Infiltration BMPs

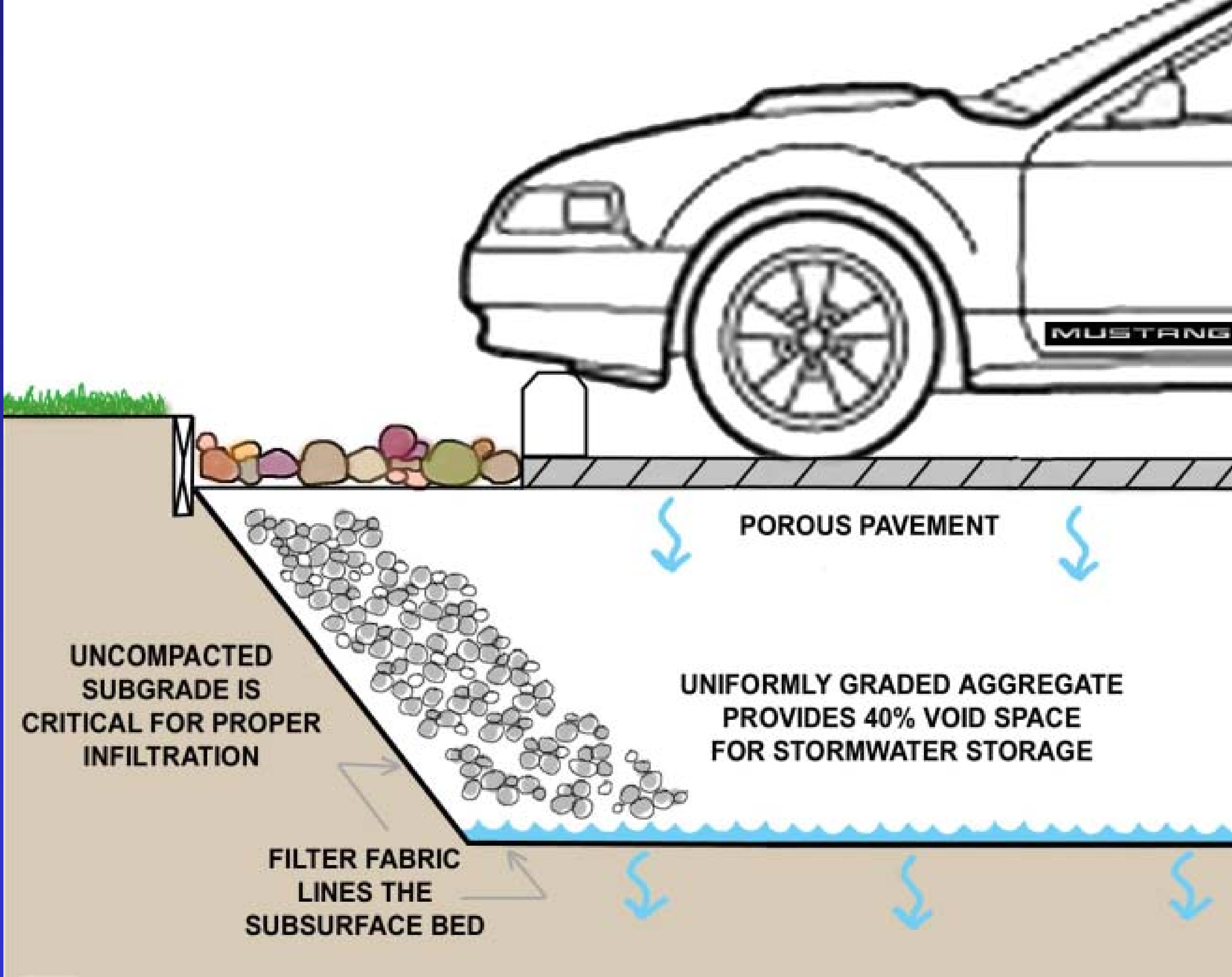
Design Guidelines

Stormwater Management in PA in the 21st Century

- **RATE CONTROL** alone is no longer adequate
- **VOLUME REDUCTION** is required
- **WATER QUALITY** (pollutant removal) is also required

VOLUME REDUCTION options

- INFILTRATION (soil mantle)
- STORAGE/REUSE (structural systems)
- VEGETATED SYSTEMS (ET)



MUSTANG
POROUS PAVEMENT
UNCOMPACTED
SUBGRADE IS
CRITICAL FOR PROPER
INFILTRATION
UNIFORMLY GRADED AGGREGATE
PROVIDES 40% VOID SPACE
FOR STORMWATER STORAGE
FILTER FABRIC
LINES THE
SUBSURFACE BED

Three Levels of Green Roofs – Stuttgart

1 – Above Parking Garage

2 – 2nd Floor

3 – Top of Building

INFILTRATION BMPS

- Infiltration Beds Beneath Porous Pavement
- Infiltration Trenches, Drains
- Infiltration Swales w/ Vegetation
- Infiltration Berms (sloped areas)
- Infiltration Planting Beds & Playfields

What about water quality?

