State of the Science using Trees for Stormwater Management……

TREES for a Cleaner San Francisco BAY
Storms vs. Rains
Loam vs. Rock/Sand
Rescue Existing Trees

PRESENTED BY:
KestrelDesignGroup
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Kestrel Design Group
University of Minnesota

June 17, 2015
SMCWPPP

San Francisco Bay: USDA Zone 9/10….

San Francisco: Zone 10…..Type IA Storms….23.5" Annual Precipitation
San Mateo: Zone 9….Type IA Storms….21" Annual Precipitation
Santa Clara: Zone 9….Type I Storms….14.5" Annual Precipitation

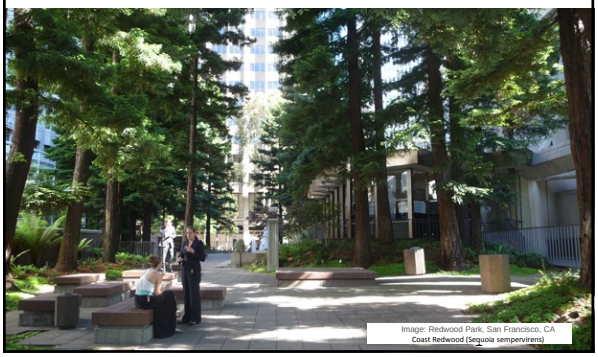

Image: Redwood Park, San Francisco, CA
Coast Redwood (Sequoia sempervirens)

Big Trees to Clean SF BAY
Good & Bad

Presentation Overview:

I. Introduction: Why Use Trees for Stormwater
II. Keys
III. Latest Policy Developments
IV. Latest Research Developments
V. Texas Trees and Stormwater
VI. Case Studies
VII. Questions & Answers

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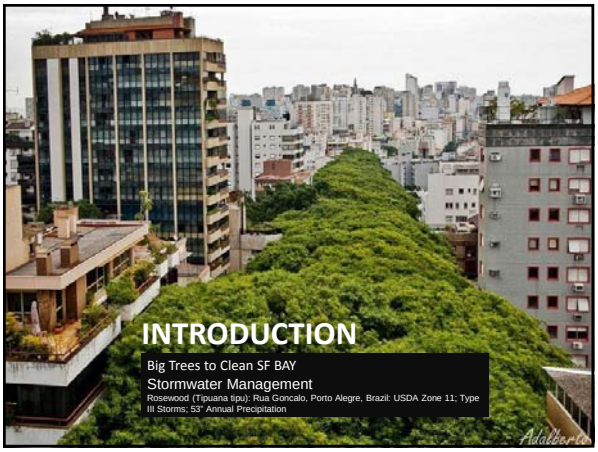


INTRODUCTION

Big Trees to Clean SF BAY
Stormwater Management
Rosewood (Tipuana tipu): Rua Goncalo, Porto Alegre, Brazil: USDA Zone 11; Type III Storms; 53" Annual Precipitation

Adalberto

So You Want an Urban Forest that Cleans Water?

DO This……

- Codify Minimum LOAM Soil VOLUMES FIRST >1000cf
- DIVERSIFY Species
- No Single Tree Genus >5%
- Set Minimum CANOPY TARGET >25% West of the Mississippi River with Deadline
- FIND & FILL GAPS with Trees
- Plant Lots of SMALL TREES with LARGE SOIL Volumes
- Monitor & Apply Responsive O&M

Don't Do This…..

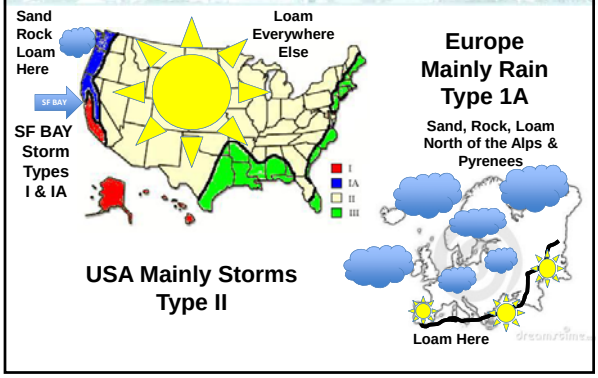
- Plant Trees in Small PITS
- Plant Trees in COMPACTED SOIL or SAND or STRUCTURAL SOIL
- Plant Lots of A FEW Species
- Plant Trees Only After COMPLAINTS
- Plant Tree Root Packages LOW
- Plant Trees As BEFORE
- Announce a MILLION Tree Planting Program Applying Above Steps
- Respond to Merchants Complaining about Trees BLOCKING Their SIGNS by Removing Trees

5 KEYS to a SUCCESSFUL URBAN FOREST
Become Part of Stormwater System

1. REQUIRE LARGE (2:1) ROOTABLE SOIL VOLUMES
2. SPECIES DIVERSITY (UTC <5% GENUS)
3. DIRECT STORMWATER to TREES
4. SHOW STORMWATER VALUE of TREES
5. CALCULATE STORMWATER CREDITS for TREES

Request Portion of Stormwater Budget >$50

Does it Rain? or Storm? Loam? Sand? Rock?



