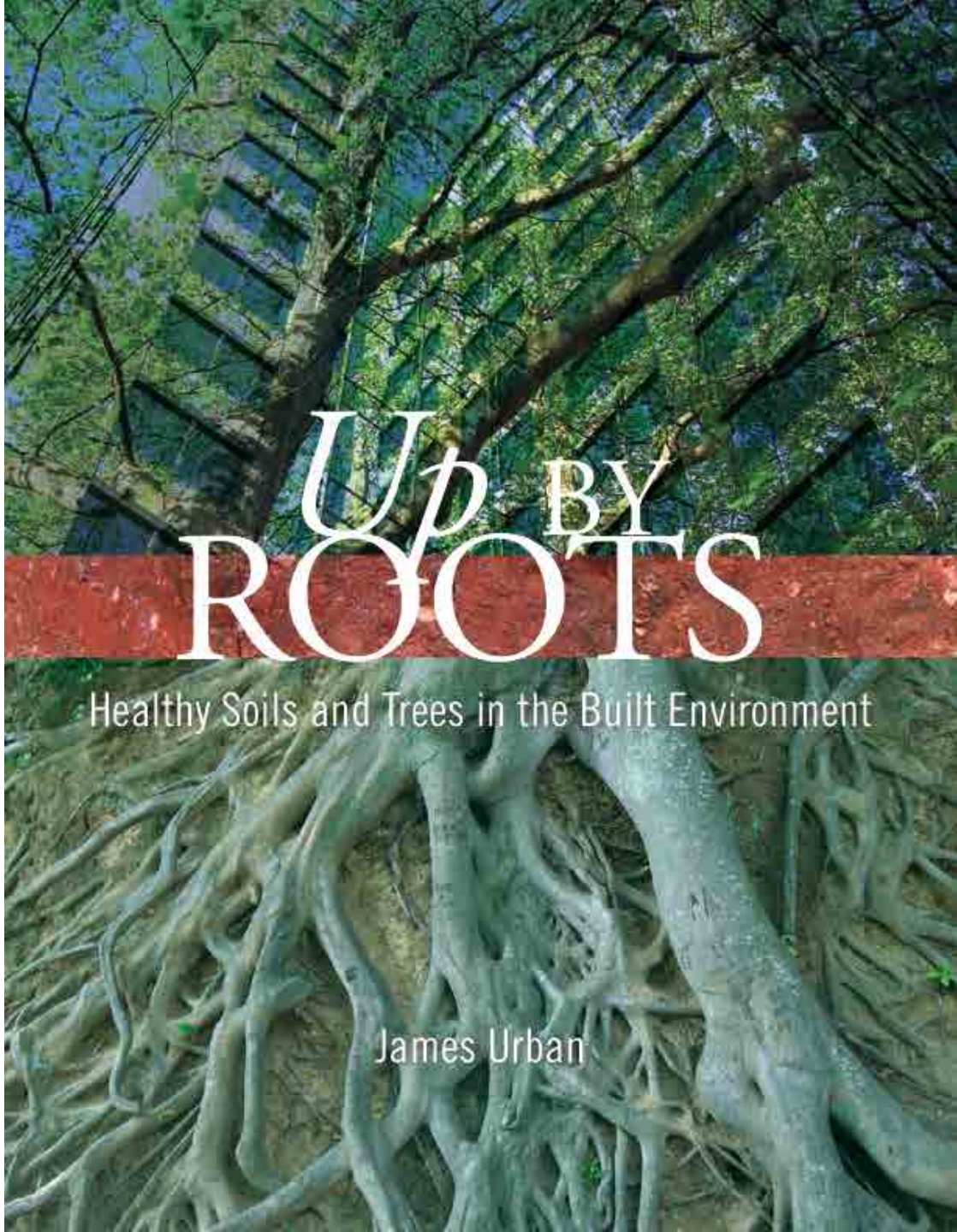
Arboricultural Association
Amenity Arboriculture Conference

Structural Soils
Load Bearing Surfaces
Engineering Solutions

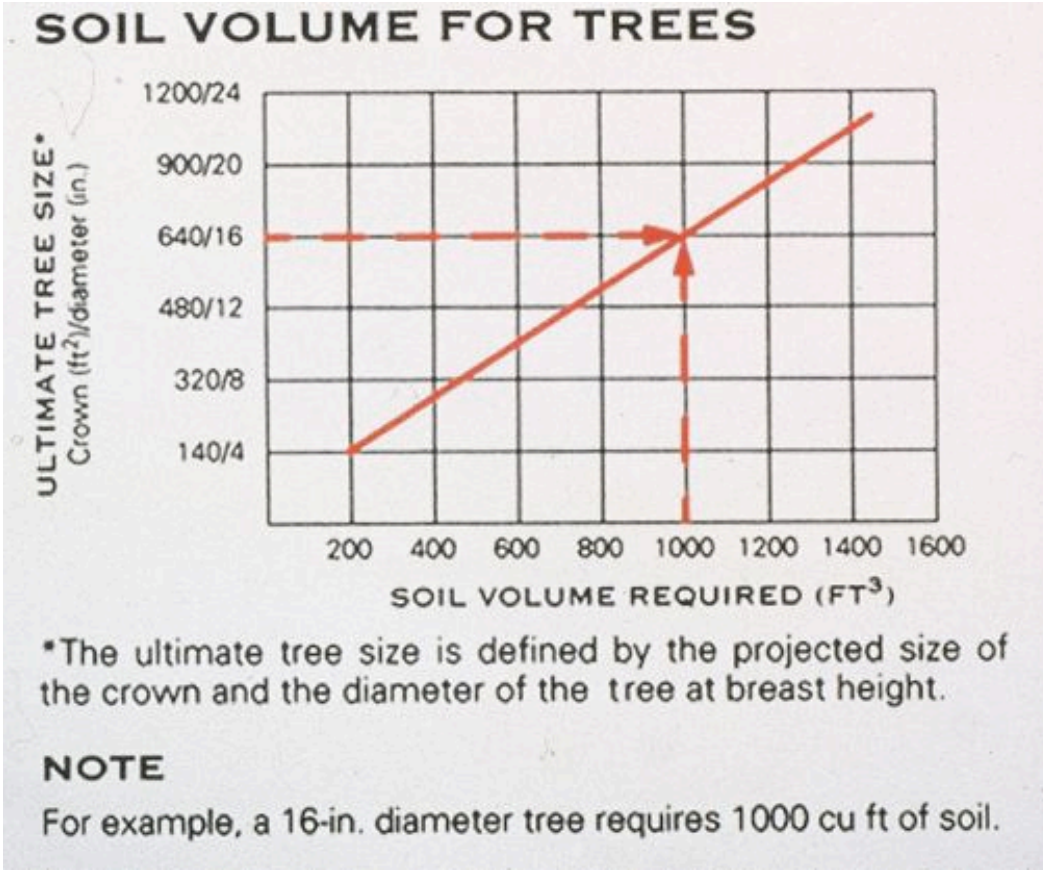
James Urban, FASLA, ISA
Urban Tree + Soils
Annapolis, Maryland



So the **SUDS** session is all about BEER!