POLLUTANT	INFILTRATION PRACTICES	*Stormwater Wetlands*	*Stormwater Ponds Wet*	*Filtering Practices*	*Water Quality Swales*	*Stormwater Dry Ponds*
Total Phosphorus	70	49	51	59	34	19
Soluble Phosphorus	85	35	66	3	38	-6
Total Nitrogen	51	30	33	38	84	25
Nitrate	82	67	43	-14	31	4
Copper	N/A	40	57	49	51	26
Zinc	99	44	66	88	71	26
TSS	95	76	80	86	81	47

Water quality benefits of porous pavement with infiltration from "National Pollutant Removal Performance Database for Stormwater Treatment Practices" Center for Watershed Protection, June 2000

Guidelines for Infiltration BMPs

- **SITE CONDITIONS and CONSTRAINTS**

  Depth to SHWT – 2 feet

  Depth to bedrock – 2 feet

  Minimum infiltration rate – 0.1”/hr.

  Setback from water supplies – 50 ft.

  Setback from buildings w/basements – 20 ft. down-gradient/100 ft. up-gradient

  Setback from septic beds – 50 ft.

  Special Areas considerations

Depth Constraints

- Derived from septic field experience
- Septic issue is GW pollution by pathogens or mounding beneath bed
- SW issue is reduced infiltration
- SW relies on soil mantle to remove NPS
- Thickness of soil required to treat NPS

Can we infiltrate SW in thinner soil mantles?

- YES, but we may have to build the bed bottom close to the surface and design finished surface grade above surface
- SHWT constraints may require seasonal variations in volume management

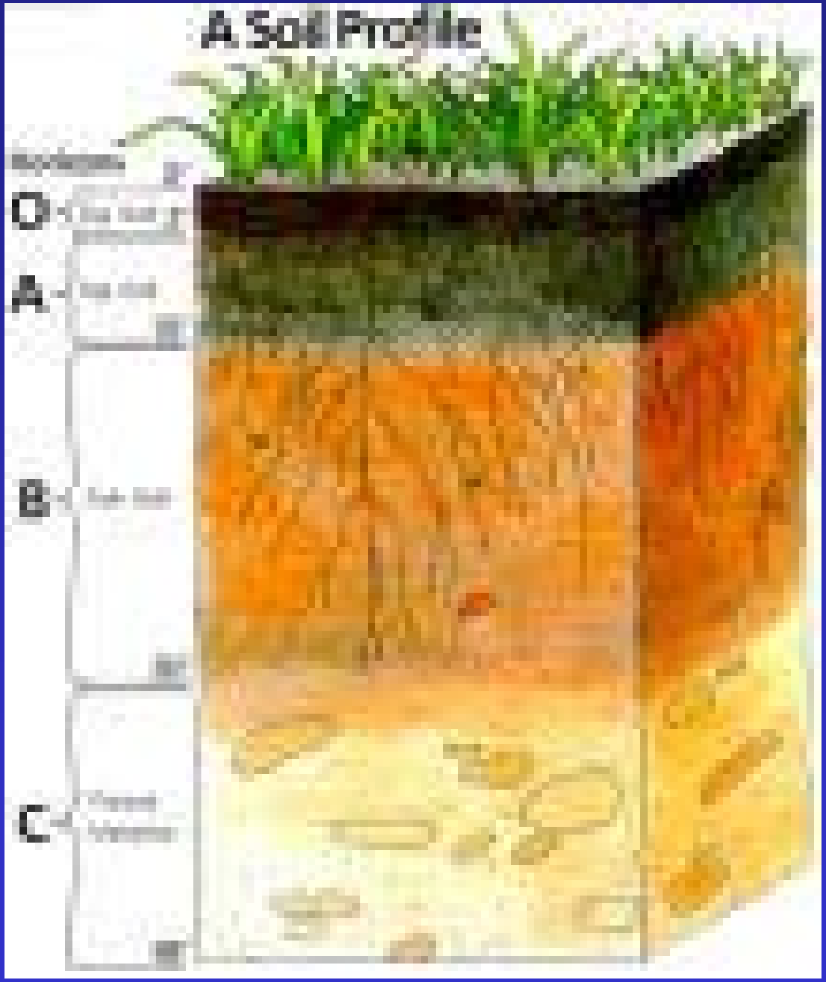
Impact of System “Failure”

- With septic bed, health impact to GW
- For SW infiltration, volume reduction is diminished on seasonal basis
- For SW, pollutant removal may be less

Slow infiltration soils

- An infiltration rate of 0.1 inches/hour will accommodate the 2-year rainfall increase in 24 hours
- Slow infiltration means increased bed area and/or depth
- Ideal infiltration rates of 0.5”/hr to 3.0 “/hr will allow greater ratio of impervious area to bed area