Trees to Clean San Francisco Bay: Big Trees, Small Storms & Evapotranspiration

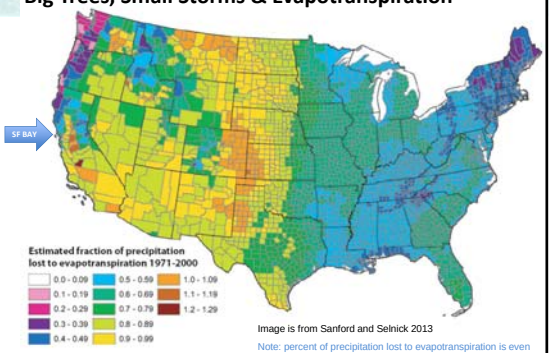
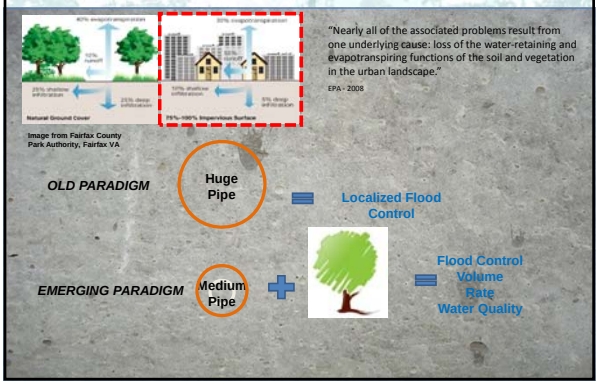


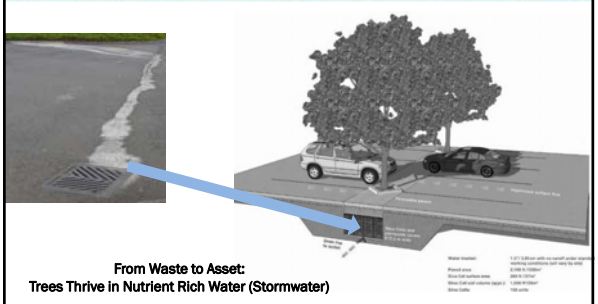
Image is from Sanford and Selnick 2013

Note: percent of precipitation lost to evapotranspiration is even more than 40% in most of the US

Big Trees For Stormwater Management? YES



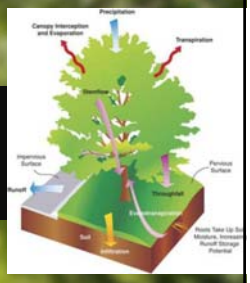
San Francisco Bay & Trees for Stormwater Management? YES



From Waste to Asset:
Trees Thrive in Nutrient Rich Water (Stormwater)

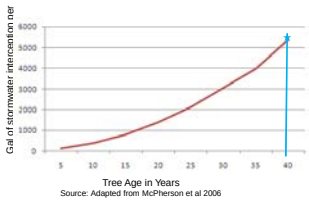
Big Trees as "Green Stormwater Infrastructure"

- Trees intercept and evapotranspire rain
- Soil Structure holds runoff for deep infiltration and for later use by trees
- Soil and mulch adsorb and filter pollutants
- Trees and microbes take up and transform pollutants



What's So Great About Big Trees?

Stormwater Interception by Hackberries versus Age of Tree



Source: Adapted from McPherson et al 2006

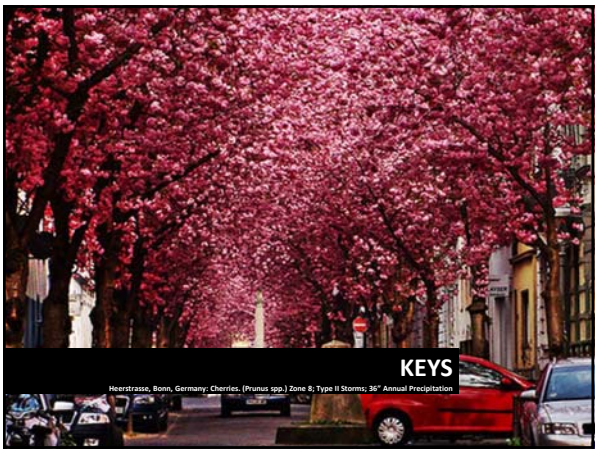
*"A **30 inch DBH tree** provides 70 times the ecological services of a **3" DBH tree."***

