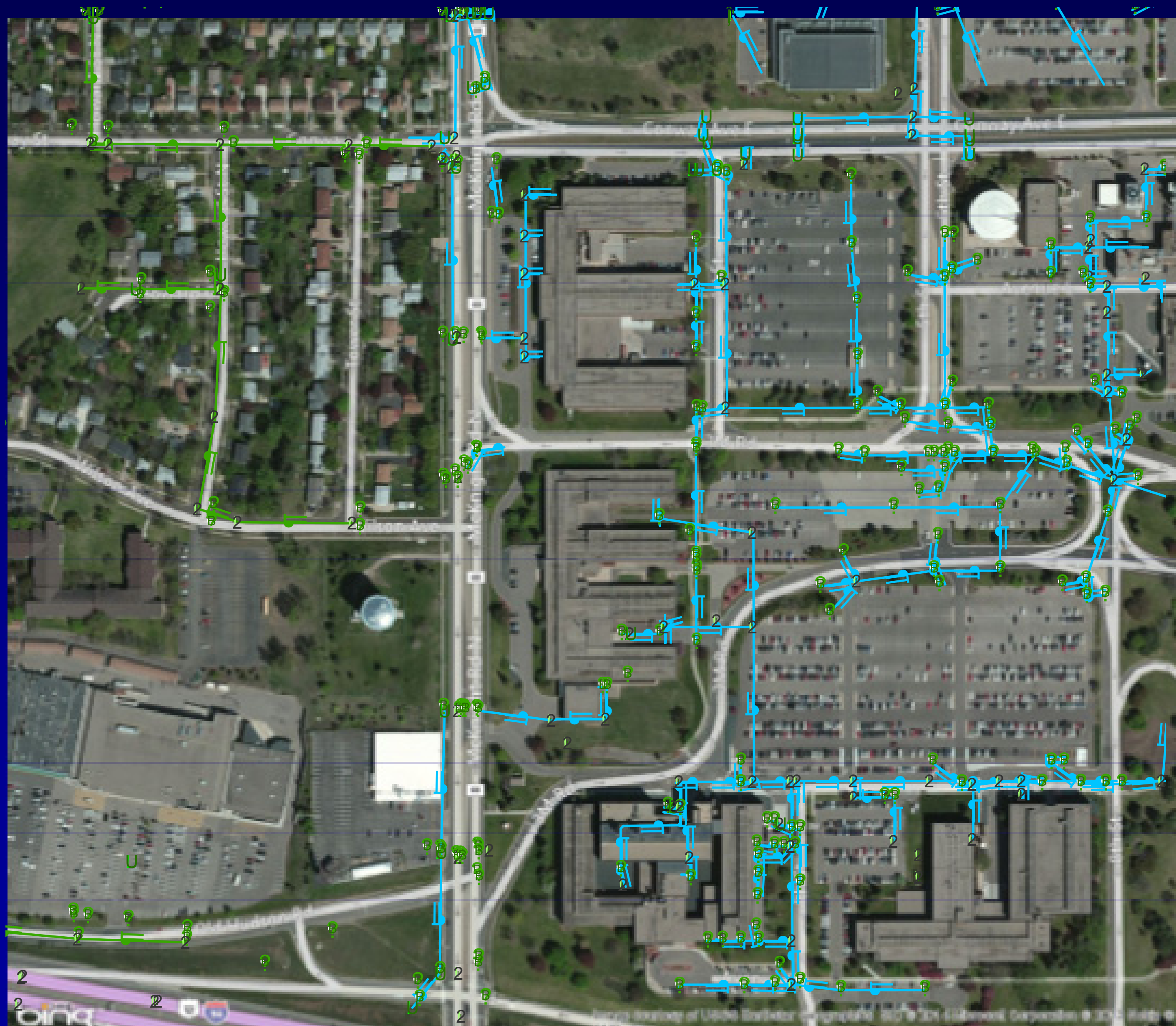
- Not just an urban phenomenon

The average person sees roads, parking lots, houses

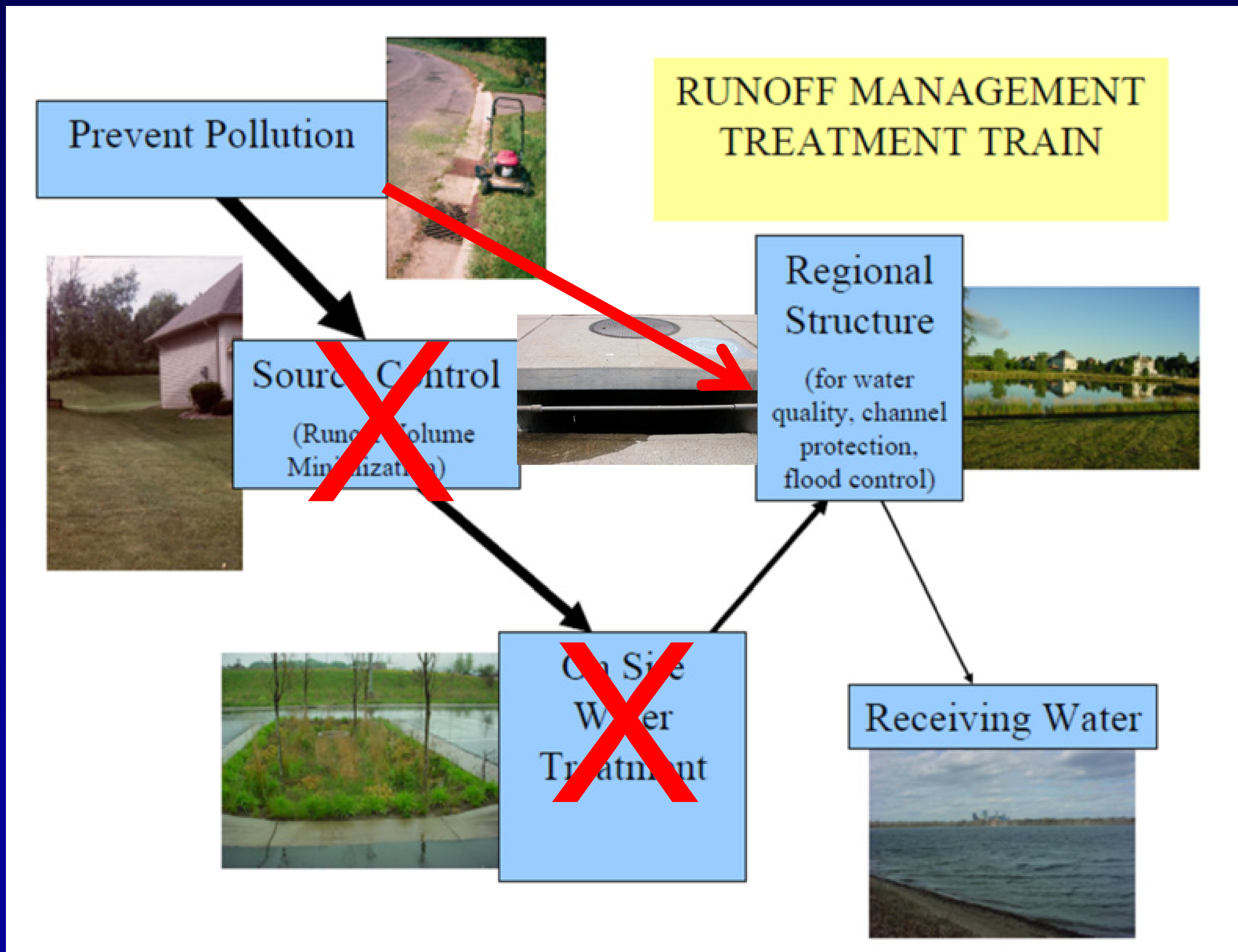
The stormwater engineer sees this



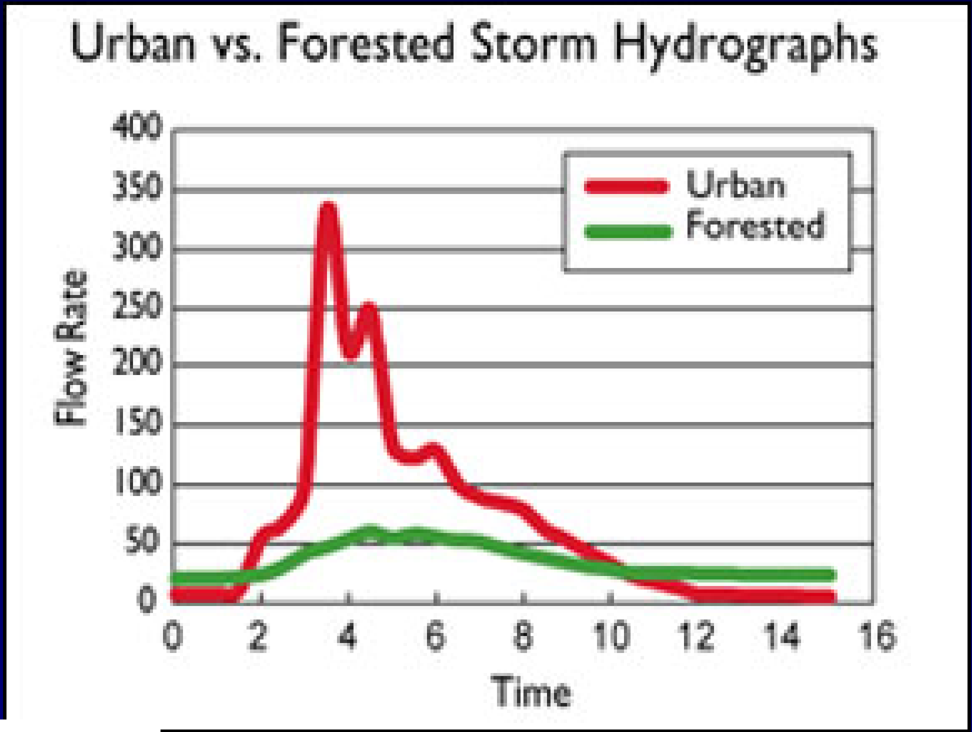
Urban areas have artificial hydrologic conveyance systems