Soil Horizons

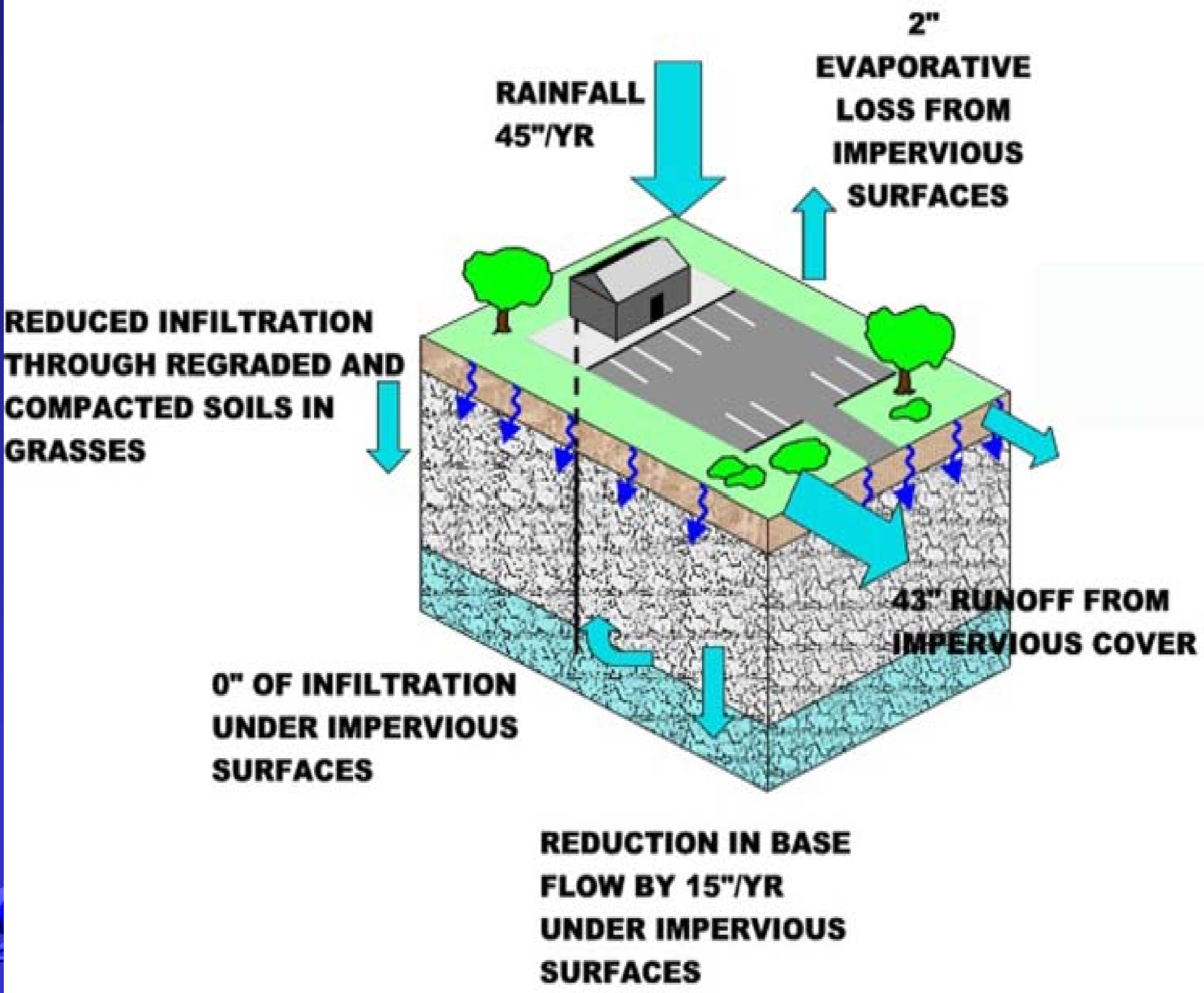


- Layer of Soil Parallel to Surface
- Properties a function of climate, landscape setting, parent material, biological activity, and other soil forming processes.
- Horizons (A, E, B, C, R, etc)