McPherson et al, 2004 USDA Forest Service & UC Davis: Co-Author of i-Tree

What's So Great About Big Trees?
Interception

Stormwater Interception Hackberry vs Age of Tree

Images from http://www.tankwatersolutions.com.au/rainwater_tanks.php



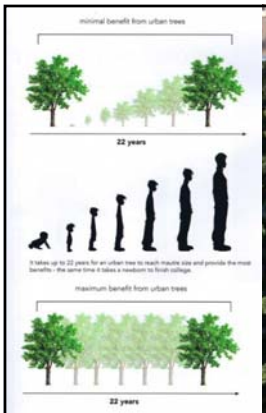
What do Trees Need to Get Big? Will We Ever Know? YES We Know

Trees Need Large Volumes of Oxygenated Soil

"Ideal" Conditions

Grabosky, Trowbridge and Bassuk (2002)

Projected Growth: 1 Square in the AIR. 2 Cubic in the GROUND
....OR
Projected Growth: 65 Cubic Feet per 1" DBH
OR....
>1,000 to Cubic Feet



Badon, Thomas, 2013, Surviving in the Urban Environment, ASLA, _Scape, Issue #17: 9-11.

Why ARE MOST USA & Int'nl CHAMPION TREES Growing in LOAM SOIL?

Why AREN'T More Champion Trees Growing in COMPACTED SOIL or SAND or ROCK?

Why Would We Use Anything Else But LOAM SOIL?

Pride & Joy

A Special Tree…..

Spilled Diesel?
Hours of Idling Machines?
Concrete & Sheetrock Soil Amendments?
String Trimmer Bark Treatments?
Deep Trunk Immersion?
Once Yearly Watering?
Salt Spray Foliar Feedings?
&
Ran out of Money?

Actual conditions: Average street tree has access to **between 0.9 m³ (32 ft³) to 1.8 m³ (64 ft³) of soil.**

MSP MN: Honeylocust (Gleditsia triacanthos)
Zone 4; Type II Storms; 31" Annual Precipitation

Let's End Magical Thinking about Trees*

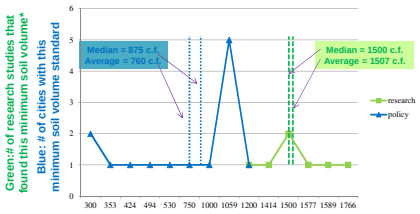
*Peter MacDonagh
The Kestrel Design Group

KEY #1: LARGE (>1,000 CF) ROOT SOIL VOLUME = 95% GOOD TREES

Walt Disney World Orlando FL
USDA Zone 9; Type III Storms; 51" Annual Precipitation

- **Evaluated 1,127 Parking Lot Trees: 1-30 Years Old; 21 Spp.**
  - **Define Tree Success: Good, Fair, Poor, Dead**
  - **Relationships: Soil Vol & Tree Condition**
  - **Test Applicability: Soil Vol Recommendations**
- **GOOD CONDITION**
  - **100% of Trees in 1,500 CF (Cubic Feet)**
  - **95% of Trees in 1,000 CF**
  - **84% of Trees in 500 CF**
  - **65% of trees in 100 CF**

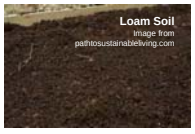
Meta-Study: Minimum Soil Volume Standards Policy (N=12) vs. Research (N=6)

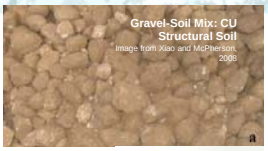


METASTUDY: RESEARCH RESULTS - Minimum Rootable Tree Soil Volumes based on Field Studies or Water or Nutrient Requirements vs
POLICY STANDARDS - Minimum Tree Rootable Soil Volume Standards in North American Municipalities

Studies included: Bakker. J.W., 1983; Lindsey, P. and N. Bassuk, 1991; Kopinga, J., 1991; Kent, D., S. et al 2006; Schoenfeld, P.H. 1975; Helliwell, D.R. 1986; Schoenfeld, P.H. and J. van den Burg, 1984

Urban Plaza Research: Bartlett Tree Research Lab 2004-2013 (9 Years) USDA Zone 8….Type II Storms…42" Annual Precipitation