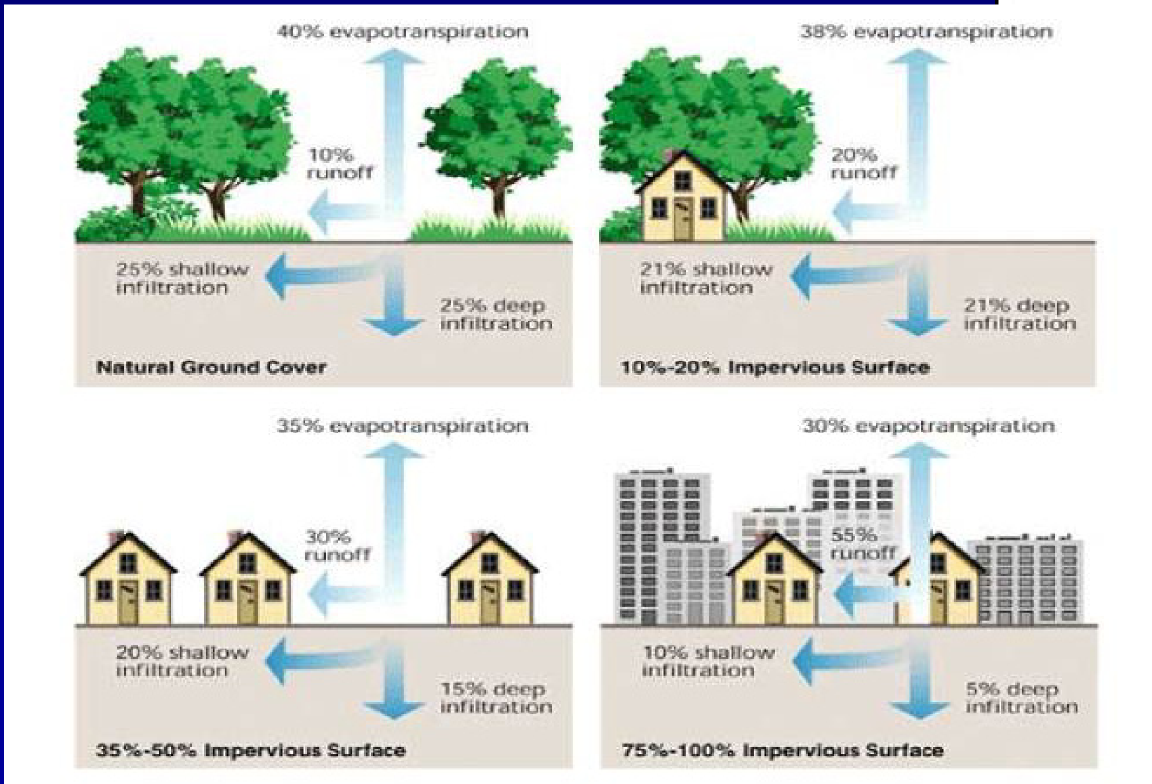
Until maybe the past 10 years or so, the goal was to get water off the landscape



Connected impervious surfaces: more runoff and flashy hydrographs



Maryland Sea Grant



Federal Interagency Stream Restoration Working Group

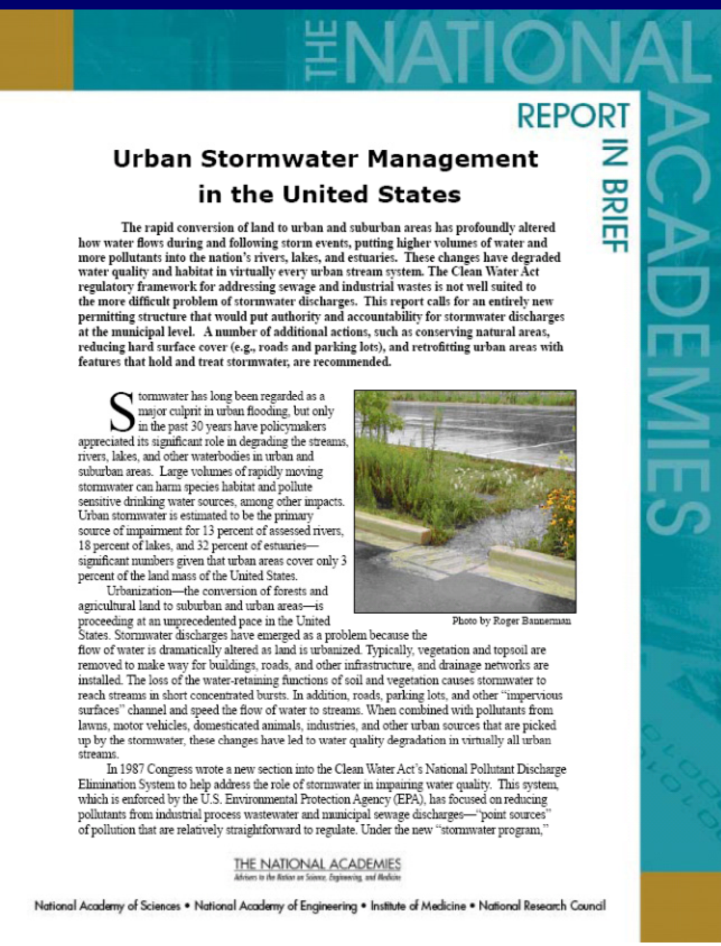
Photo: Clinton River Watershed Council

Photo: Univ. North Carolina, Chapel Hill

Photo: NOAA

National Academies 2008 report

"Past practices…have been ineffective at protecting water quality in receiving waters … Stormwater control measures that harvest, infiltrate, and evapotranspire stormwater are critical to reducing the volume and pollutant loading of small storms"



THE NATIONAL ACADEMIES

REPORT IN BRIEF

Urban Stormwater Management in the United States

The rapid conversion of land to urban and suburban areas has profoundly altered how water flows during and following storm events, putting higher volumes of water and more pollutants into the nation's rivers, lakes, and estuaries. These changes have degraded water quality and habitat in virtually every urban stream system. The Clean Water Act regulatory framework for addressing sewage and industrial wastes is not well suited to the more difficult problem of stormwater discharges. This report calls for an entirely new permitting structure that would put authority and accountability for stormwater discharges at the municipal level. A number of additional actions, such as conserving natural areas, reducing hard surface cover (e.g., roads and parking lots), and retrofitting urban areas with features that hold and treat stormwater, are recommended.

Stormwater has long been regarded as a major culprit in urban flooding, but only in the past 30 years have policymakers appreciated its significant role in degrading the streams, rivers, lakes, and other waterbodies in urban and suburban areas. Large volumes of rapidly moving stormwater can harm species habitat and pollute sensitive drinking water sources, among other impacts. Urban stormwater is estimated to be the primary source of impairment for 13 percent of assessed rivers, 18 percent of lakes, and 32 percent of estuaries—significant numbers given that urban areas cover only 3 percent of the land mass of the United States.

Photo by Roger Bannerman

Urbanization—the conversion of forests and agricultural land to suburban and urban areas—is proceeding at an unprecedented pace in the United States. Stormwater discharges have emerged as a problem because the flow of water is dramatically altered as land is urbanized. Typically, vegetation and topsoil are removed to make way for buildings, roads, and other infrastructure, and drainage networks are installed. The loss of the water-retaining functions of soil and vegetation causes stormwater to reach streams in short concentrated bursts. In addition, roads, parking lots, and other "impervious surfaces" channel and speed the flow of water to streams. When combined with pollutants from lawns, motor vehicles, domesticated animals, industries, and other urban sources that are picked up by the stormwater, these changes have led to water quality degradation in virtually all urban streams.

In 1987 Congress wrote a new section into the Clean Water Act's National Pollutant Discharge Elimination System to help address the role of stormwater in impairing water quality. This system, which is enforced by the U.S. Environmental Protection Agency (EPA), has focused on reducing pollutants from industrial process wastewater and municipal sewage discharges—"point sources" of pollution that are relatively straightforward to regulate. Under the new "stormwater program,"

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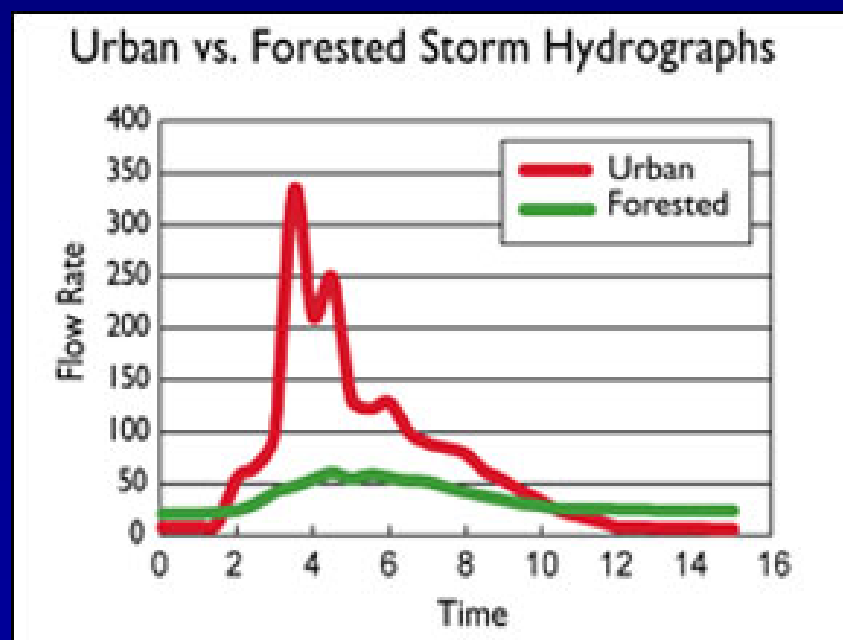
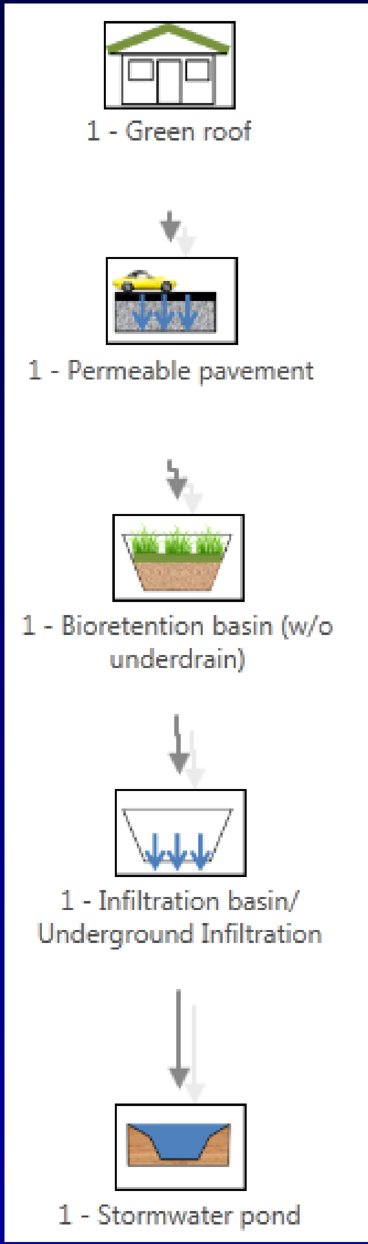