Image Source: University of Texas, 2002

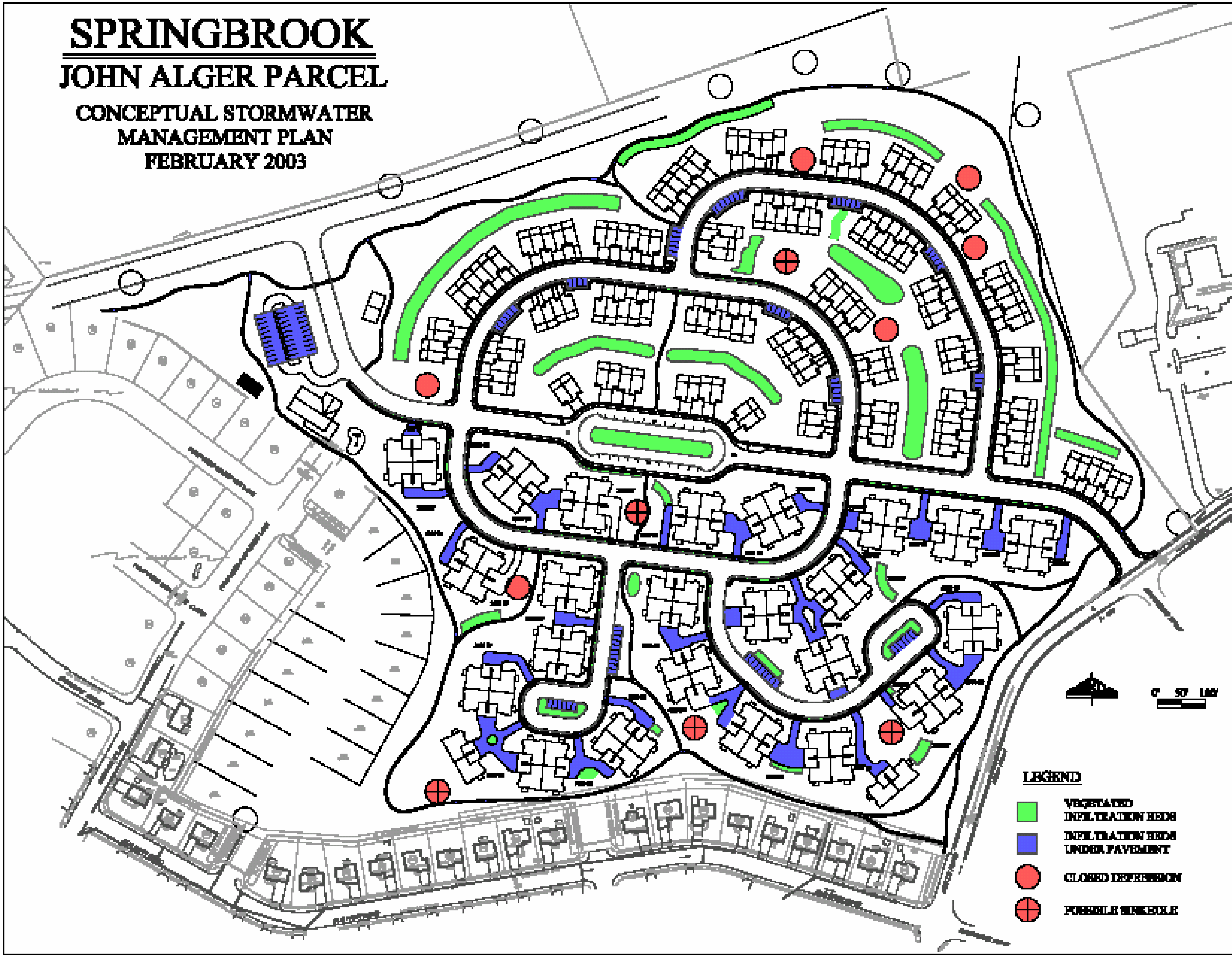
SW Setback Guidelines

- Protect GW quality
- Protect other infiltration beds (septic)
- Protect structures from seepage
- Guidelines dimension are function of relative location (up or downhill)


RAINFALL
45"/YR
2"
EVAPORATIVE
LOSS FROM
IMPERVIOUS
SURFACES
REDUCED INFILTRATION
THROUGH REGRADED AND
COMPACTED SOILS IN
GRASSES
43" RUNOFF FROM
IMPERVIOUS COVER
0" OF INFILTRATION
UNDER IMPERVIOUS
SURFACES
REDUCTION IN BASE
FLOW BY 15"/YR
UNDER IMPERVIOUS
SURFACES

Special Areas Considerations for Infiltration BMPs

- Carbonate: Distribute infiltration, don't concentrate runoff
- Urban: limited opportunity in cities
- Mining: Infiltration over abandoned seams may increase acid mine drainage
- Highways: Most soils cut or fill within ROW



SPRINGBROOK
JOHN ALGER PARCEL
CONCEPTUAL STORMWATER
MANAGEMENT PLAN
FEBRUARY 2003
LEGEND
VEGETATED INFILTRATION BEDS
INFILTRATION BEDS UNDER PAVEMENT
CLOSED DEPRESSION
POSSIBLE SINKHOLE

Guidelines for Infiltration BMPs

- **DESIGN CONSIDERATIONS**

  Do Not infiltrate in compacted fill

  Isolate “hot spot areas”

  Level bed bottom (1% or less)

  Preserve soil mantle (limit excavation)

  Geotextile separation

  Loading ratios: impervious area to bed bottom area

  Hydraulic head/depth of water

  Drawdown time – 72 hours

  Positive overflow

Soil Mantle Considerations

- Undisturbed soil is preferred
- Can infiltrate on disturbed sites if not compacted – testing required
- Site location comes <u>before</u> structures

Design Considerations for Pollutant Control

- Isolate “Hot Spots” of pollution
- Fueling islands, dumpsters, materials storage (garden centers, yards)
- Prevent rainfall – canopies, covers
- Trench drains - separate from runoff
- Pre-treat or convey with wastewaters

Infiltration bed design

- Flat bottom to distribute (1% or less)
- Minimize earthwork –fit to site
- Terrace beds or trenches on slopes
- Use geotextiles to separate bed from soil and prevent erosion inflow to bed during construction
- If used for E&S, do not excavate to grade

Hydraulic design

- Loading ratio: impervious cover ratio to bed bottom, generally 5:1
- Limit head: horizontal vs. vertical storage – spread it out
- Positive overflow: set outlet below surface, prevent scour
- Assure volume storage is available; empty bed (drawdown) in 72 hours


7. 3. 2002

Construction Guidelines

- Minimize compaction of beds
- Placement of storage medium with care
- Liberal use of geotextiles in beds
- Careful E&S to protect exposed soil


CASE


15. 8. 2002


2. 7. 2002

Common Bulk Density Measurements

Undisturbed Lands **Forests & Woodlands** **1.03g/cc**	**Residential Neighborhoods** **1.69 to 1.97g/cc**
Golf Courses - Parks, Play Fields **1.69-1.97**	**CONCRETE** **2.2g/cc**


20. 6. 2002

Benefits of Infiltration

- Maintain Hydrologic Balance
- Remove Pollutants
- Prevent increased downstream flows
- Recharge Groundwater
- Maintain Streamflows