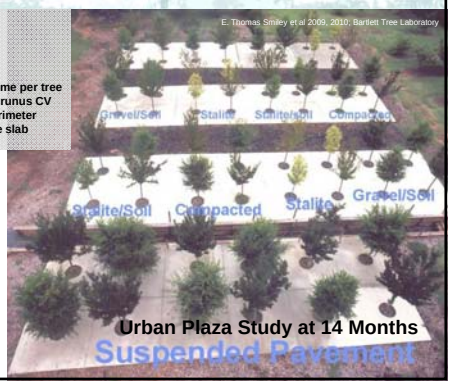


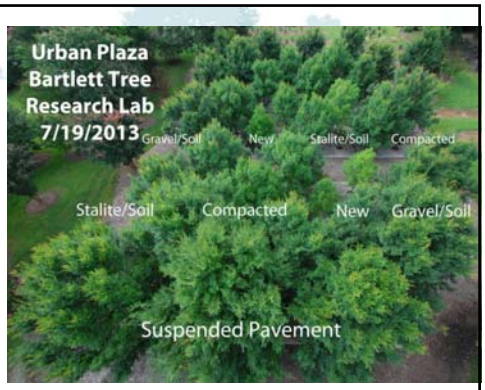
Treatments:

- **Suspended pavement (sandy clay loam <85% Proctor)**
- **Compacted soil (95% Proctor)**
- **Gravel – Soil mix (80/20%, 1-1.5" dia) (95% Proctor)**
- **Stalite – Soil mix (80/20%, .75-1" dia) (95% Proctor)**
- **Stalite - (100%) (95% Proctor)**
- **Sand Based Soil**

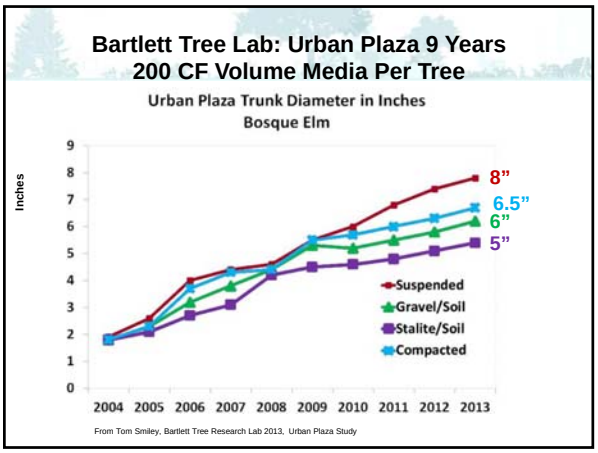
Urban Plaza Research At The Bartlett Tree Research Lab 2004-2013; 200 CF Per Tree; 100 SF Paving

Planted 2004
10' x 10' x 2' deep
3m x 3m x 0.6m deep
Irrigated
12 Trees per Media Type
200 cf/5.7 m3 Media volume per tree
Ulmus "Homestead" & Prunus CV
Geotextile & Geogrid Perimeter
4"/102mm thick concrete slab
Tom Smiley, Bartlett Tree Lab 2013





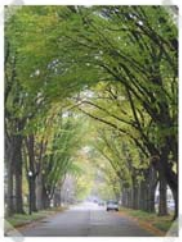
Urban Plaza Bartlett Tree Research Lab 7/19/2013
Tom Smiley, Bartlett Tree Lab 2013



KEY #2: SPECIES DIVERSITY (<5% UTC per GENUS)

We Had Big Urban Trees & Lost Them
SuperTrees that Can Grow in Any Media?
BUT Can't Survive Monocultures!

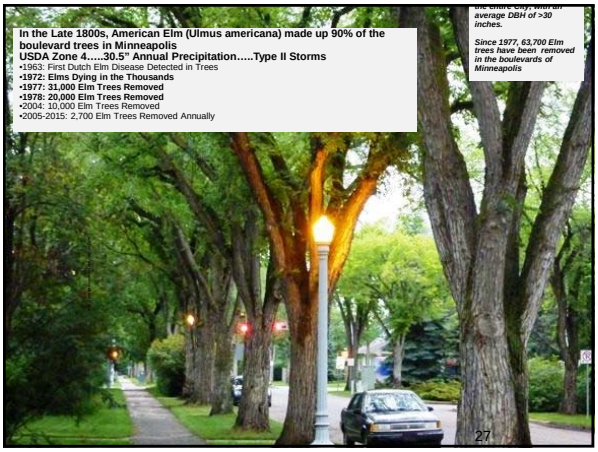
American Chestnut: Chestnut Blight



American Elms: Dutch Elm Disease

American Ash: Emerald Ash Borer

Image to the right from the Forest History Society, Inc. at http://www.appalachianwoods.com/appalachianwoods/history_of_the_american_chestnut.htm 26