That would be football

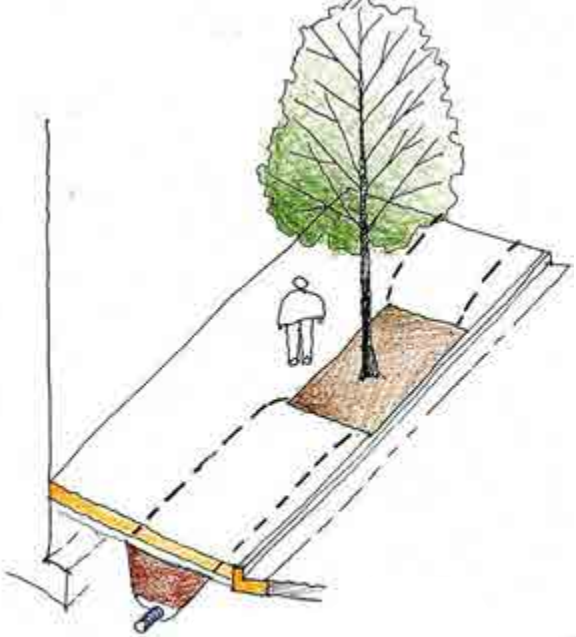
Fill our cities with large mature trees



ca 1986

The soil chart – Myth, truth or half truth?
1,000 cf per tree or 3,000 cf?
Shared volumes vs isolated volumes?

Sky Forest, Japan / PWP 2000

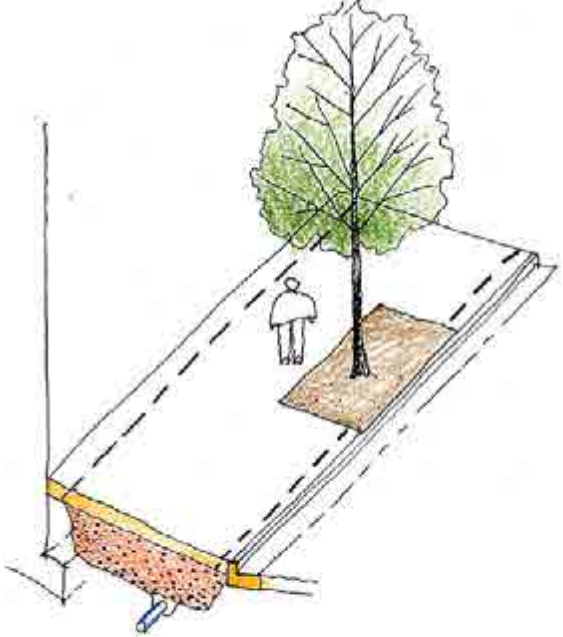


Sidewalk as bridge

Reinforced concrete

Site built structures

Concrete forming systems



Structural soil

SBSS
Sand Based Structural Soil

Amsterdam Tree soil
Not vehicular loading
74-86% proctor

Pine Swallow / Craul SBSS

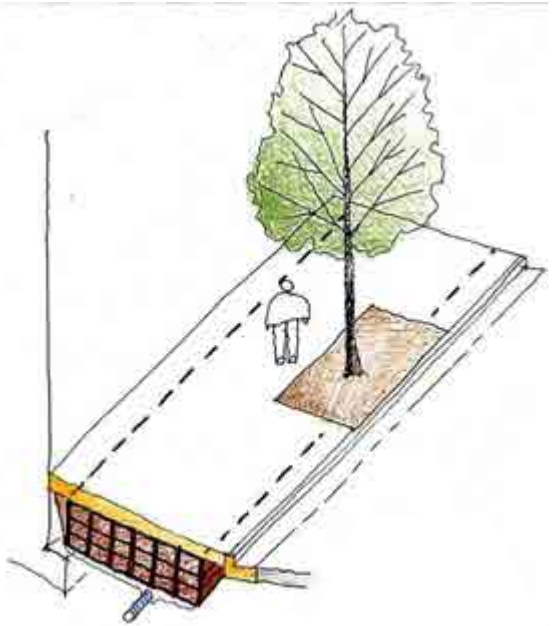
Various other SBSS formulas

Rafts over SBSS

GBSS
Gravel Based Structural Soil

CU soil

Various other GBSS formulas



Soil Cells

Post and deck structure

Segmented structure

This approach allows multiple soil types which is a significant factor in how the systems perform!

It is not just the structure but what is the soil and how much?

Calculating effective soil volume is critical to any discussion as to how well any of the systems perform!

Goals for soil under pavement

Load bearing – How do you define in the UK? In the US:

Supporting material must be compacted to 95% of maximum density (proctor).
and / or
Structure must support required vehicle weight and motion.

Example: US H-20 equivalent – **14,500 kg per axle** with vehicle traveling **48 km/hr.**

Support tree growth to maturity

Soil quality – Loam soil is the standard.
***Soil* quantity** - 30 Cubic meter *Effective volume*.

T**ree root dynamics** and **sidewalk lifting** prevention.

Compatible with other urban structures, utilities, and utility repair.

Flexible in layout to respond to urban conditions and obstructions.

Water into and **out of** the soil.

Compatible with SUDS goals.

Research into systems and soil options – Tree growth

Amsterdam Tree Soil compacted above 90%

Bassuk - CU GBSS soil vs loam soil

Smiley - Loam soil vs CU GBSS

Smiley/Urban – Boston SBSS vs Loam soil

Smiley- Loam soil under pavement vs open soil 30 year study

Smiley – Comparative study Silva Cells, Stratta Cells, GBSS and SBSS

Oliver Buhler – Post construction study of structural sol

Kristoffersen – Growing trees in road foundation materials

Ingerslev – 10 year study of GBSS

Sonti – Urban soils

Kramer et al – Post planting comparative study SBSS, GBSS vs loam soil

Rahman et al – Tree pit design and soil composition

The trend in all this research is that loam soils perform best to grow trees. Trees will grow in all the options but better in some than others. **They are not equal particularly when soil volume is controlled**.

What is the **efficiency of the soil** in each option and soil type? And what is the cost per cubic meter of the **effective soil volume**?

Loam Soil
In Silva Cells

2010

GBSS
CU soil

1999

2013

Is it reasonable to make these kinds of comparisons?

2009

Studies controlled for soil volume

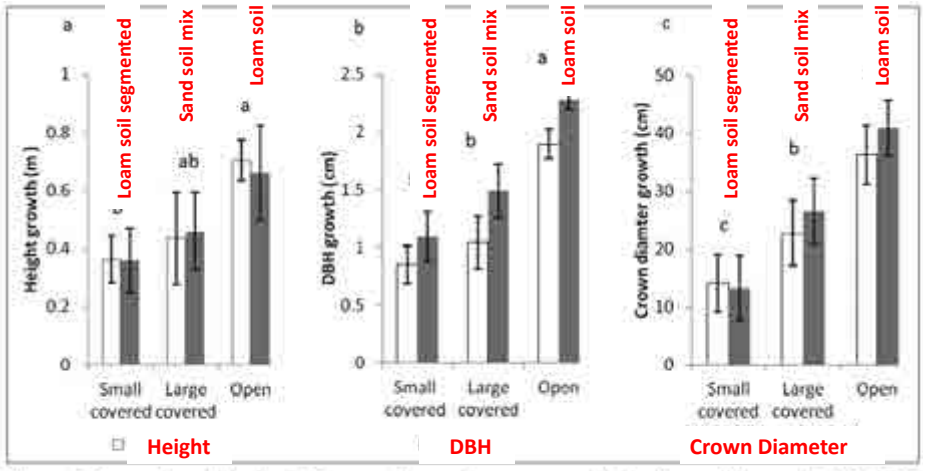
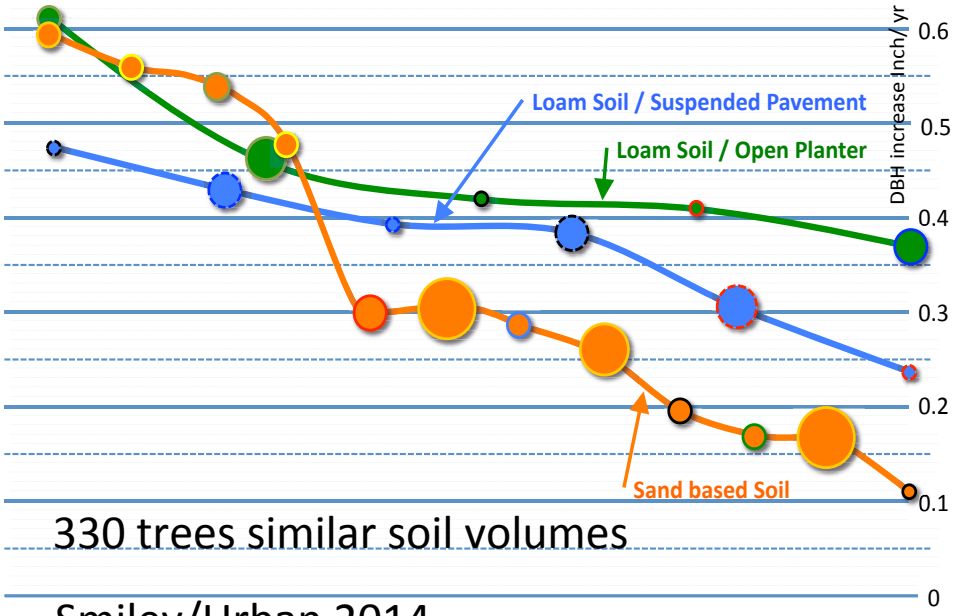