Intermission

General Rules for Soils Testing for Infiltration BMPs

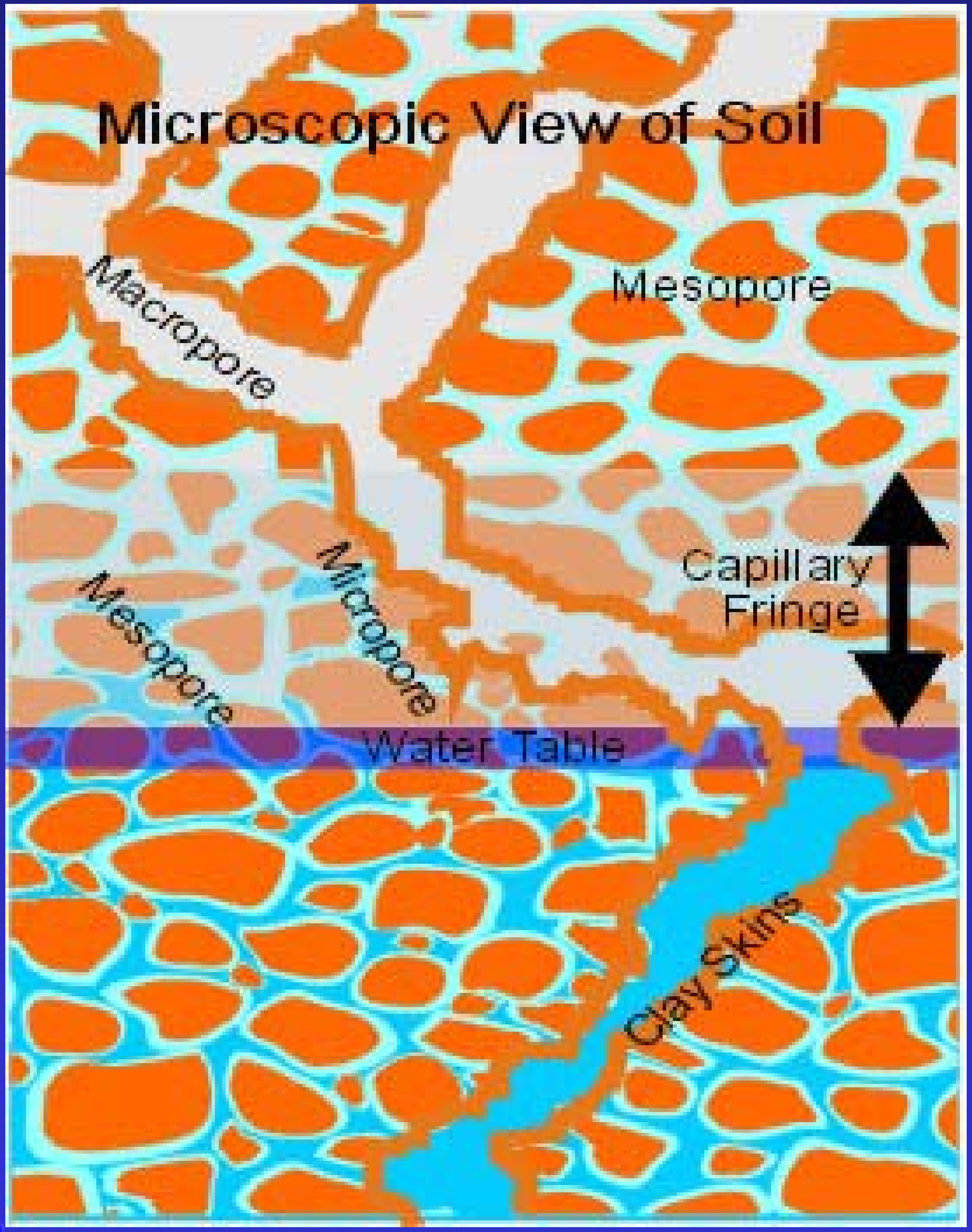
Purpose of Infiltration Testing

- Determine Suitability for Infiltration BMPs
- Determine Rate of Infiltration
- Design appropriate BMP
- Using Soil for Stormwater Management

How Does Water Move through Soil?

Soil is composed of solid particles of different sizes (minerals and organic matter) often "glued" together into tiny aggregates by organic matter, mineral oxides and charged clay particles. The gaps between the particles link together into a meandering network of pores of various sizes. Through this pore space the soil exchanges water and air with the environment. The movement of air and water also allows for heat and nutrients to flow.