Overview of Infiltration BMPs

- Bioretention (rain gardens)
- Tree boxes/trenches
- Infiltration basins/trenches
- Permeable pavement
- Swales
- Turf management / impervious disconnection



Stormwater treatment train

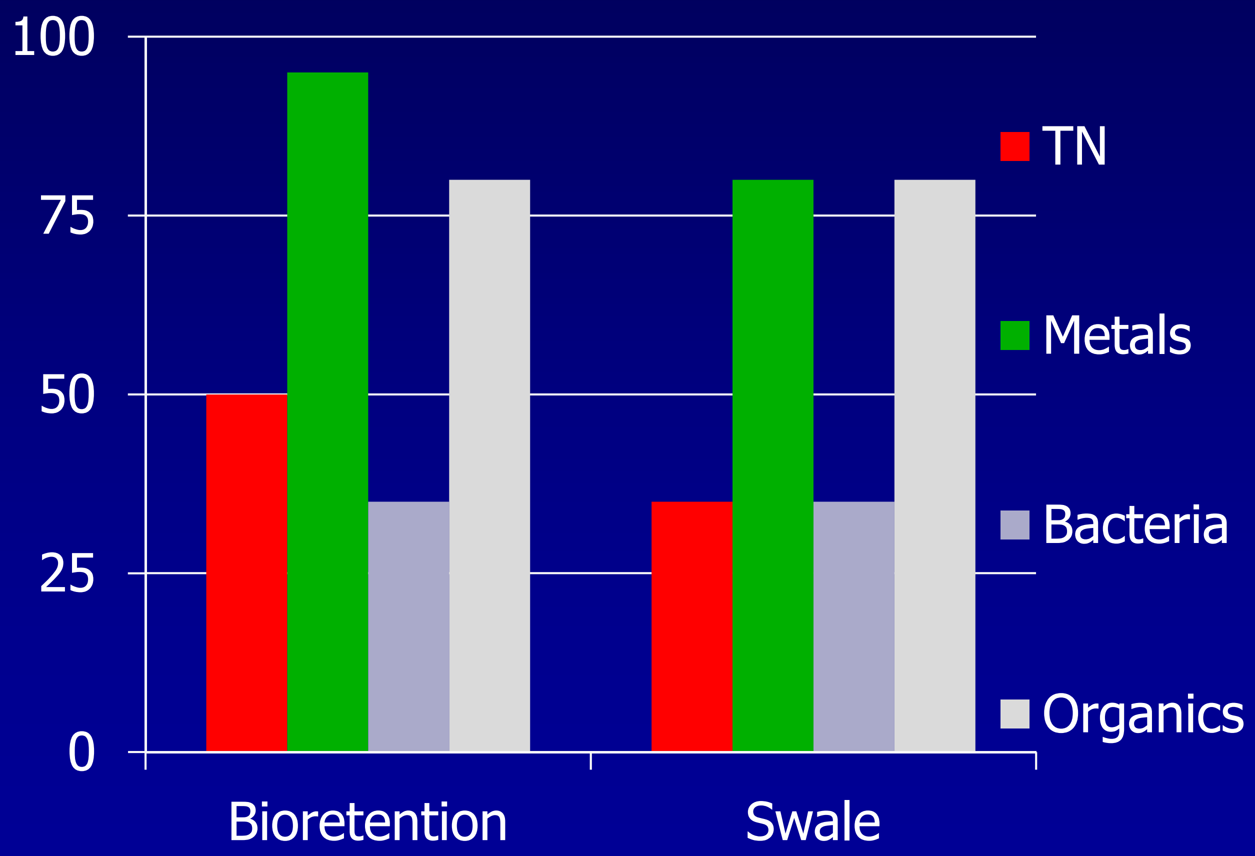
BMP = Treatment system

Nonpoint source BMPs are specific practices or activities used to **reduce or control impacts** to water bodies from nonpoint sources, most commonly by reducing the loading of pollutants from such sources into storm water and waterways.

Photo: Capitol Region Watershed District

Photo: South Brunswick Township

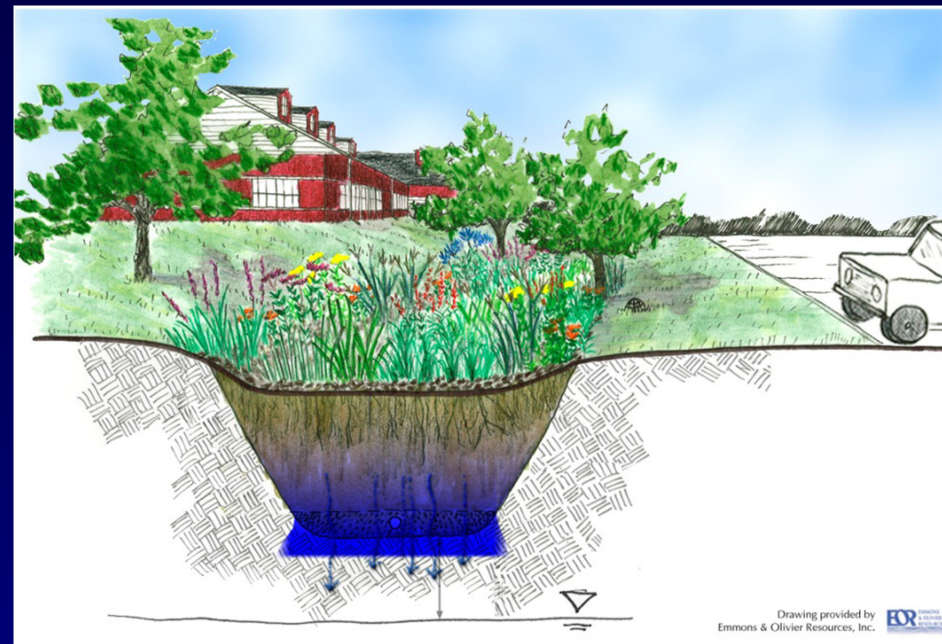
Stormwater Infiltration BMP = Treatment system



Pollutant removal % (MN SW Manual)

Bioretention/ Bioinfiltration (rain garden)

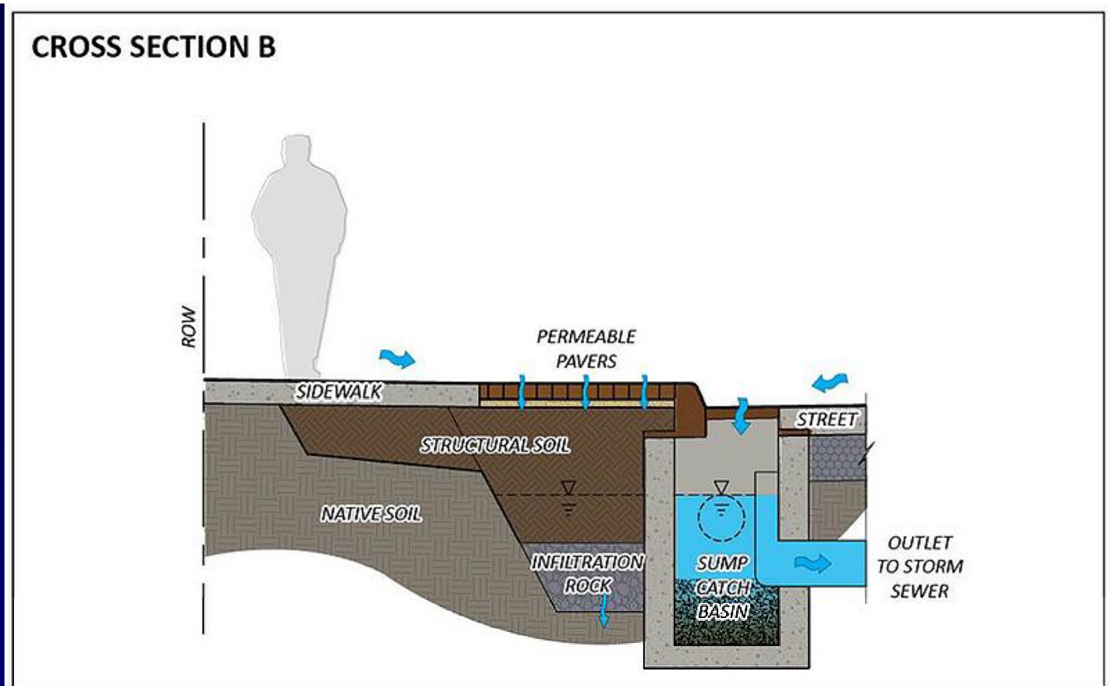
- Organic media and vegetation
- 5 acres or less
- Small storm events
- Throughout the treatment train
- Treatment mechanisms: filtering, settling, biological, ET, adsorption



Burnsville rain garden. Photo: Barr Engineering

Tree box or trench (bioretention)

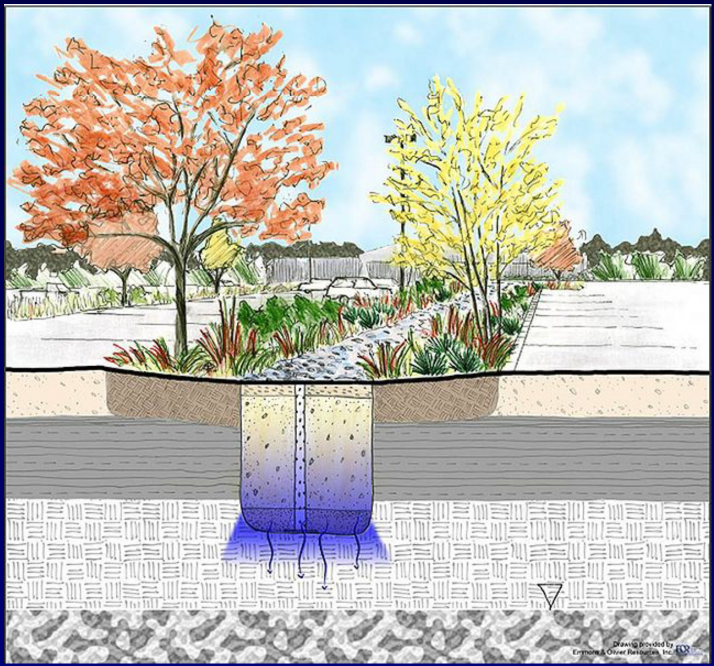
- Engineered media
- Small storm events
- Throughout treatment train
- Good retrofit BMP
- Treatment mechanisms: filtering, settling, biological, ET, adsorption