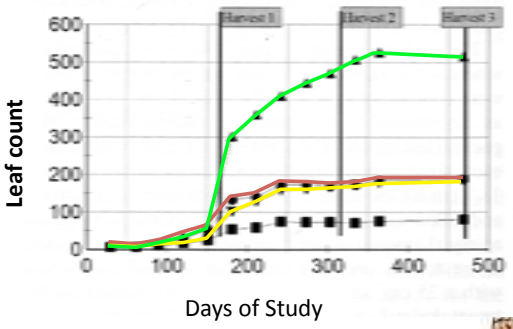
Figure 2. Annual growth rate in *Pyrus calleryana* trees grown in the three pit types in 2010–2012 (n = 5): (a) height, (b) DBH, (c) crown diameter increment.

Rhamen et al 2013

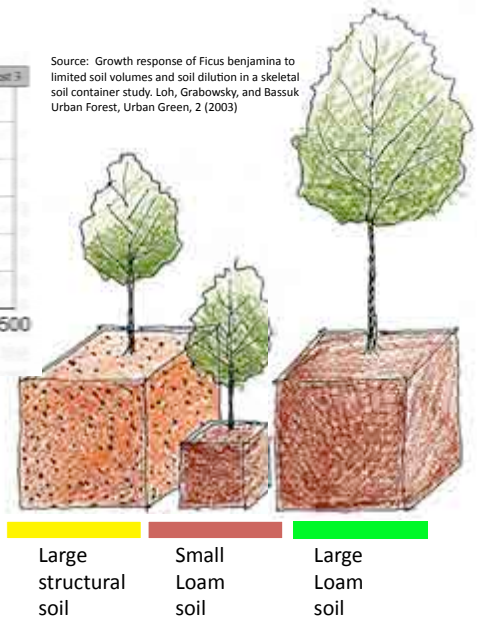


330 trees similar soil volumes

Smiley/Urban 2014



Source: Growth response of Ficus benjamina to limited soil volumes and soil dilution in a skeletal soil container study. Loh, Grabowsky, and Bassuk Urban Forest, Urban Green, 2 (2003)



Large structural soil and small loam soil have equal amounts of loam soil.

Bassuk et al 2003

Smiley 2012



























Each system had the same space.

Smiley / Bartlett Field Trials 2014/15


Smiley – Bartlett Field Trails

Testing the tree growth effectiveness of different load bearing soil options. Planted in August 2014, photos September 2015

Silva Cells

Unscreened clay loam/sand /compost.
Installed by James Urban.
2.503 cu yards soil prior to compaction.


Strata Cells

Unscreened clay loam/sand /compost.
Installed by Craig Melvin.
2.03 cu yards soil prior to compaction (23% less soil).
Significant soil settlement and required replanting trees.


Gravel Based Structural Soil

Soil mixed to CU Soil specification.
Installed by Tom Smiley


Sand Based Structural Soil

Soil Mix observed and approved by Bob Pine
To meet Pine/Swallow SBSS specification.

The UK Raft approach is a SBSS system with a load spreading structure on top.

Largest and smallest in each treatment

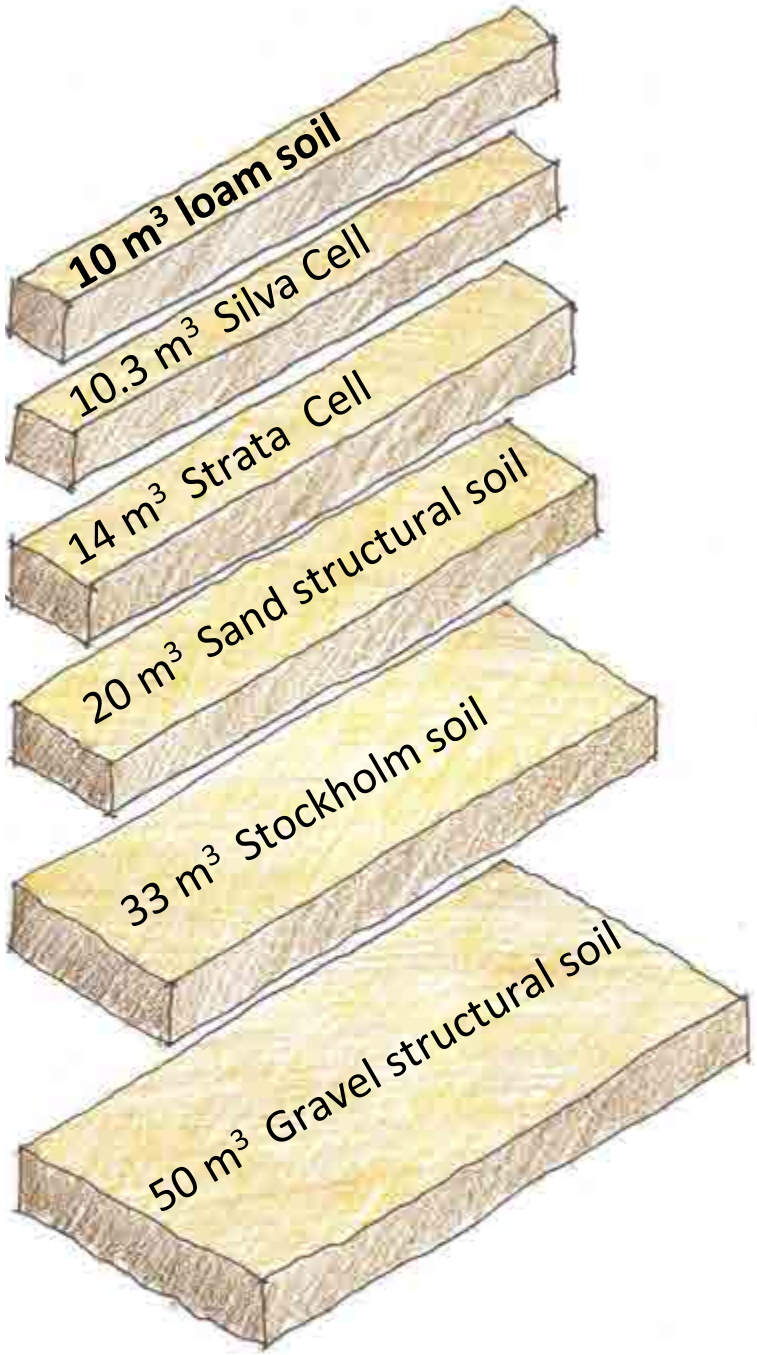
When using any of these options you should……..