Saskatchewan Centre for Soil Research



Soil Macropores

> 0.1 mm in diameter

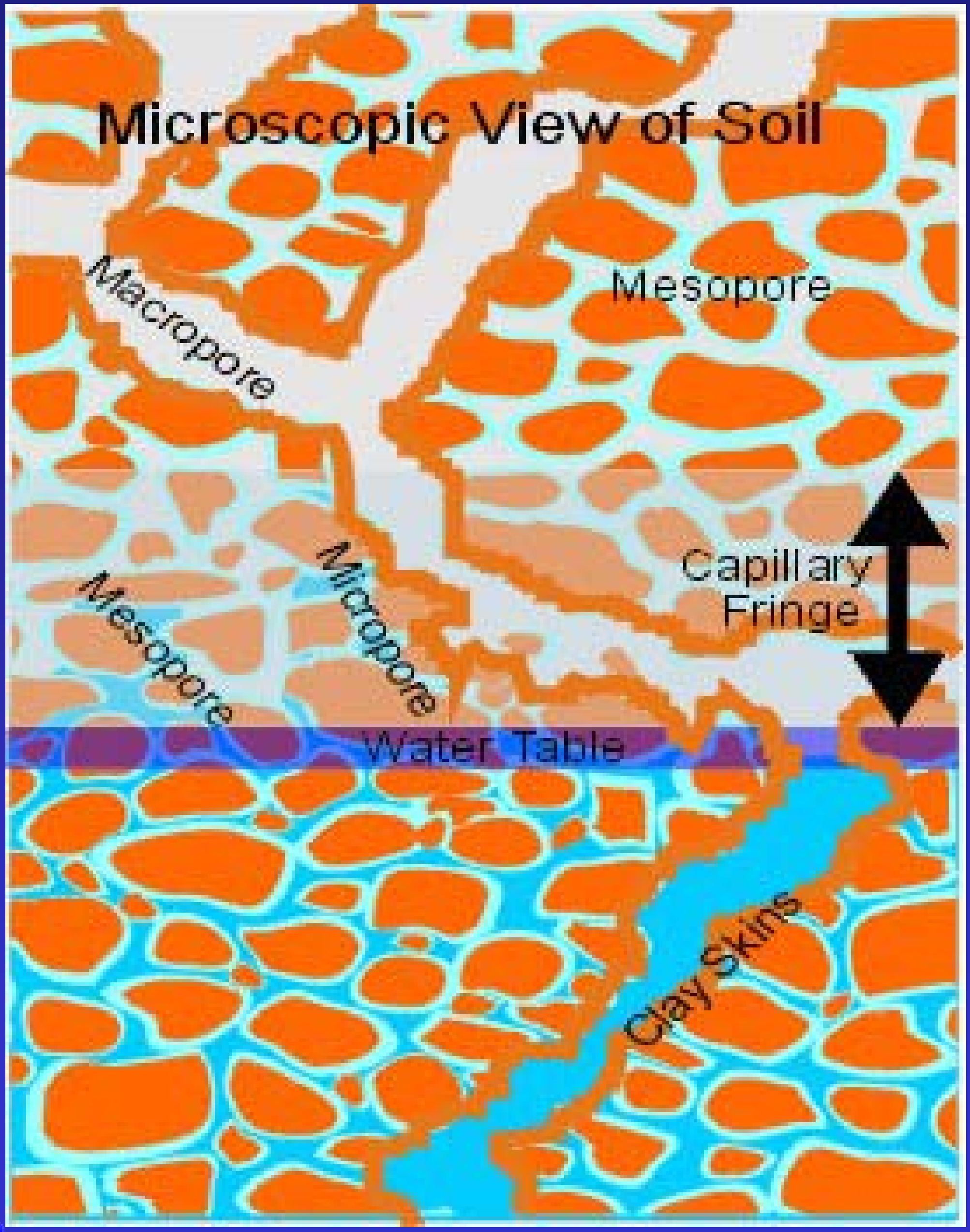
Formation of Soil Macropores

- Root Systems (living and decaying)
- Water Movement
- Large and small organisms
- Freeze-thaw cycle
- Soil shrinkage (dessication of clays)
- Weathering processes

Characteristics of Soil Macropores

- Provide primary mechanism for air and water movement
- Decrease with depth
- Destroyed by compaction, soil disturbance, loss of organic material
- Convey water under saturated conditions

The conductivity of soil macropores (pores > 0.1 mm in diameter) can be as much as ten times the conductivity of the soil matrix.



Soil Macropores

> 0.1 mm in diameter

Soil Tests

- Lab tests to determine hydraulic conductivity based on grain size, shape, and porosity based on a homogeneous sample will not represent field conditions.
- Darcy's Law may not represent movement through macropores.
- Tests need to be conducted in the field.

"*I can foretell the way of celestial bodies, but can say nothing about the movement of a small drop of water.* "

Galileo Galilei

Engineering analysis of soils

- Analyzed soil as a structural material
- Bearing capacity, consolidation, etc.
- Little understanding of biological and chemical processes
- Compaction of soil considered essential

Wastewater analysis of soils

- Design of a stone/sand bed that allows both aerobic decomposition and infiltration
- Shallow bed to provide oxygen transfer
- Daily loading of wastewater