Images: Capitol Region Watershed District

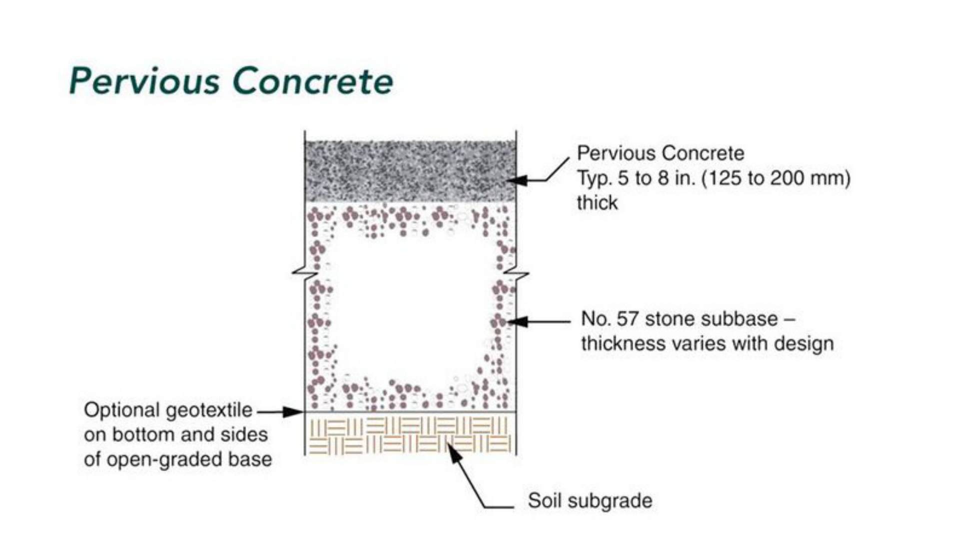
Infiltration basin/trench

- Pretreatment needed
- Up to 50 acres
- Medium to large storm events
- Downgradient in treatment train
- Treatment mechanisms: primarily filtering; some adsorption, biological



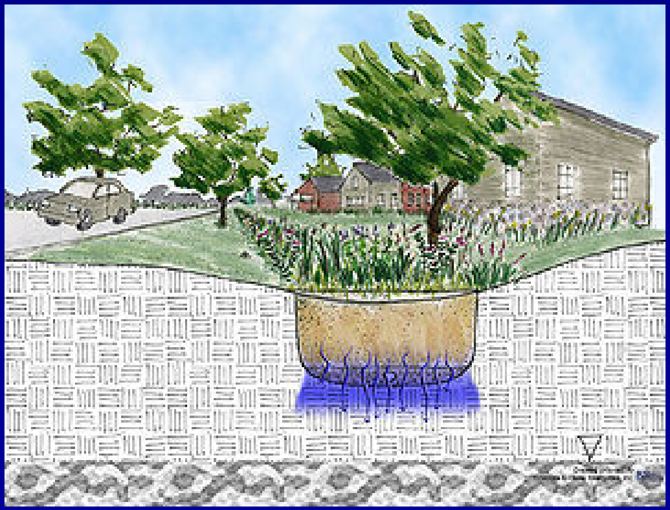
Permeable Pavement

- Pretreatment required
- Regular maintenance
- Size varies
- Anywhere in treatment train
- Treatment mechanism: primarily filtering

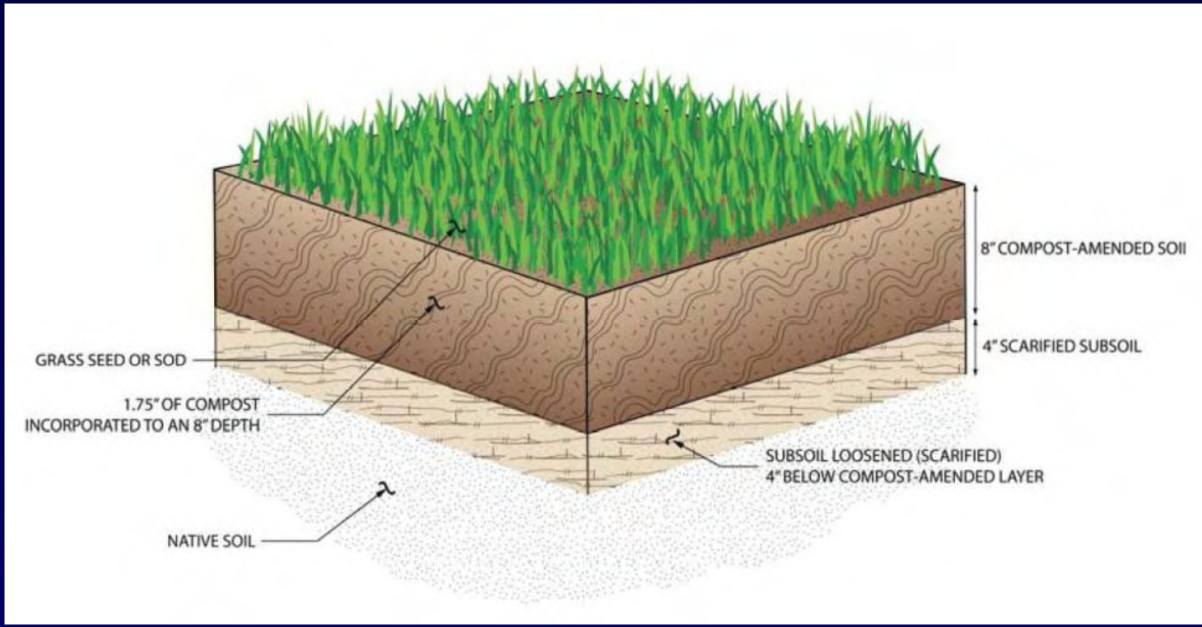


Swales/grass channels

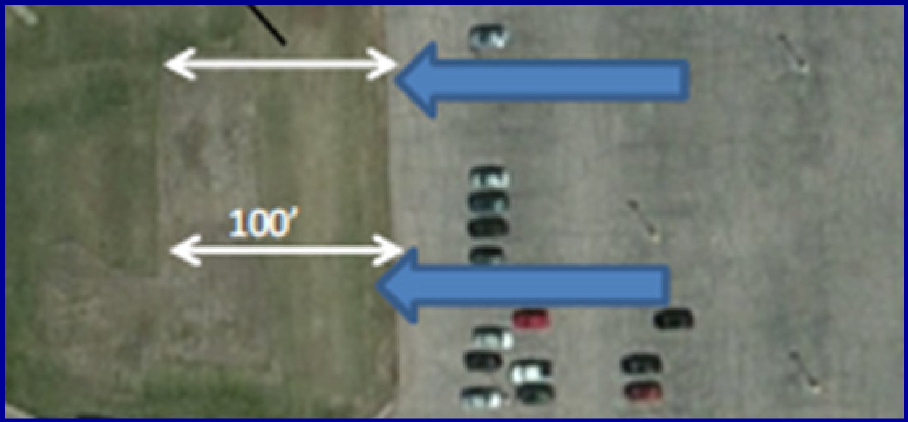
- Can infiltrate water if soils are highly permeable
- Primarily a filtration BMP
- Anywhere in treatment train
- Treatment mechanism: primarily filtering; some biological, adsorption



Other infiltration practices



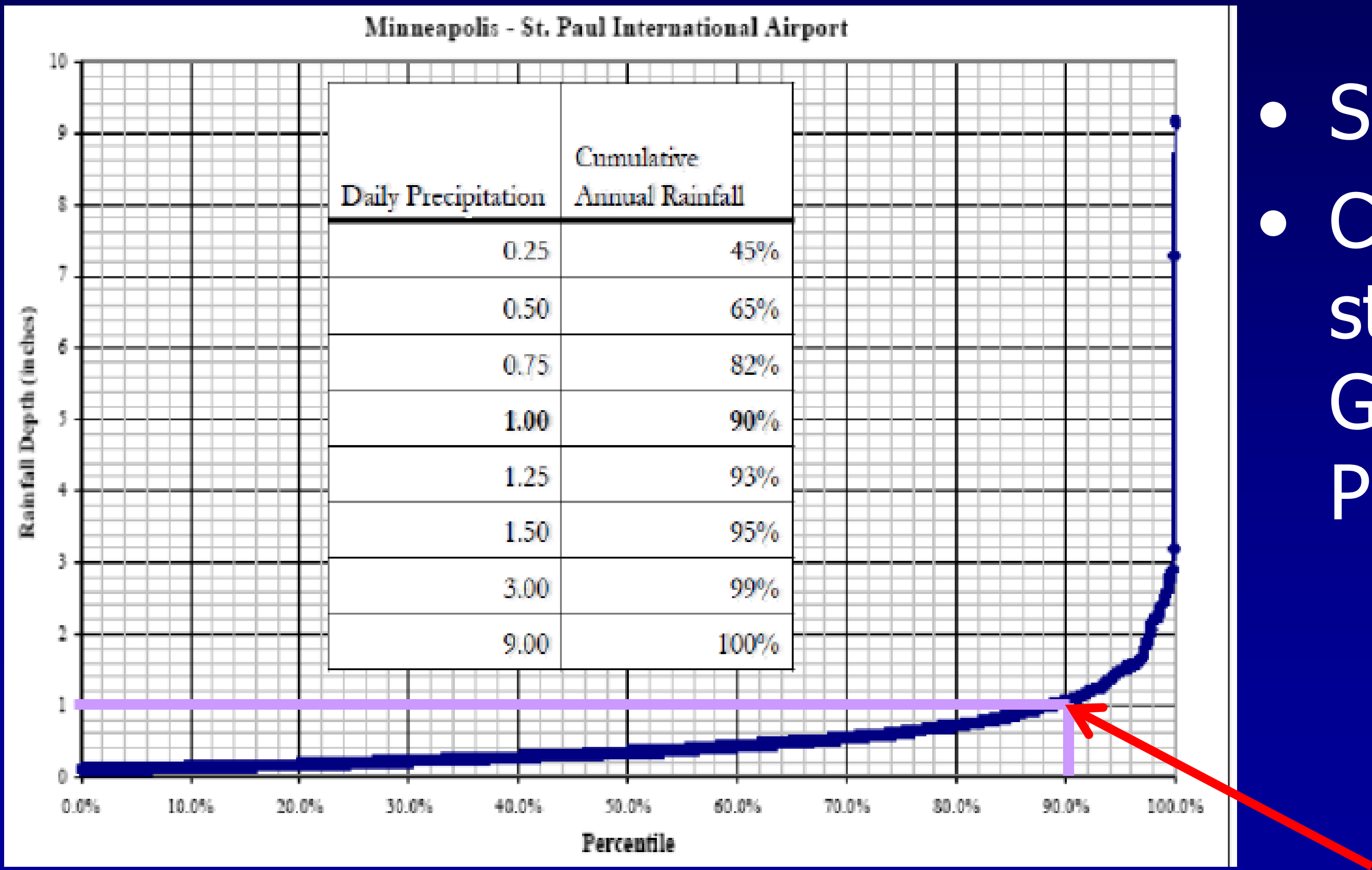
- Improved turf
- Impervious surface disconnection
- Treatment mechanism: function of the receiving area



Volume reduction requirements are becoming more prevalent

- Several WMO’s in Metro area
- Construction stormwater General Permit
- Municipal stormwater General Permit
- Cities, counties, etc.