Calculate the soil volume based on efficiency.
The following is a reasonable estimate:

Assuming:

Loam soil	100% efficient
then	
Silva cells	93% efficient [1]
Strata cells	71% efficient [2]
Sand based structural Soil	50% efficient [3]
Stockholm structural soil	30% efficient [4]
Gravel based structural soil	20% efficient [5]

Substitutions must be required to provide the equivalent effective soil volume of the original tender!



Efficiency calculation assumptions

1. Silva cells is 7% space devoted to structure.
2. Strata cells is 6% space devoted to structure. In the Bartlett field trial study held 23% less soil than Silva Cells.
3. Sand based structural soil based on observed reductions in growth in the Smiley/Boston study.
4. Stockholm Soil has 30% void space for soil and roots the rest is rock.
5. Gravel based structural soil contains 20% soil the rest is rock.

Soil volume requirement assumptions
A mature large canopy tree needs **much more** than **30 m³** of loam soil.

The Dortmund Square, Leeds, project case study stated that **28 m³** of soil will grow a 100 year old tree. (TGAD - Trees in Hardscapes)

Most UK Silva Cell projects are undersized
as I suspect are most other systems. This is a simple math equation.

But… the **adjacent ambient soil** may often provide some of the additional needed soil volume!

How much more?

Do a soil survey as a part of the design process!

PS: you need to get water IN and OUT of the soil for the trees to grow!


Dortmund Square

So on to the **SUDS!**

Sustainable Urban Drainage Systems

And trees!

I hope there is a beer at the end of today sessions!

The new rain water paradigm is a significant change in the way we build cites.

BUT….. Are landscape architects (or engineers) "EXPERTS" at this?

Remember…….
Since ancient times, we have evolved solutions to **conflicts** between **rain water** and **human development.**

The new water paradigm must **understand** these **conflicts** and **not reintroduce** an **old problem**.

I do not think most of us know what we are doing in this area of design!

Rain water treatment goals

Floatables

Hydrocarbons

Coarse Sediment

Chemical pollutants

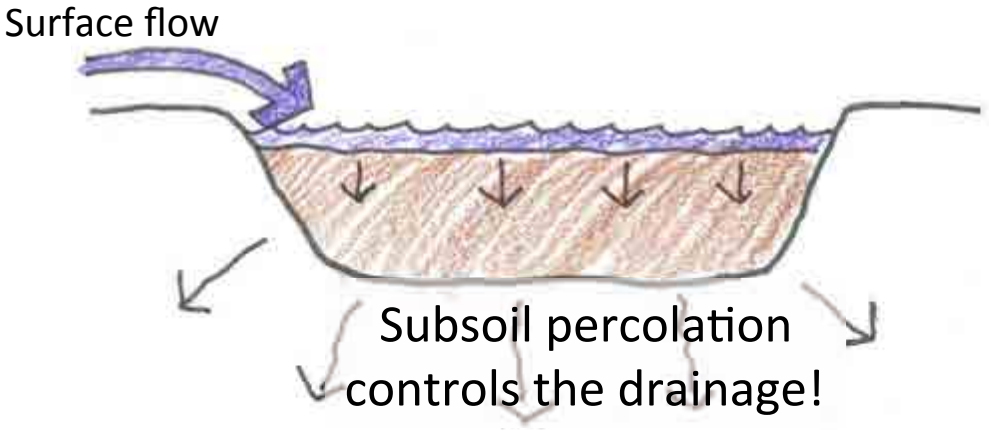
Fine Sediment / Turbidity

Runoff reduction

Each of these goals suggest **different solutions** and sometimes finding a solution to one may make another one worse!

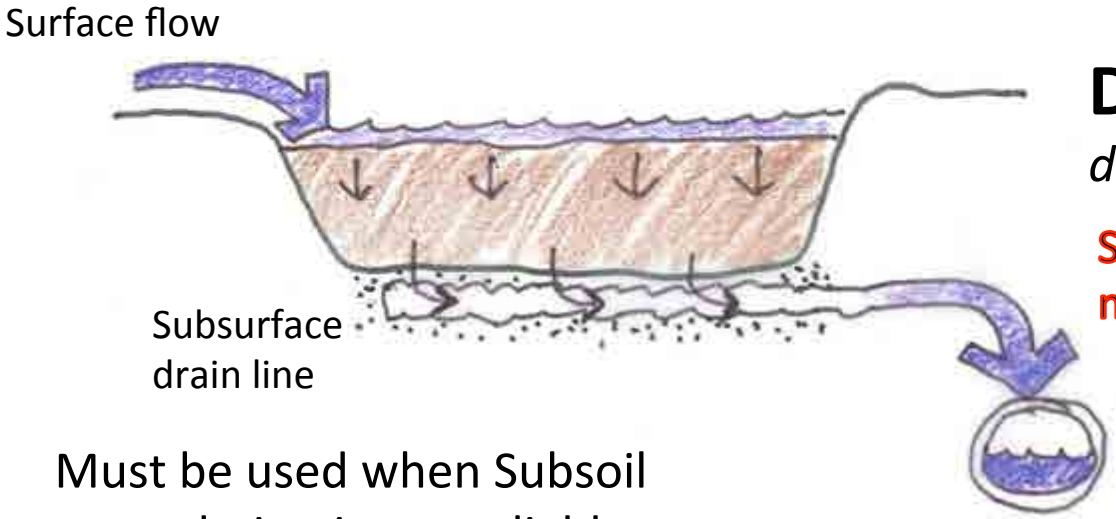
Must hold the water on the site as long as possible **but** not have that water cause problems. **Very thin range** between success and failure.

Water storage terminology



Retention: *Water stays on site and infiltrates into soil.*

This can kill trees if the soil or the subsoil drains too slowly!