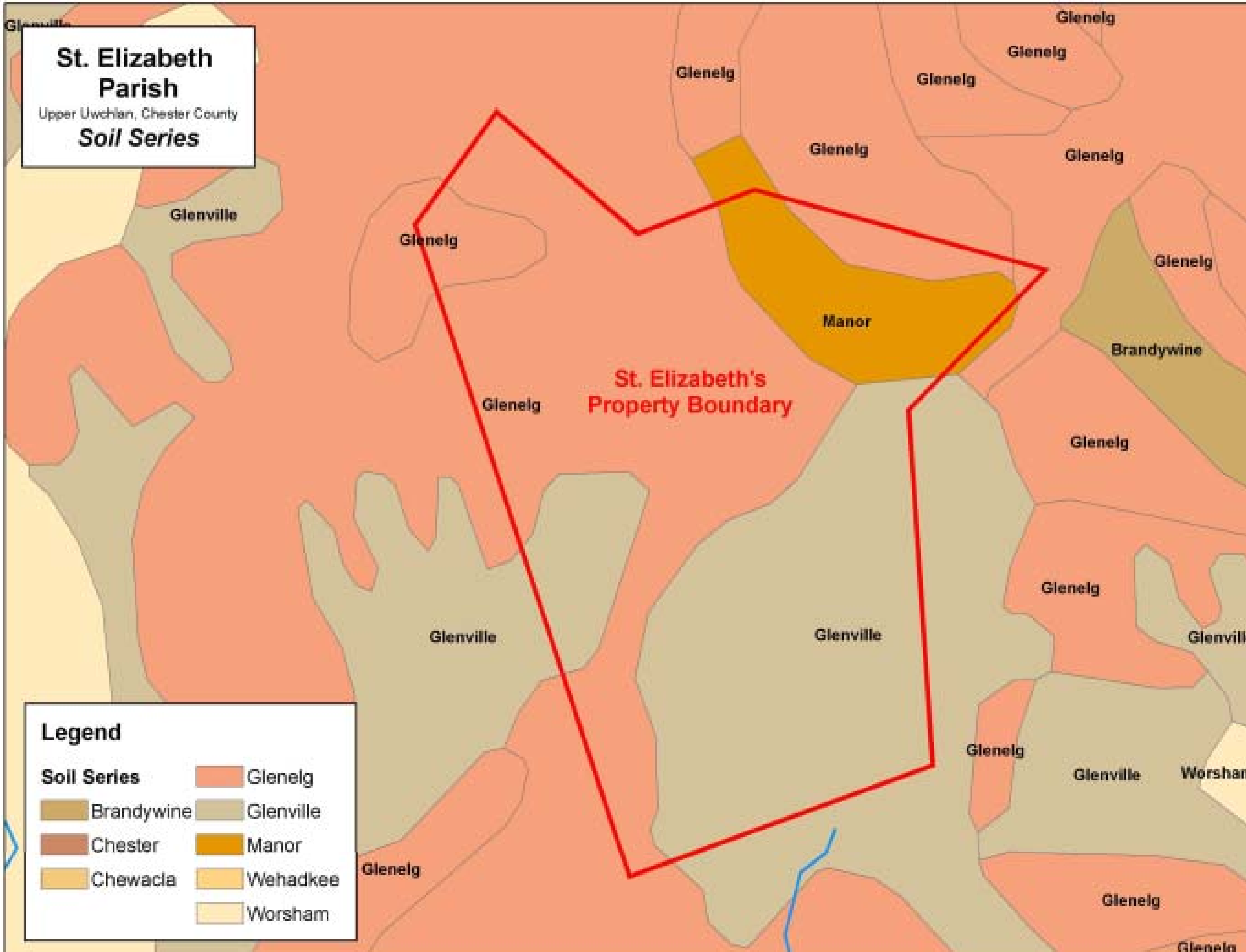
Deep Hole and Percolation Tests

Recommended Approach

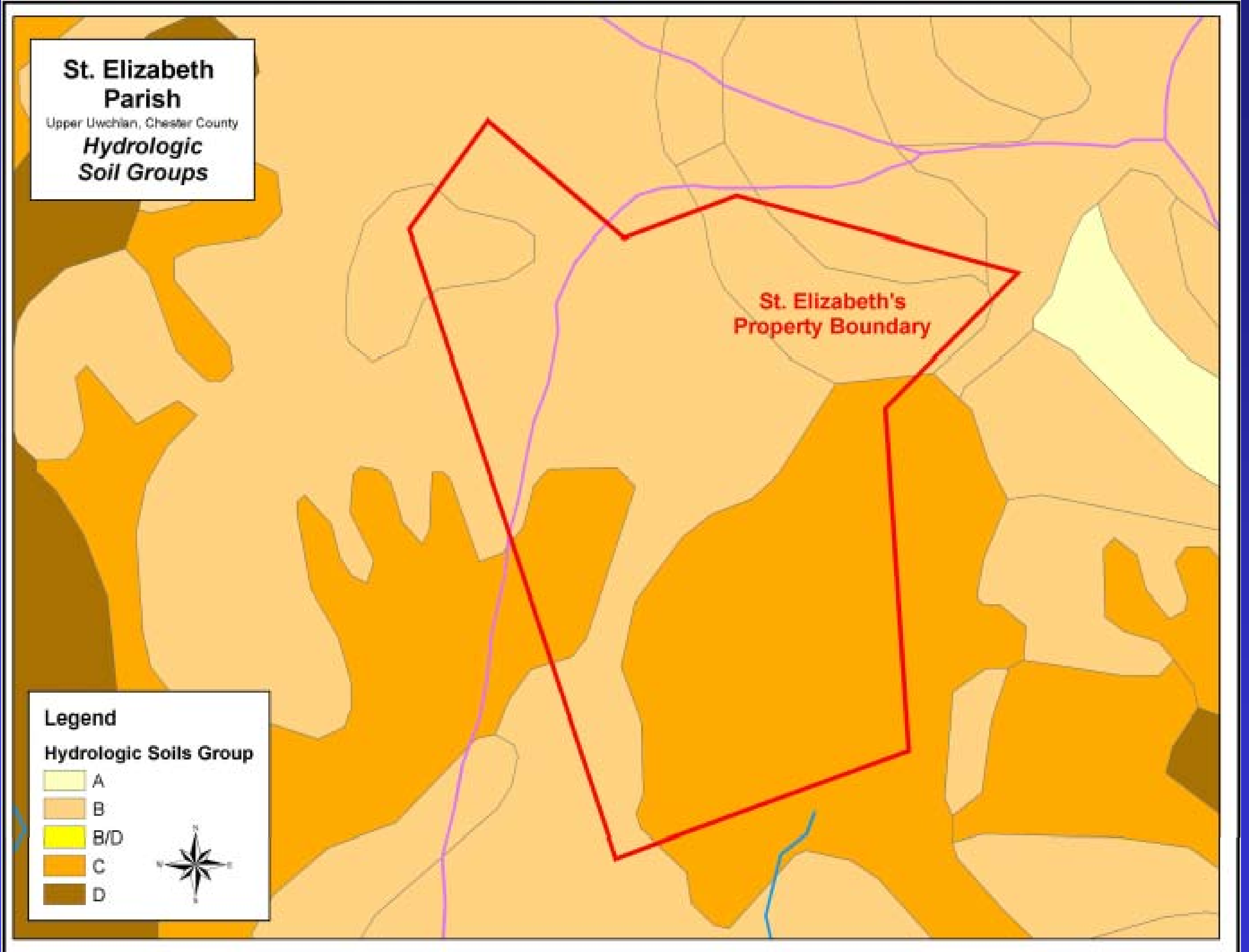
- Desktop Evaluation
  - Site Conditions
  - Potential BMP locations
- Deep Hole observation
  - Multiple Testing Locations
- Infiltration Tests
  - Percolation tests
  - Infiltrometer
- Design Considerations
    - Safety factor