Volume reduction requirements are becoming more prevalent



Daily Precipitation	Cumulative Annual Rainfall
0.25	45%
0.50	65%
0.75	82%
1.00	**90%**
1.25	93%
1.50	95%
3.00	99%
9.00	100%

- Several LGUs
- Construction stormwater General Permit

Regulations and guidance

- Permits
- No effluent standards for stormwater infiltration discharges to groundwater
- 7060.0500 NONDEGRADATION POLICY
- Guidance
  - EPA Brownfield guidance
  - MDH Wellhead guidance
  - Minnesota Stormwater

These guidance documents tell you how to infiltrate and when not to infiltrate

Construction stormwater permit

- Requires 3 foot separation from BMP to water table
- Requires pretreatment for infiltration BMPs
- Requires on-site soil testing
- Has prohibitions (karst, DWSMA, etc.)
- Refers permittees to guidance in MN Stormwater Manual

Minnesota Stormwater Manual

Bioretention

Stormwater wetlands > Pollution prevention > Bioretention

Minimal Impact Design Standards
for enhancing stormwater management in Minnesota

Bioretention is a terrestrial-based (up-land as opposed to wetland) water quality and water quantity control process. Bioretention employs a simplistic, site-integrated design that provides opportunity for runoff infiltration, filtration, storage, and water uptake by vegetation.

Bioretention areas are suitable stormwater treatment practices for all land uses, as long as the contributing drainage area is appropriate for the size of the facility. Common bioretention opportunities include landscaping islands, cul-de-sacs, parking lot margins, commercial setbacks, open space, rooftop drainage and street-scapes (i.e., between the curb and sidewalk). Bioretention, when designed with an underdrain and liner, is also a good design option for treating potential stormwater hotspots (PSHs). Bioretention is extremely versatile because of its ability to be incorporated into landscaped areas. The versatility of the practice also allows for bioretention areas to be frequently employed as stormwater retrofits.

A raingarden in a commercial development, Stillwater, Minnesota.

The individual articles comprising this section on bioretention may be viewed as a single article.
Note: Due to an unresolved bug, when viewing a formula in a combined article, the math markup (used for equations) is displayed. Thanks.

Acknowledgements

Bioretention articles

- Bioretention terminology (including types of bioretention)
- Overview for bioretention
- Design criteria for bioretention
- Construction specifications for bioretention
- Operation and maintenance of bioretention
- Cost-benefit considerations for bioretention
- Soil amendments to enhance phosphorus sorption
- Supporting material for bioretention
- External resources for bioretention
- References for bioretention
- Requirements, recommendations and information for using bioretention BMPs in the MIDS calculator

MN Stormwater Manual

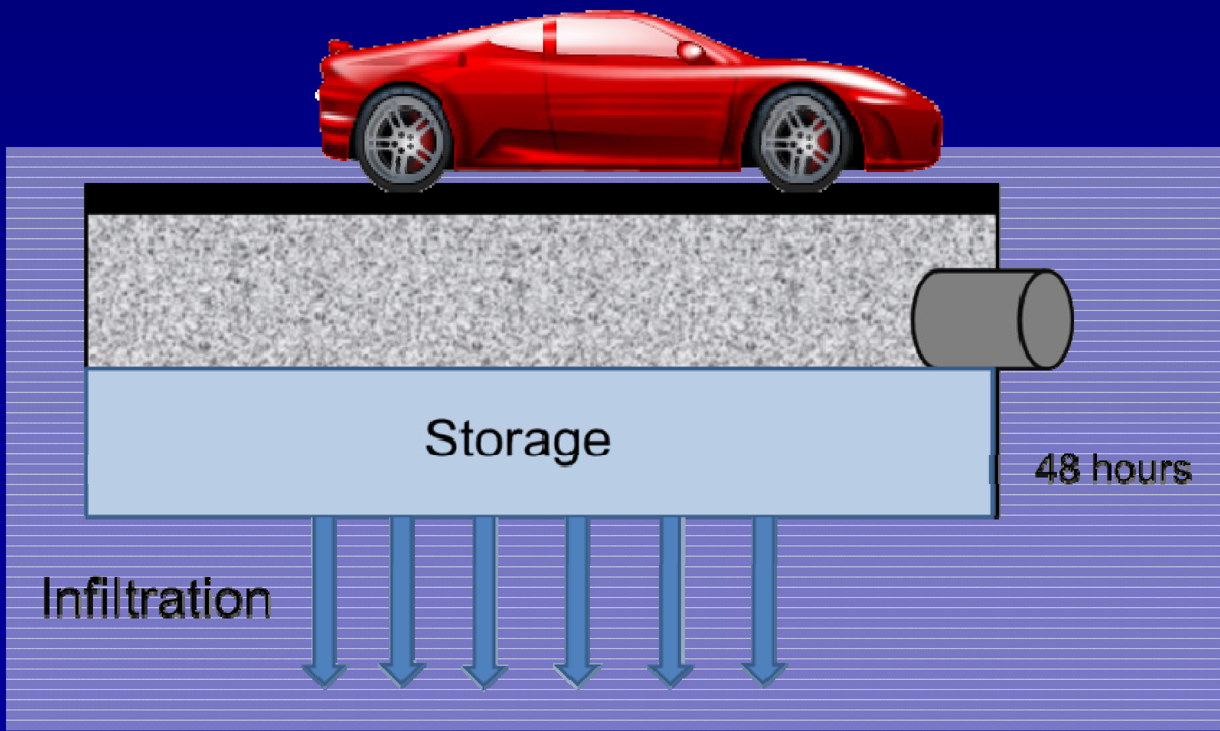
- Guidance for infiltration
  - How to determine infiltration rate at a site
  - Karst areas
  - Shallow depth to groundwater or bedrock
  - Potential stormwater hotspots
- Future guidance
  - General information on infiltration
  - Wellhead protection areas
  - Contaminated soils and groundwater
  - Mounding

Groundwater Impacts from Stormwater Infiltration – a potpourri of known unknowns?

We actually do know a fair amount and are learning more

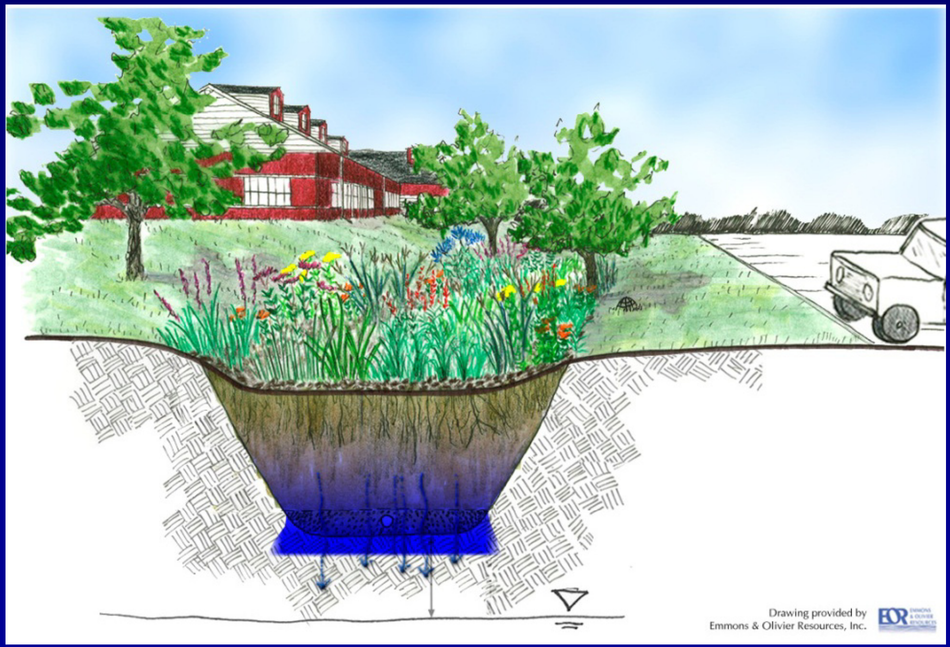
Potential impacts on groundwater

- Water quality
- Recharge
- Mounding and water levels
- Baseflow



Groundwater recharge from stormwater infiltration is highly focused

- A rain garden designed to treat 1 inch of runoff from 1 acre of impervious infiltrates could infiltrate about 39 feet of water in a year