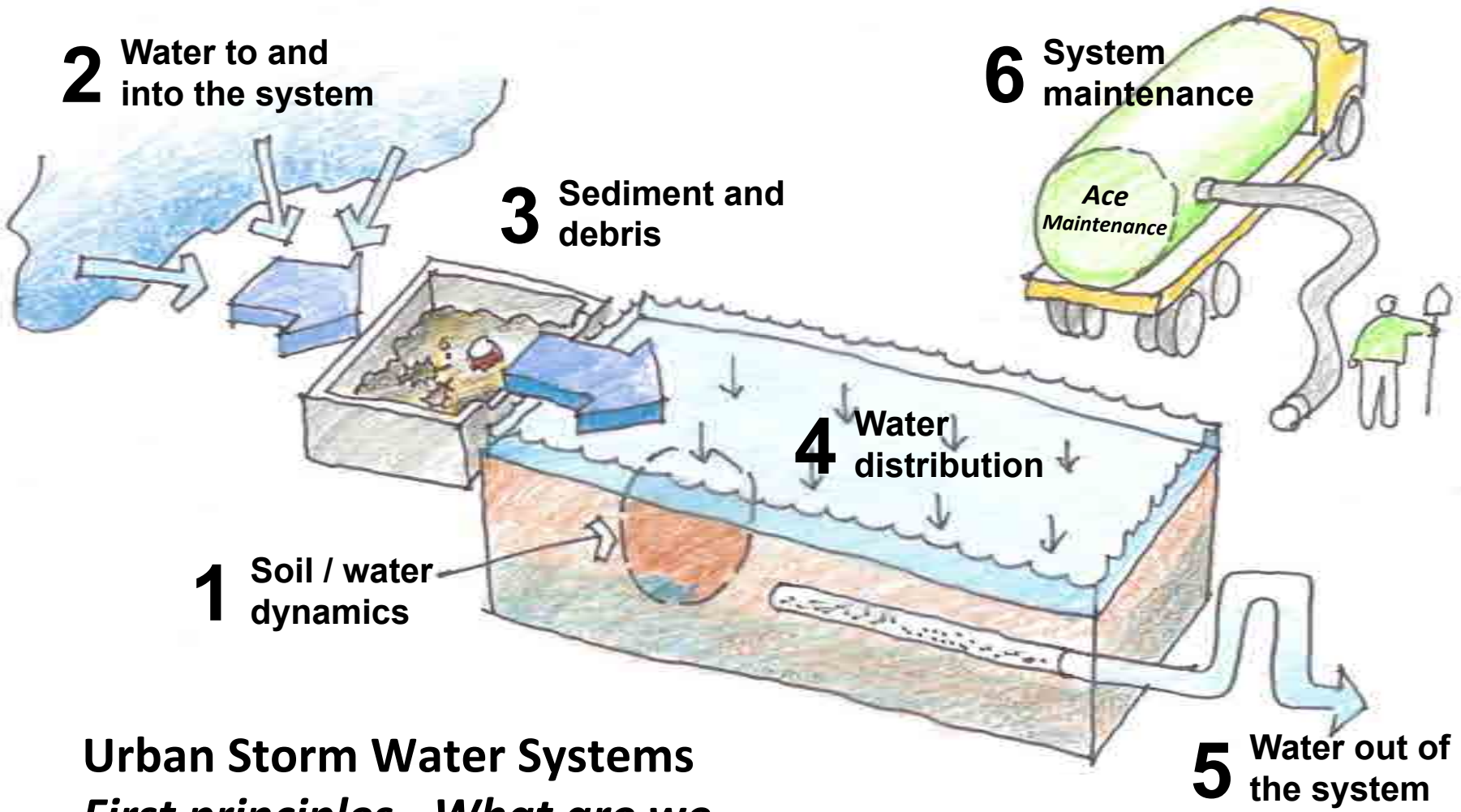


Detention: *Water slowly drains off site.*

Soil MUST drain slowly or it does no good as a SUDS system

Must be used when Subsoil percolation is **not** reliable

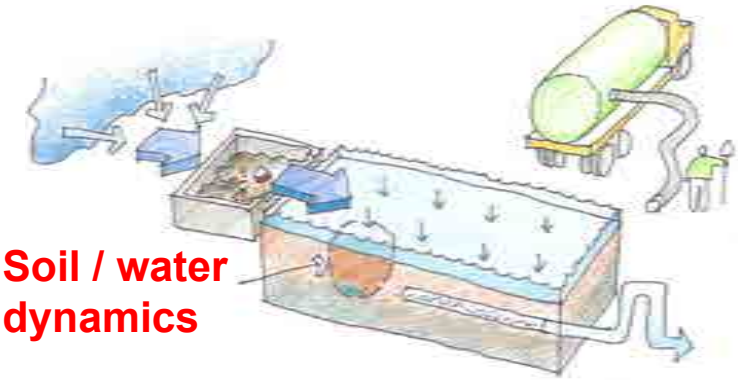
Storm drain pipe
or daylight outfall



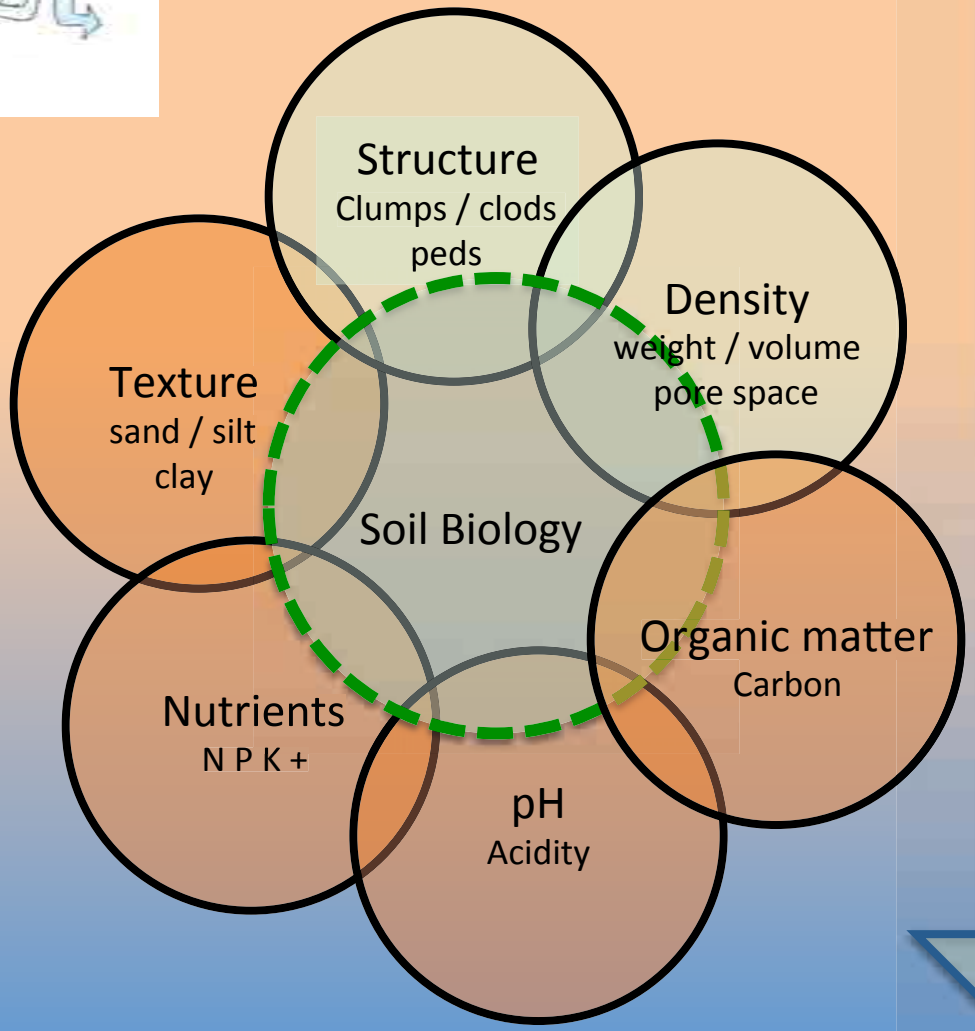
Urban Storm Water Systems

First principles - What are we doing wrong!

1 Soil / water dynamics



The interrelationships of ***Structure, Density and Profile*** are critical to understanding water movement



Air and water movement / soil profile

Water Movement thru the soil

Infiltration rates are set by:

- Soil type ***and***
- Soil structure / preserved peds ***and***
- **Soil compaction**

Bio-retention soils have too much sand and too much compost!

Unscreened sandy loam soil

Sand/compost bio-retention soil mix

Screened sandy loam soil mix

3. Water Movement thru the soil

Water drains too fast

Piping and **fine particle migration**?

Bio-retention **soil** drains too fast?

1”/hr too slow

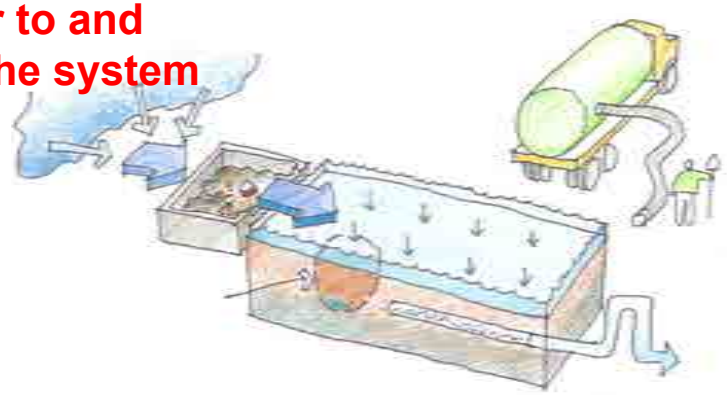
5” /hr too fast

2”-3”/hr just right!