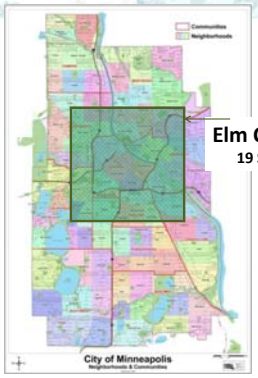


53 Square Miles

Minneapolis Chain of Lakes
Correlative Study
MacDonagh 2014: Unpublished

Relationship of Tree Species Diversity and Water Quality

Dutch Elm Disease



Elm Canopy Loss
19 Square Miles

Minneapolis Lake Quality

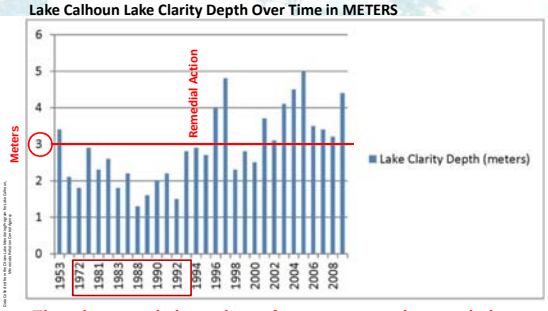
Image above: Secchi Disk
Image from Ben Meadows Catalog

Images above and right: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/citizen-lake-monitoring-program/secchi-transparency-slideshow/secchi-transparency-slideshow.html?menuid=&redirect=1

deeproot

Relationship of Tree Species Diversity and Water Quality

Lake Calhoun Lake Clarity Depth Over Time in METERS



There is a correlation to loss of tree canopy and water clarity

Following the removal of Elm trees (during the late 1970s and early 1990s), there was a marked decrease in water clarity depth in the Chain of Lakes, yet building development stopped in 1953 throughout the contributing sub-watershed around Lake Calhoun.

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Modelled Stormwater Value to Minneapolis

Benefits of Large Street Trees

American Elms

Tree size		Stormwater Interception		
DBH (cm)	DBH (inches)	cubic meters/ tree/yr	Gal/tree/ yr	cf/tree/yr
38	15	5.4	1,427	191
114	45	63	16,640	2,225

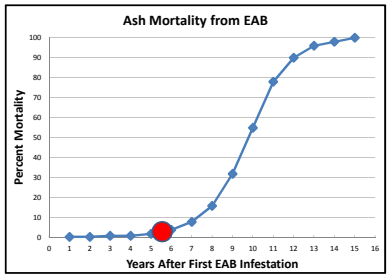
Total street tree population 120,676

-American Elms: 9.9% of total street trees
-30.75% of total street tree stormwater benefits (total tree stormwater benefits) = 3,400,000 cf
= 78 acre feet
= Candlestick Park: 78 feet Deep Water

-3142 total elms >36" DBH = 2.6% of total street tree population = 1,163,000 cf
= 27 acre feet

Source: Minneapolis Municipal Tree Resource Analysis, McPherson et al, 2005, and personal communication

EAB: A Predictable Pattern of Losses

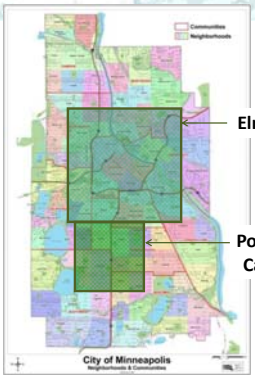


Based on data from Dr. Dan Herms, The Ohio State University

MPRB 5000 Ash Trees being Removed Annually; Average Ash >18" DBH

Relationship of Tree Species Diversity and Water Quality

Dutch Elm Disease & Emerald Ash Borer

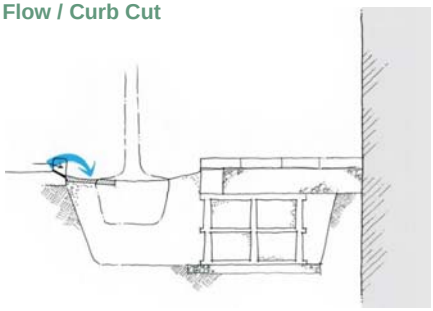


Elm Canopy Loss

Potential Ash Canopy Loss

KEY #3: DIRECT STORMWATER TOWARDS TREES

Sheet Flow / Curb Cut



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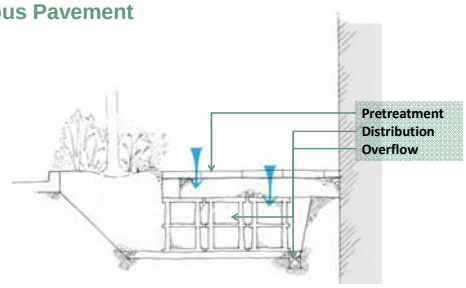
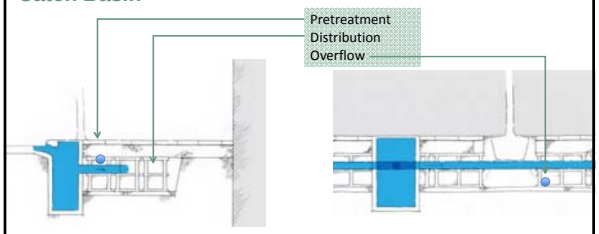
DIRECT STORMWATER TOWARDS TREES