Groundwater mounding

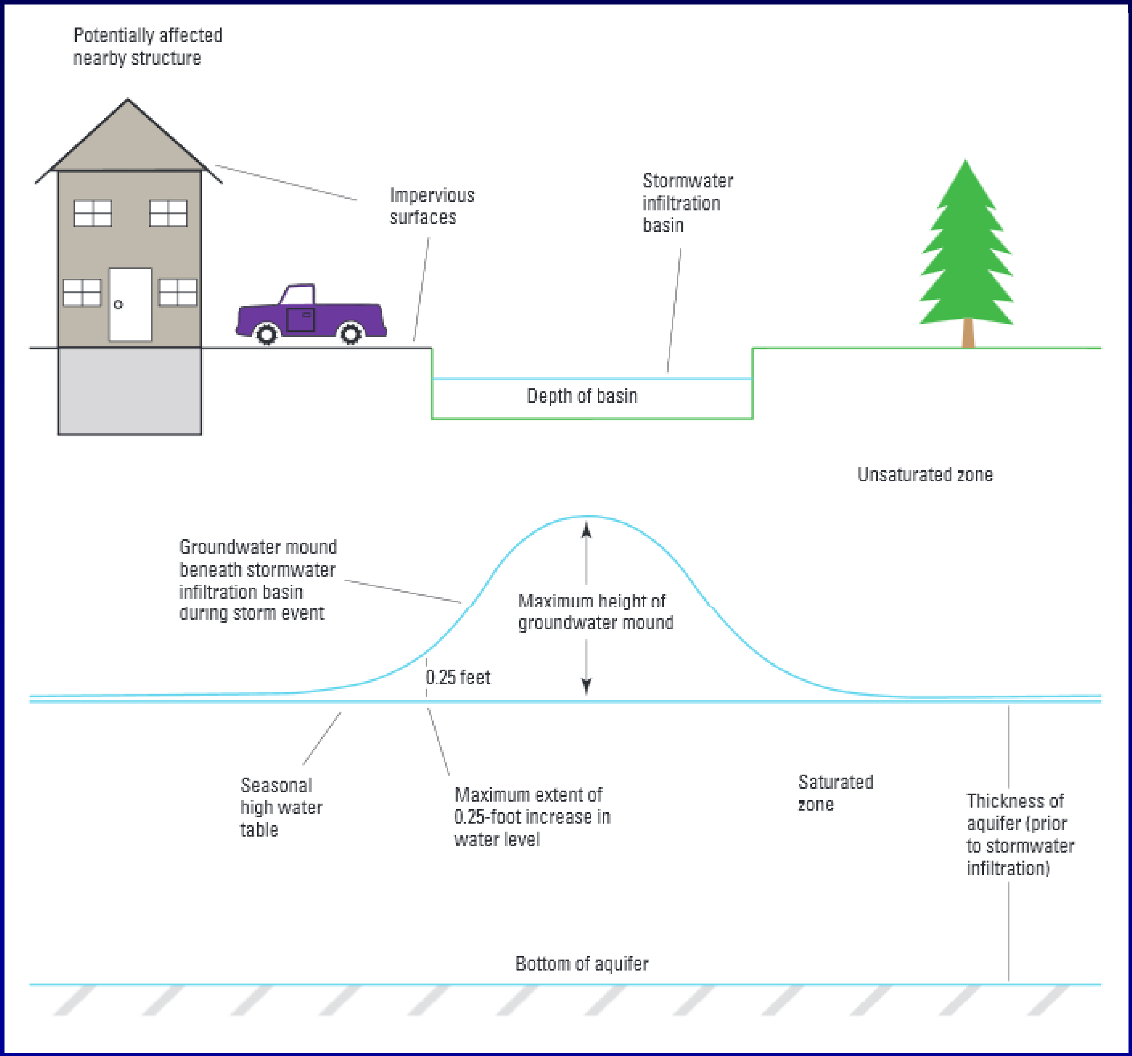
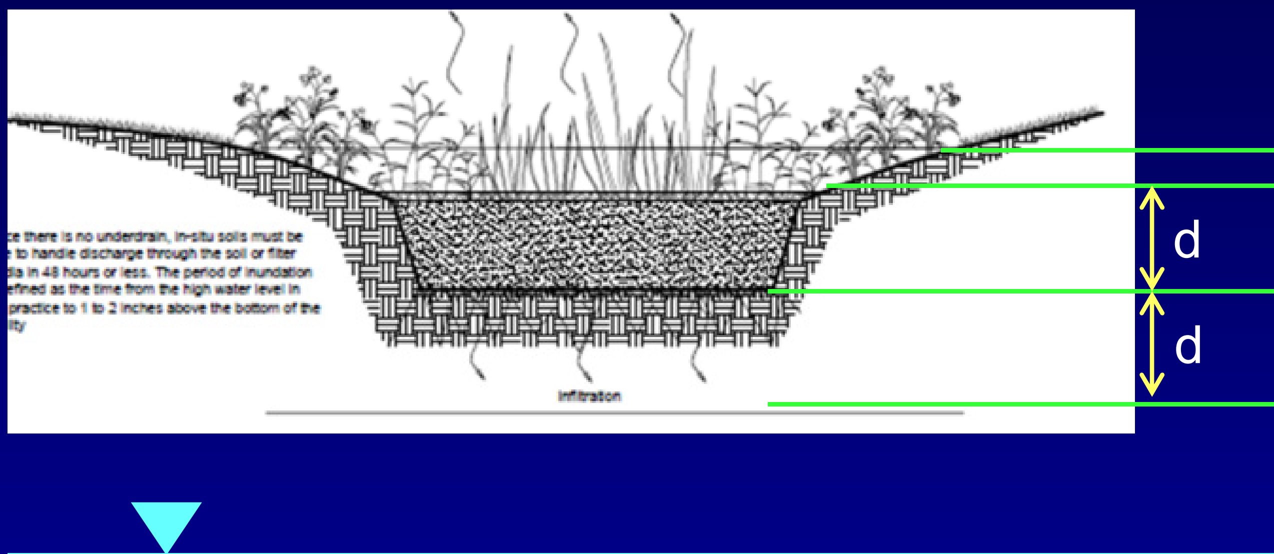


Image from USGS

- Could affect:
  - structures
  - contaminants
  - wells
  - local hydrology

General guidance – New Jersey



<u>Location of item of concern</u>

No concern

Generally no concern

Limited concern

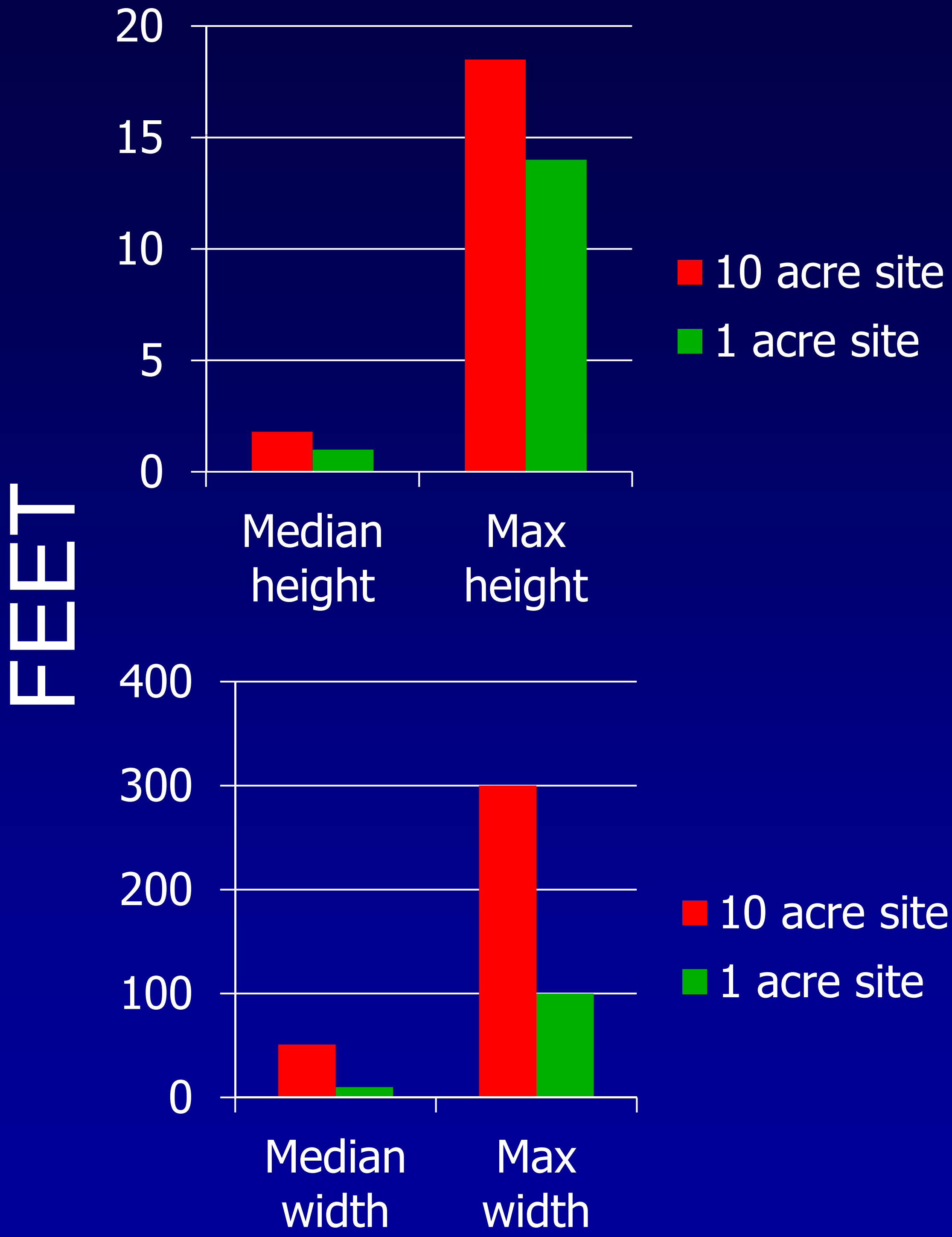
Collect soil info;
measure DTW

d = depth of media in infiltration practice

Item of concern = structure, contamination, etc.

Thompson et al. (2007)

- Analytic model assumptions
  - Known infiltration rate
  - Known travel time to water table
  - No storage losses
  - Uniform infiltration
  - Sides of infiltration practice are vertical
  - 1D flow beneath water table
- If these are violated, use numerical methods. Richard’s equation commonly used.