(at required compaction and structure)

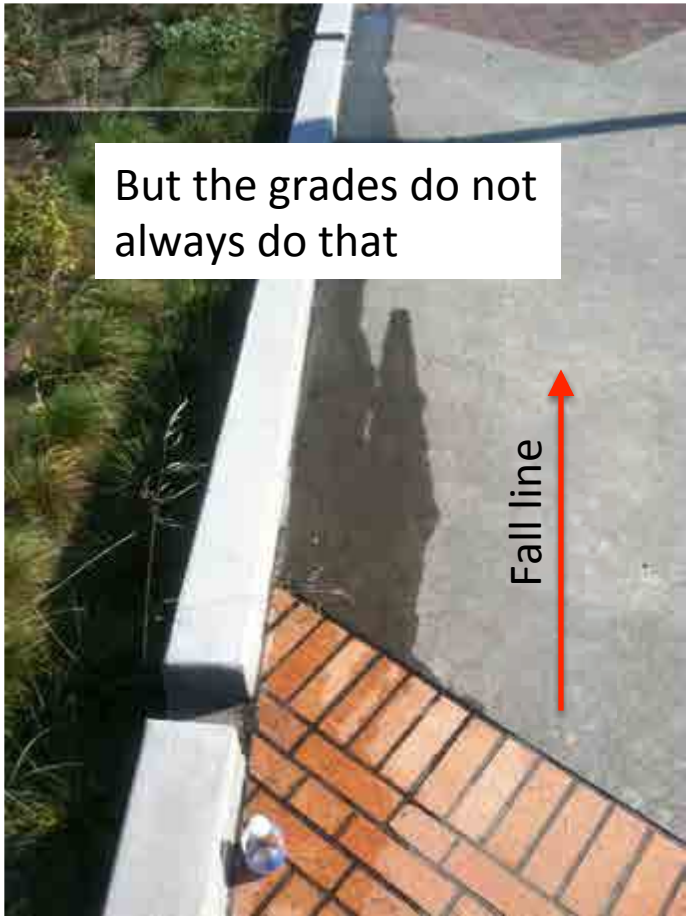
55% sand 30% soil 10% compost

2 Water to and into the system



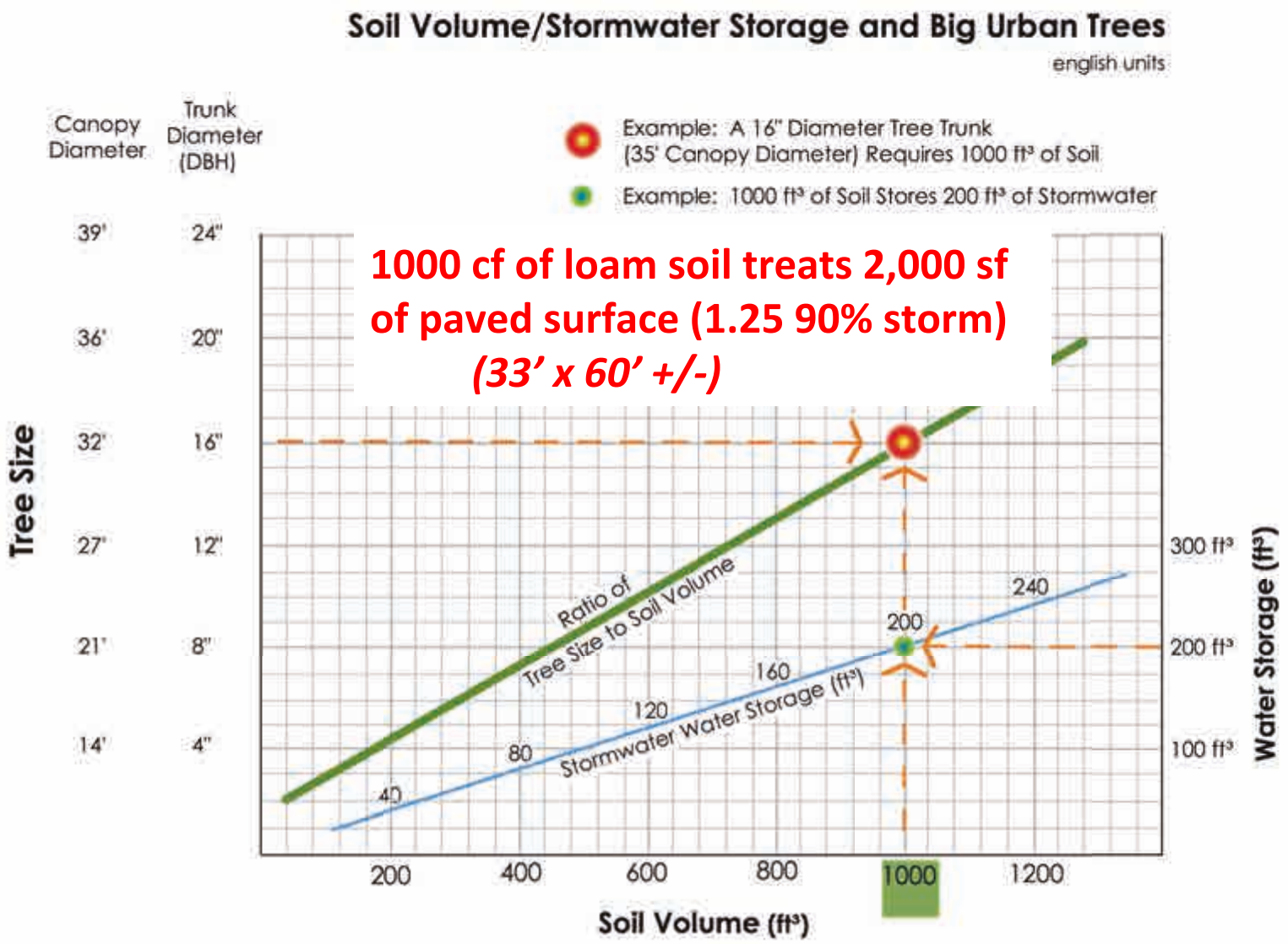
Grading toward the water access points

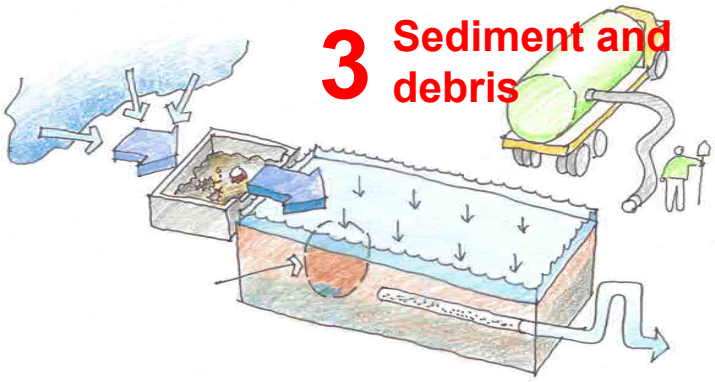
*And correctly size the drainage area for the **macropores** in the soil volume!*