Porous Pavement



DIRECT STORMWATER TOWARDS TREES

Catch Basin



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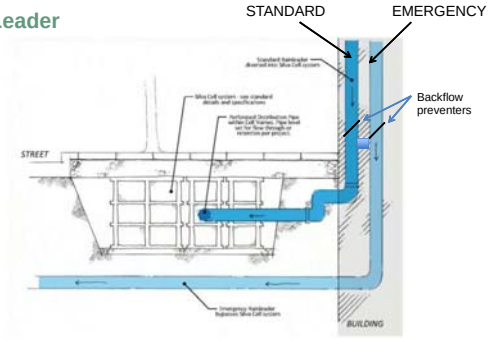
DIRECT STORMWATER TOWARDS TREES

Rain Leader



KEY #4: SHOW STORMWATER VALUE of TREES

Directly Connected Impervious Drainage Area (DCIA)

Zone 8; Type III Storms; 47.5" Annual Precipitation

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North Carolina State University Research

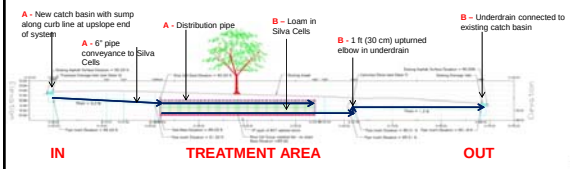
- Two Tree/Soil/Silva Cell systems installed and monitored
- Both are Crape Myrtle Trees
- 2 different media: differ in organic matter content
- Wilmington, NC: 1 on Orange Street, and 1 on Ann Street
- 59 storms above 0.10 inches
- 47.6 inches during 11 months monitoring period,
- Collected 19 sets of paired water quality samples each site

J.L. Page, R.J. Winston, W.F. Hunt III. January 27, 2014. Field Monitoring of Two Silva Cell Installations in Wilmington, NC

Images by Deeproot, 2012

NCSU Research

- Pond liner to Remove Outside Catchment Variables
- Runoff from street directed via a catch basin & sump into distribution pipe into the Silva Cells (see A)
- Underdrains with upturned elbows slow water, denitrifies, then directs runoff into the Wilmington's MS4 (see B)
- Profile by Jonathan Page, NCSU Biological and Agricultural Engineering



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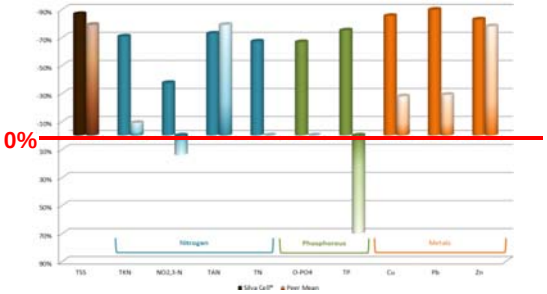
NCSU Research
Water Quality Results

Loam in Silva Cells at Wilmington vs.
Mean Traditional Bioretention Results From Peer Reviewed Literature



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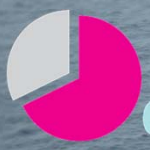
NCSU Research
Percent of Runoff Treated



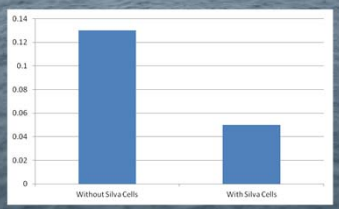
68% of the runoff was treated by the Ann St Silva Cell system

Significantly less bypass is expected at typical Silva Cell installations because:

1) Pond liner was used so no exfiltration was possible – for typical Silva Cell installations pond liner is NOT so exfiltration is possible.
2) Drainage area to these Silva Cell systems (1 tree per 0.1 acre) was significantly greater than typical installations

NCSU Research
Peak Flow Reduction

Despite pond liner and large drainage area,
mean peak flow decreased 62% from 0.13 cfs to 0.05 cfs

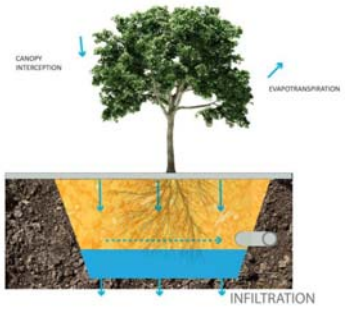


KEY #5: CALCULATE STORMWATER CREDIT FOR TREES

Minnesota Stormwater Manual: Tree Chapter

http://stormwater.pca.state.mn.us/index.php/Trees

- Tree quality and planting
- Soil quality
- Minimum soil volume
- Techniques available to provide rootable soil under load bearing surfaces.
- Species list for tree SCMs
- Maintenance
- Inspection form
- Monitoring