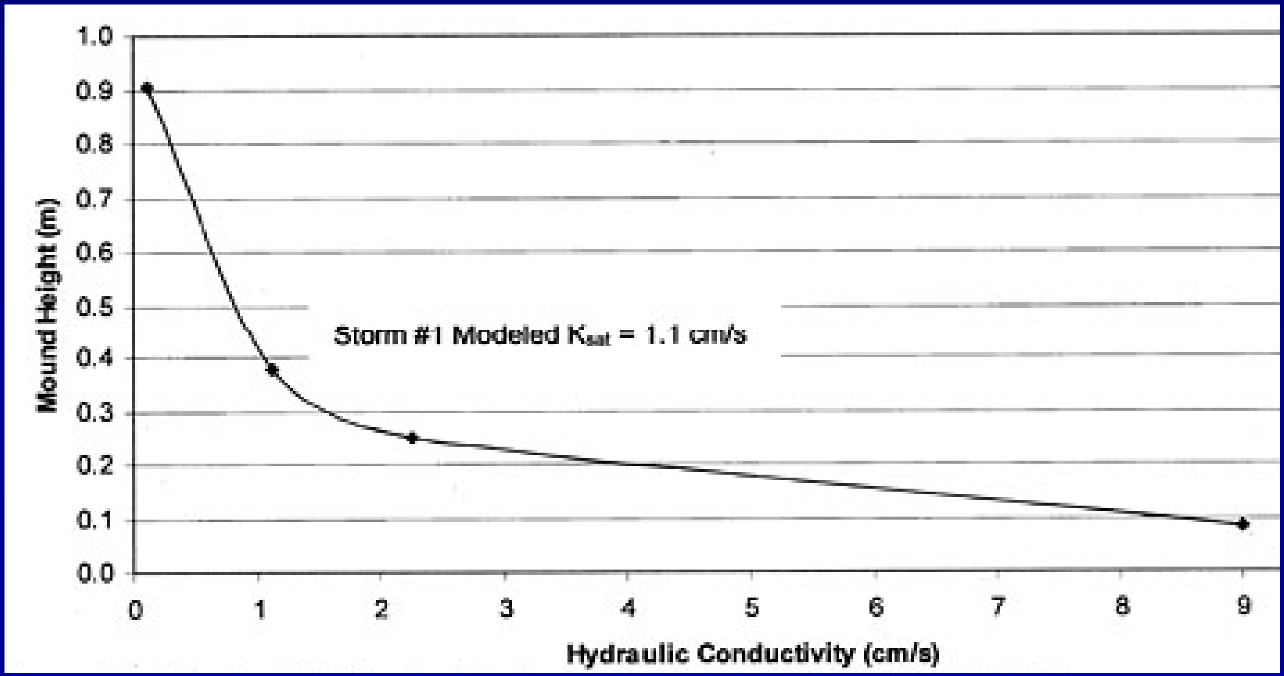
USGS simulations

(http://pubs.usgs.gov/sir/2010/5102/support/sir2010-5102.pdf)

- Used Hantush equation with simplifying assumptions
- Recommend using a flow model such as Modflow

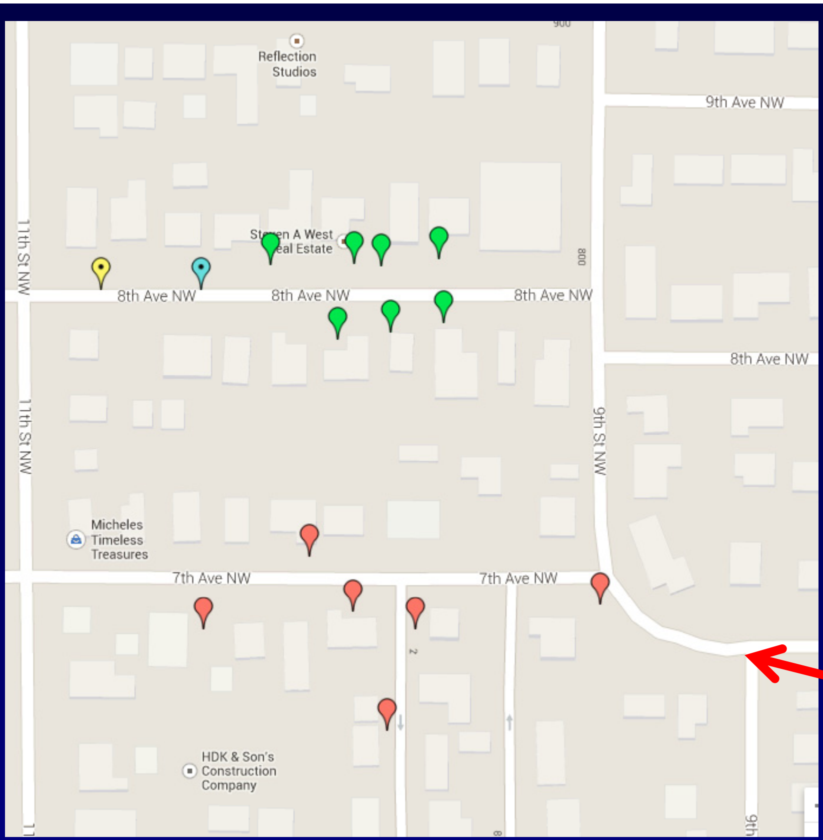
Factors that increase mounding potential

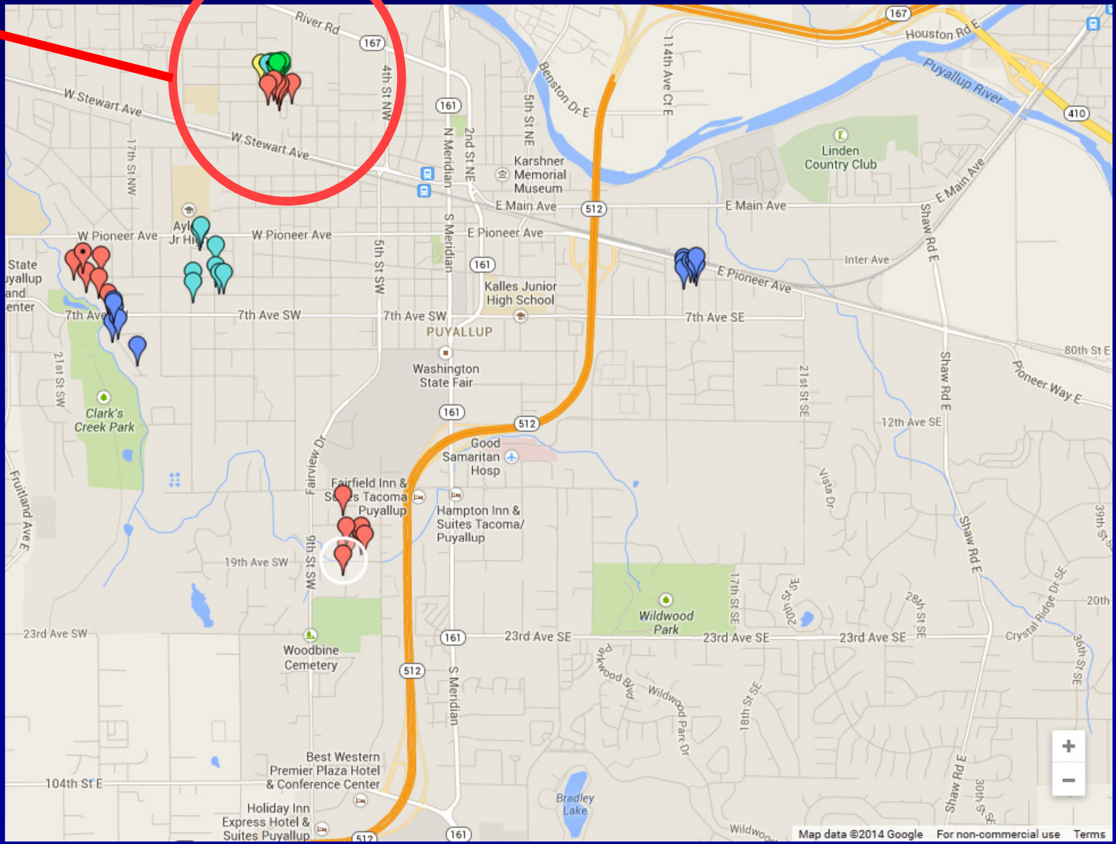
- Lower aquifer K/soil permeability
- Water table closer to surface
- Decreasing aquifer thickness
- Depth of infiltration BMP
- Square/circular and clustered BMP configurations



Thompson et al., 2007

Implementation of BMPs is opportunistic, often leading to clustered BMPs





Studies suggest the following

- Primary concern is larger rapid infiltration systems
- Conduct a site reconnaissance and identify nearby
  - structures
  - contamination
  - surface water features
  - wells
- If mounding may be a concern
  - **Get good data for unsaturated zone underlying the infiltration practice**
  - Consider different designs for the practice
  - If feasible, decrease depth of the practice

Groundwater recharge

- L.A. Study: Implementation of a ¾" infiltration standard would increase recharge by 3.12 inches/yr (http://www.usbr.gov/lc/socal/reports/LASGwtraugmentation/AppC.pdf)
- Boston study: Implementation of a 1 inch standard would increase recharge by 3.6 inches/yr (https://www.cityofboston.gov/images_documents/Stormwater%20recharge%20Boston_tcm3-31988.pdf)
- If you take the rain garden example I gave earlier, make some simple assumptions, in a watershed with 33% impervious annual recharge is about 2.5 inches

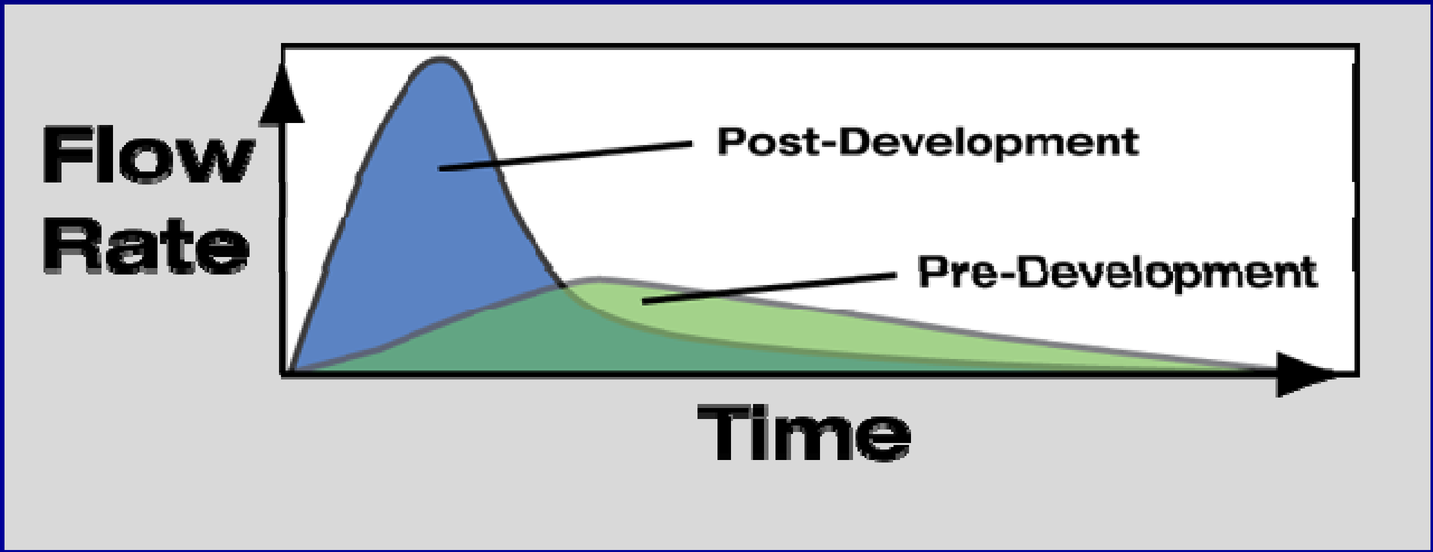
Aquifer effects – requires modeling

- Philadelphia study: Conversion of 40% of existing impervious to infiltration results in max. water table increase of 3 to 6 feet (http://www.aaees.org/downloadcenter/EESAppliedResearchandPracticeV14P1.pdf)
- Syracuse study: extensive use of bioretention in high impervious areas results in max. 7 foot increase in water table after 30 years (Endreny and Collins; Ecological Engineering, 35 (2009), 670-677)

Effects on baseflow

Can stormwater infiltration increase baseflow (primary objective is to restore stream hydrology)?