Water Into the System

Sizing the system



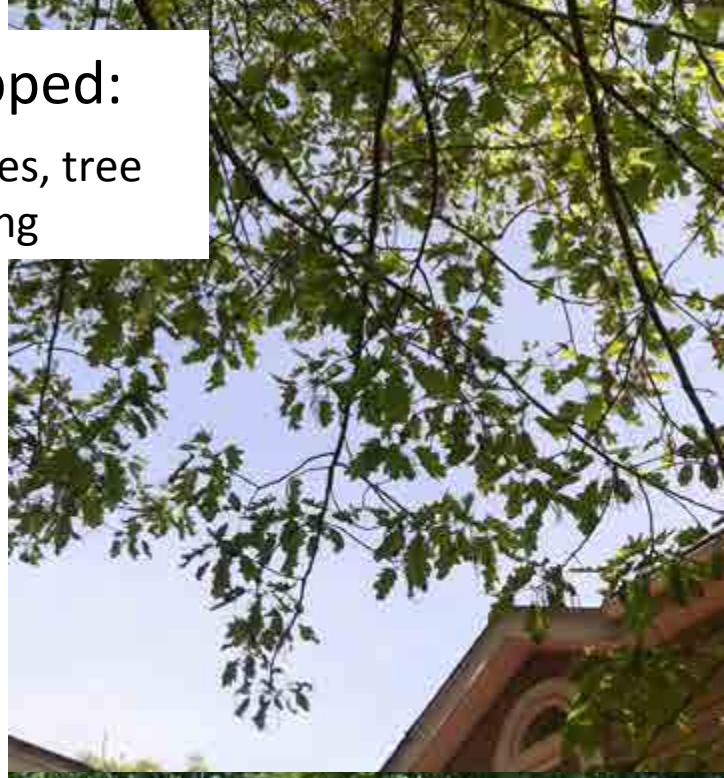


Clogging at the Entry Point

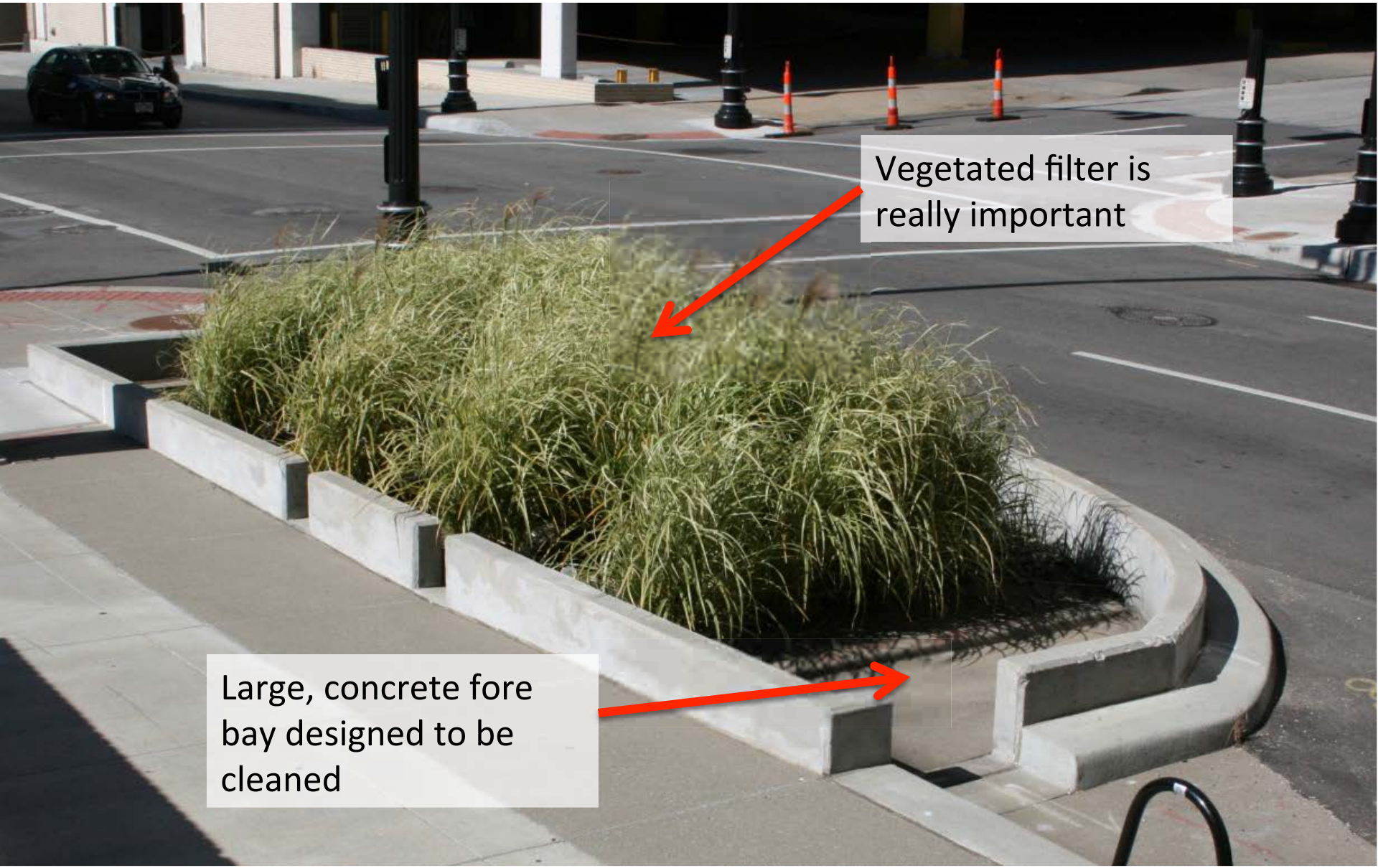
One mature oak tree dropped:

Plus a constant fall of other leaves, tree parts and pollen all year long

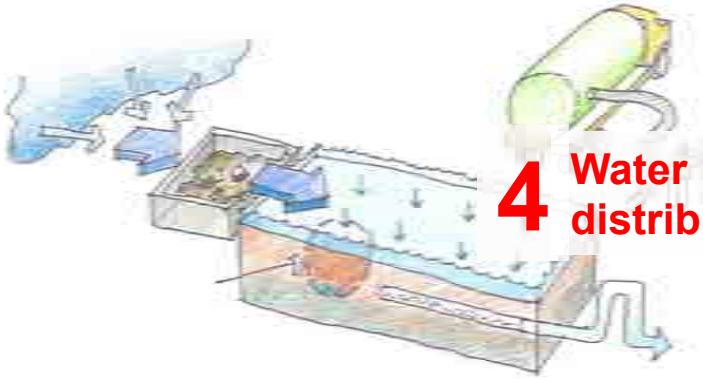
200 gallons of leaves
20 gallons acorns



50 gallons of catkins


Vegetated filter is really important
Large, concrete fore bay designed to be cleaned

Or use pervious pavers



4 Water distribution

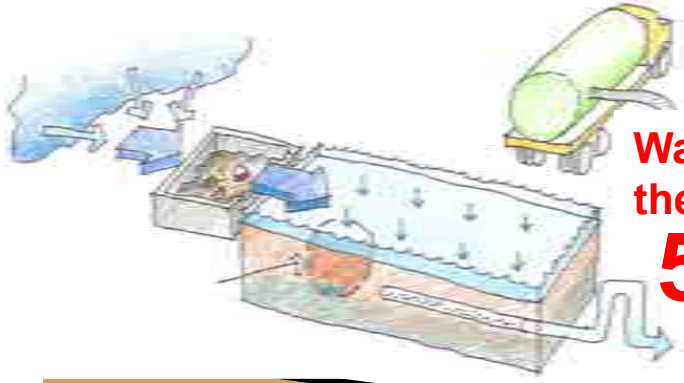
Pervious pavers are best.