Minnesota Stormwater Manual: Tree Chapter

Stormwater Credits Using Properly Planted Trees for Stormwater: Minnesota 2014

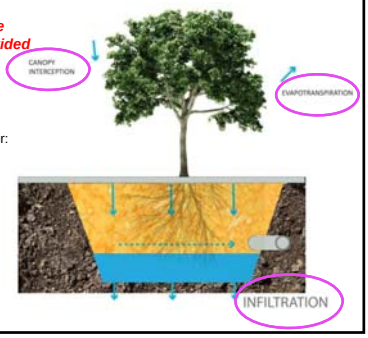
http://stormwater.pca.state.mn.us/index.php/Trees

1) Infiltration + 2) Evapotranspiration (ET) + 3) Interception

Full ET credit for a mature tree is given IF 2 c.f. of soil is provided per s.f. of canopy

Volume based performance goals for:

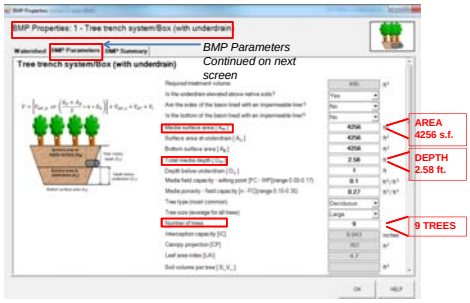
- New development
- Redevelopment
- Linear Development
- Sites with Restrictions



Minnesota Stormwater Manual: Tree Chapter

Example Tree Credit Calculation Sample Scenario

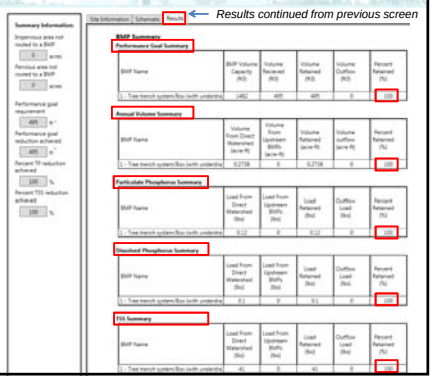
- Watershed: 270' long x 20' wide sidewalk (0.12396 acres)
- Tree SCM: 266' long x 16' wide x 2.58' deep
- Silva Cells with 9 large trees, 30' oc

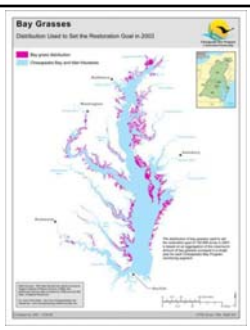


Minnesota Stormwater Manual: Tree Chapter

Example Tree Credit Calculation Sample Scenario

Results continued from previous screen





Chesapeake Bay Tree Credits: 2016

Upland Forest Conservation; Individual Tree Planting; Existing Tree Rescue

deeproot

caption 52

What's The Point of This Slide?

Washington, D.C.|36% tree cover

http://www.nationalgeographic.com/news-features/urban-tree-canopy/

Washington has more green space per capita than any other similarly sized U.S. city—a legacy of Federal government support.

The District spends more money on its trees than any other city: $10 million per year.

•San Francisco Bay: Trees for Stormwater

Trees Tolerant of Extreme Saturation

Bald Cypress
River Birch (Species & "Heritage")
Hackberry
Kentucky Coffee Tree
Tupelo aka Blackgum
Southern & Sweetbay Magnolia
American, English & Dahoon Holly
Swamp White Oak
Southern Live Oak
Eastern Arborvitae
Hedge Apple aka Osage Orange
Box Elder
Rosebay Rhodendron
Black Spruce
American Larch
Buttonbush

deeproot

•San Francisco Bay: Trees for Stormwater

Trees Tolerant of Moderate Saturation

Montezuma Cypress
Dawn & Coast Redwood
American Elm DED Resistant (Homestead, Princeton,
Lacebark Elm
Sugarberry
Sweetgum
London Planetree ('Bloodgood' & 'Columbia")
Arizona Planetree
Yellow Buckeye
Shagbark Hickory
Burr Oak
European Hornbeam
Western Arborvitae
Zelkova
European Larch
Littleleaf Fig

deeproot

•San Francisco Bay: Trees for Stormwater

Trees Tolerant of Intermittent Saturation & Drought

Bald Cypress
Montezuma Cypress
Burr Oak
Hedge Apple aka Osage Orange
Littleleaf Fig
Arizona Planetree
Tanoak
Vitex
Desert Willow

deeproot

•San Francisco Bay: Trees for Stormwater

Trees Tolerant of Drought

Montezuma Cypress
Burr Oak
Hedge Apple aka Osage Orange
Littleleaf Fig
Arizona Planetree

deeproot

•San Francisco Bay: Trees for Stormwater

Trees to Avoid

Red Maple
Red Oak
Laurel Swamp Oak
Water Oak
Cottonwood

deeproot

So You Want a Great Urban Forest?