Photo: Univ. North Carolina, Chapel Hill

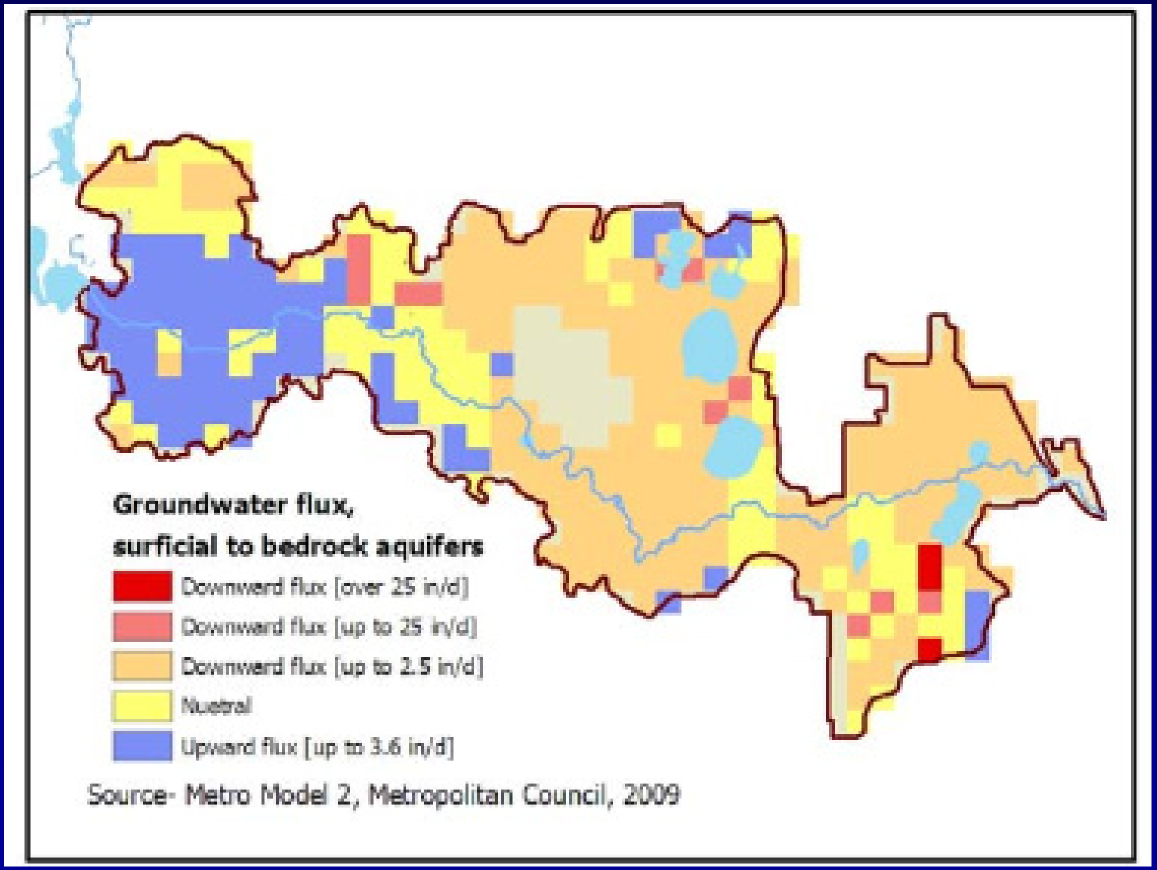


What do we mean by baseflow?

- Hamel et al. 2013 (J. Hydrol. 485:201-211)
  - Does urbanization really decrease baseflow?
  - Is the goal a pre-development regime?
  - Local or regional?
  - What indicator to use (e.g. Q90 flow)?
  - Anthropogenic effects (leaks, illicit discharges, interception, climate change)

Challenges in estimating baseflow effects

- Accounting for ET
- Accounting for deep percolation
- Tracing flow paths from the BMP
- Local complexities



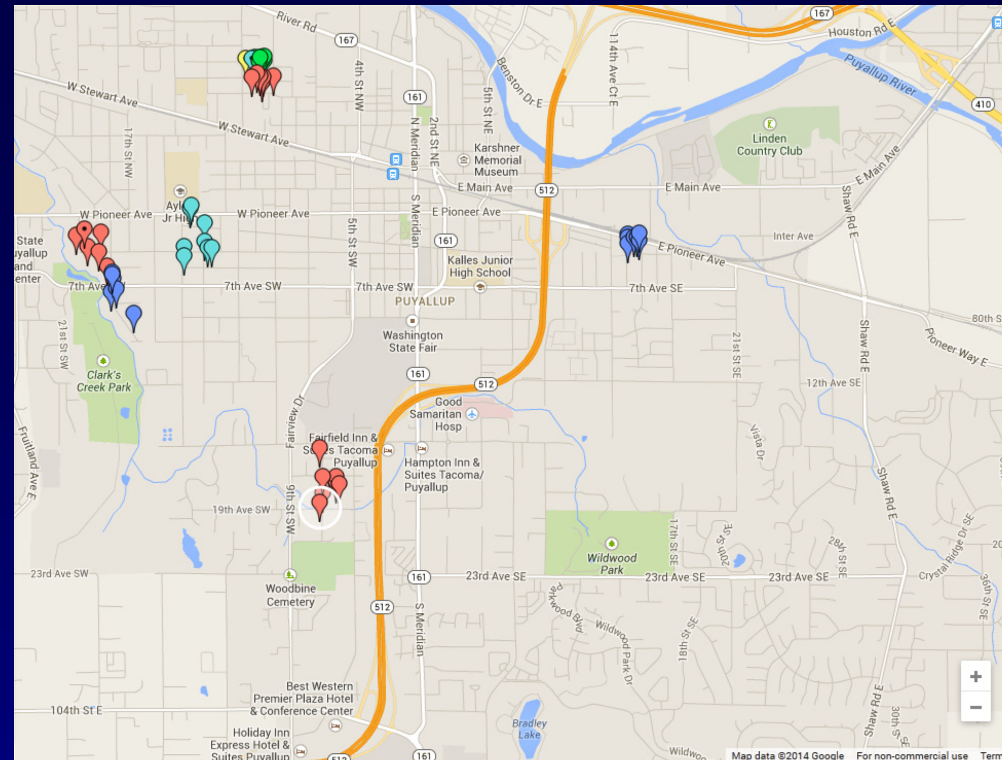
Moore et al.
https://www.google.com/search?q=minnehaha+creek+hydrogeology+profile&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:en-US:official&client=firefox-a&channel=fflb

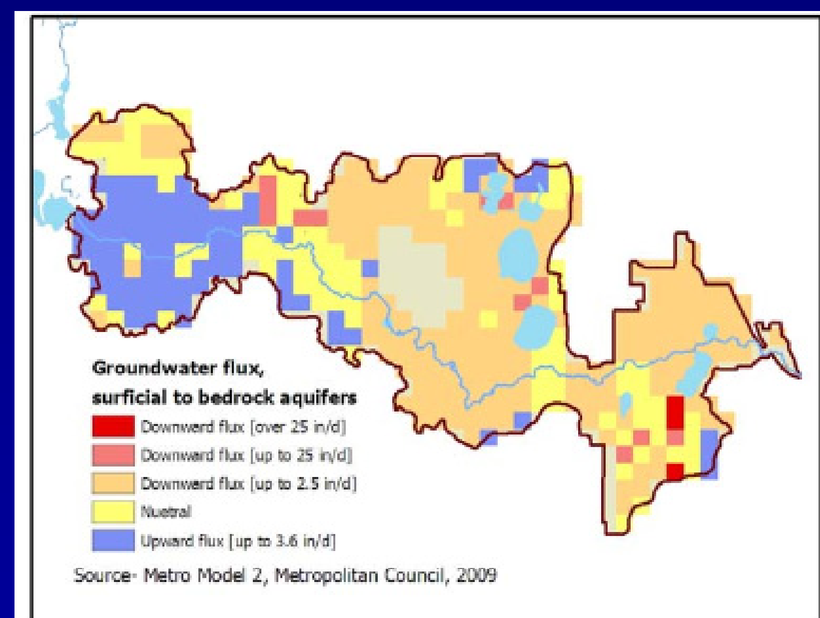
Baseflow continued

- Hamel and Fletcher (2013) (http://documents.irevues.inist.fr/bitstream/handle/2042/51322/3B81-182HAM.pdf?sequence=1)
  - Chose low flow as their metric
  - Localized structures alone could not restore low flow regime
  - Capture systems and local structures together restored low flow regime to a large extent

Managing for baseflow

- Current infiltration strategies are not consistent with promoting baseflow
- Need to understand the hydrologic system (geology, soils, anthropogenic effects)
- What is the goal?





Moore et al. 2012

What next?

- Effects of individual control structures: an area of active research, particularly water quality effects
- Regional issues
  - Few on-going studies
  - What are the questions?
  - Need detailed studies coupled with modeling
  - Regional infiltration?
- More guidance – MN Stormwater Manual is one source (http://stormwater.pca.state.mn.us/index.php/Main_Page)

Questions?

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