Inlets and pipes - Robust!
Pipes must be **SET LEVEL** with **HOLES on TOP**!
The hydrology of water **exfiltration** from pipes is **not well understood** even by engineers

Need robust method to clean out pipes!

Critical with soil under pavement

Do not wrap these systems in fabric Membranes. You want the roots to get out!



Water out of the system

5

Water head above soil

Raised **overflow**

Soil

Head

Detention

Retention

To outfall

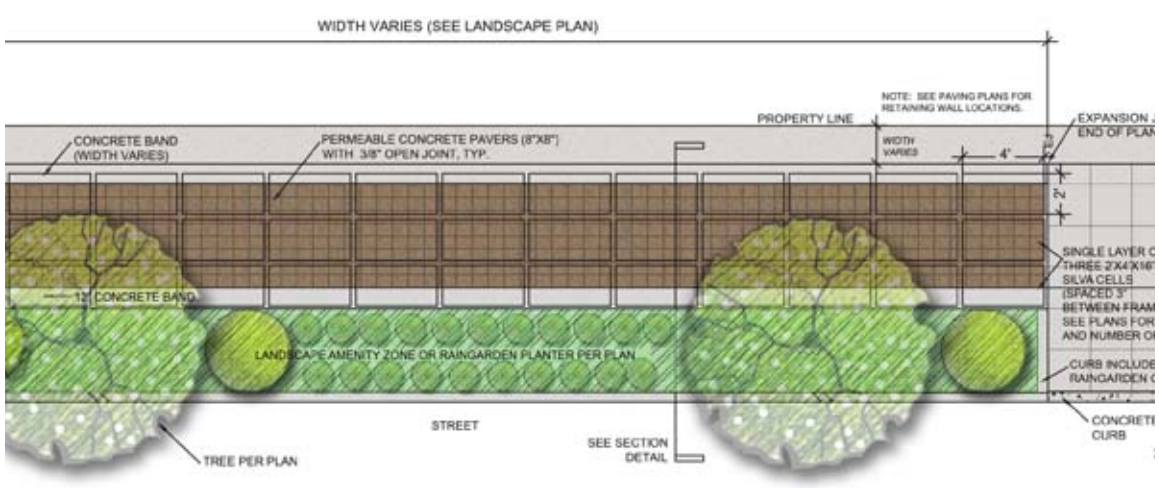
Infiltration

Perforated sub drain line

Solid stand pipe
Turned up elbow

Stand Pipe Concept

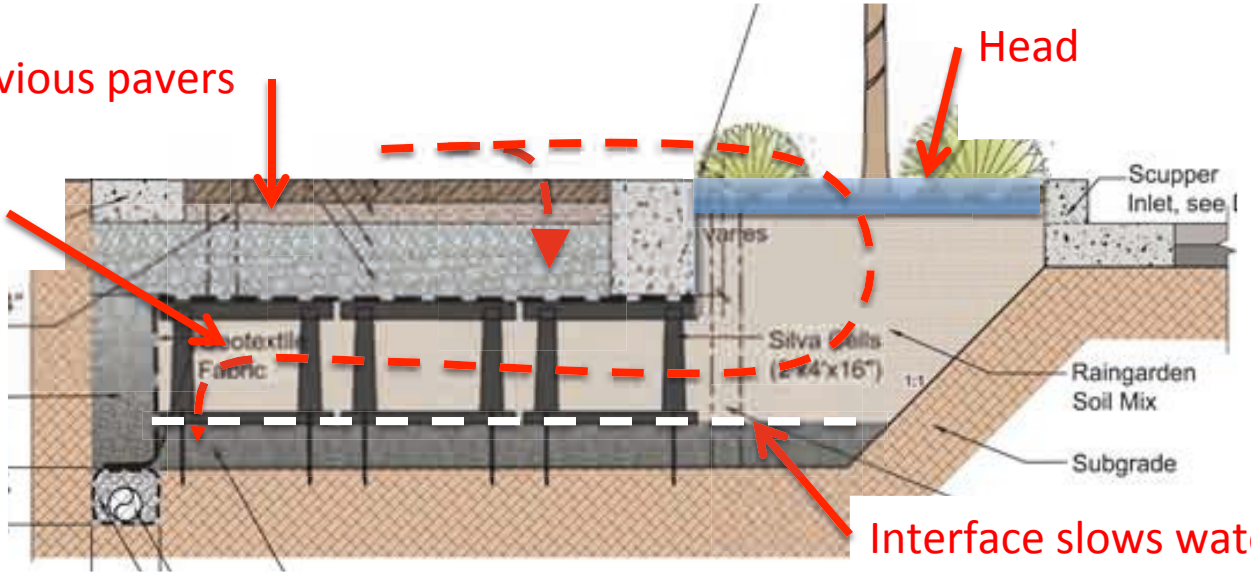
Glued joints required to make this work



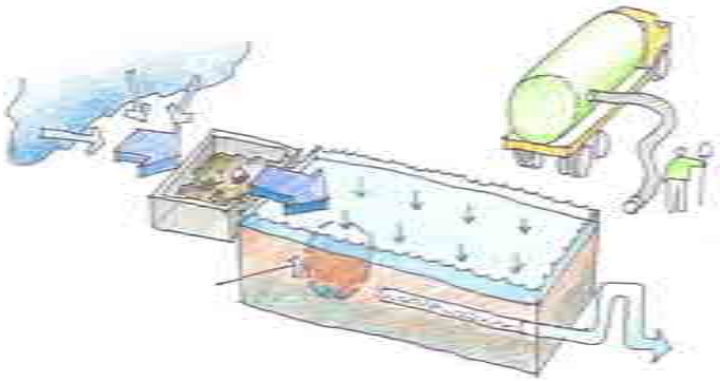
Pervious pavers

Head

Important for water to move horizontally thru the soil



Combined rain garden and below paving treatment



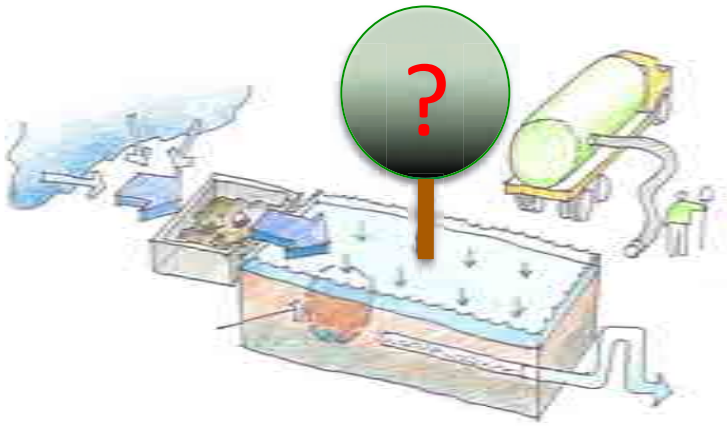
6 System maintenance

Who is maintaining the system after it is built?

Has the system been designed to be maintained?

Was the maintenance operations team part of the design review?

So where is the tree in all of this discussion?



1. If you **get the soil and water equation correct** tree will grow well.

2. If designed correctly, **these are dry *(not wet)* environments** most of the time in most climates.

3. The **volume of soil required** to treat the first inch to 1- ½" of water usually provides **sufficient soil to support a large tree**.

4. Trees will grow better in soil mixes with greater amount of unscreened soil with less sand. **Drainage rates of 2-3"/hour** at installation is great for water and trees.

5. Locate the **tree in slightly mounded areas** of the open soil zones so the tree can adapt to the inundation periods.

American yellow beer. Yuck!

Thank you.

Questions at the pub?

English bitter ale. Yum!