Desktop Evaluation

- Underlying Geology
- Soils
- Hydrologic Soil Group
- Topography and Drainage Patterns
- Streams, Wetlands, Wells,
- Land Use
  - Currently in Ag?
  - History of fill/disturbance?



St. Elizabeth Parish
Upper Uwchlan, Chester County
Soil Series
St. Elizabeth's Property Boundary
Glenelg
Glenville
Manor
Brandywine
Worsham
Legend
Soil Series
Glenelg
Brandywine
Glenville
Chester
Manor
Chewacla
Wehadkee
Worsham


St. Elizabeth Parish
Upper Uwchlan, Chester County
Hydrologic Soil Groups
St. Elizabeth's Property Boundary
Legend
Hydrologic Soils Group
A
B
B/D
C
D

Know Your Soils

- Select the right locations for Testing
  - Low, Wet areas will not drain
- Multiple Testing Locations
- Importance of Deep Hole for Visual Inspection
- Evaluate Soils – Percolation Tests
  - Test near bottom of proposed bed

Deep Hole Tests

- 72” to 90” Deep
- 2-1/2’ to 3’ Wide
- Physically Observe Conditions

Excavation of deep hole by backhoe

What is your telephone number with the area code first?

Your name?

If you have not called in before, you will be asked for company information.

Who is the contact person at the dig site?   Their phone number?

What is the best time to call the contact person?

In what county will the work be done?

In what city, twp or borough will the work be done?

In Erie, Pgh, Allentown or Phila, What is the ward #.

What is the starting address number?

What is the ending address number?

What is the street name for the work site?

What is the nearest intersecting street name?

Do you have any other site-specific location information?

Will the proposed dig site be marked in white?

If a state road, do you have a PennDOT permit number?

Latitude ?

Longitude ?

What type of work will be done?

Approximately how deep will you be digging?

What type of equipment will be used?

What are the dimensions (width, length, diameter)?

Will the work take place in the street?
Will the work take place on the sidewalk?
Will the work take place on public property?
Will the work take place on private property?
Where on private property? (use drop down box)

Private prop owner or company name working for?

Work date? (utilities need 3 working days notice) *

What is the time you will begin the work?

Is there anything else you would like to add?

Deep Hole Observations

- Soil Horizons
- Soil Texture and Color
- Pores, Roots
- Type and Percent Coarse Fragments
- Depth to Water Table
- Depth to Bedrock
- Hardpan or Limiting Layers

Number and Location of Deep Hole Tests

- Single family – 1 test at BMP location
- Larger Systems- 4 to 6 tests per acre
- Additional Tests based on changes in variability in soils, topography, geology, land use, etc.

Better to do many test holes

Test Multiple Locations

Visual Inspection Important!

Hardpan Layer


CAT
2. 3. 2000

Depth of Hardpan Varies

Deep Hole Observation Affects Design

- Depth of Hardpan Varies
- Layer is Shallow –
  - Excavate
  - Place Beds Beneath
- Hardpan is Deep
  - Place Bed Bottom 2' above Hardpan
  - "Punch Through" with Borings

Testing Previously Disturbed Areas

- Historic fill
- Surface compaction
- Deep Hole Observation even more important

Urban Retrofit – Villanova Plaza

Safety Issues

University of Michigan

Urban Retrofit


1. 5. 2003


1. 5. 2003


1. 5. 2003

How Well Does the Site Infiltrate?

- Percolation Test
- Double Ring Infiltrometer
  - ASTM D 3385-03
  - ASTM D 5093-90
- Hydraulic Conductivity – Lab Test
- Amoozemeter
- Constant Head

Limits of Budget and Time

Not an Exact Science!

- "*Remember when discoursing about water to adduce first experience and then reason"* Leonardo daVinci

Number and Location of Infiltration Tests

- Minimum 2 per Deep Hole
- At least one test at bed bottom
- Test different horizons
- Methodology- Pa Code Chapter 73


16. 4. 2003

Percolation Tests

- 6” to 10” diameter
- 12” depth
- Scarify sides and bottom
- Minimum of 8 readings or stabilized rate for 4 consecutive readings

Recommendation

- Supplement Perc Tests with Infiltrometer Tests
- Compare variations
- 10% of tests with infiltrometer

Turf-Tec Infiltrometer at shallow bench and percolation hole at deeper bench

Turf-Tec Infiltrometer – example of double ring infiltrometer

Recommended Approach

- Desktop Evaluation
- Deep Hole observation
- Infiltration Tests
- Design Considerations
  - Observed Infiltration Rate for Site Suitability
  - Safety Factor for Design: 2

THE END