DO This……

- Include Trees as Part of Stormwater System
- Codify Minimum LOAM Soil VOLUMES FIRST >800cf
- DIVERSIFY Species
- No Single Tree Genus >5%
- Set Minimum CANOPY TARGET with Deadline >40% East of the Mississippi River and in NW US
- Set Minimum CANOPY TARGET with Deadline >25% West of the Mississippi River (40% in NW US)
- FIND & FILL GAPS with Trees
- Plant Lots of Small Trees with LARGE Soil Volumes
- Monitor & Apply Responsive O&M

Don't Do This…..

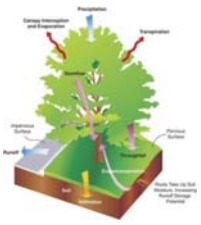
- Plant Trees in Small PITS
- Plant Trees in COMPACTED SOIL or SAND or STRUCTURAL SOIL
- Plant Lots of A FEW Species
- Plant Trees Only After COMPLAINTS
- Plant Tree Root Packages LOW
- Plant Trees As BEFORE
- Announce a MILLION Tree Planting Program Applying Above Steps
- Respond to Merchants Complaining about Trees BLOCKING Their SIGNS by Removing Trees

5 KEYS to a SUCCESSFUL URBAN FOREST
Become Part of Stormwater System

1. REQUIRE LARGE (2:1) ROOTABLE SOIL VOLUMES
2. SPECIES DIVERSITY (UTC <5% GENUS)
3. DIRECT STORMWATER to TREES
4. SHOW STORMWATER VALUE of TREES
5. CALCULATE STORMWATER CREDITS for TREES

Request Portion of Stormwater Budget >$50

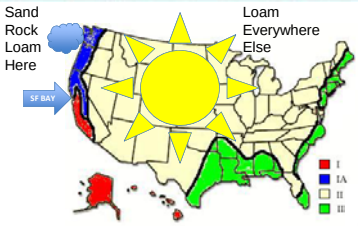
CASE STUDIES



TYPE 1A Storms e.g. Portland Oregon
New Milton UK: Lidl Grocery Store - USDA Zone 9
Ipswich UK: Plaza - USDA Zone 9
Leeds UK: Plaza - USDA Zone 9
London UK: WW II Memorial - USDA Zone 9
Stockholm Sweden: USDA Zone 8
Vancouver BC: SEFC – Zone 8

TYPE 2 STORMS e.g. West & Midwestern North America
Minneapolis MN: MARQ2 – USDA Zone 4
Calgary AB: Second Ave - USDA Zone 3
Caty TX: Willow Fork Central - USDA Zone 9
Fort Worth TX: Sundance Square - USDA Zone 8
Toronto ON: Sugar Beach – USDA Zone 5
Manhattan NY – Lincoln Plaza

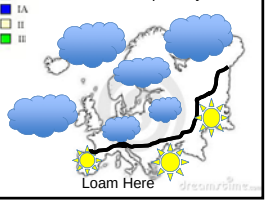
Does it Rain? or Storm? Loam? Sand? Rock?



USA Mainly Storms
Type II
SF BAY Type I & IA

Europe
Mainly Rain
Type 1A

Sand, Rock, Loam
North of the Alps & Pyrenees

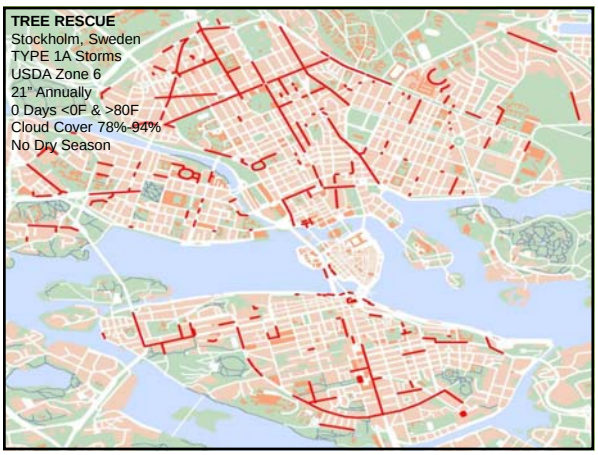


Amsterdam Soil - SBS

Type 1A Rains, Zone 7; 30" Annual

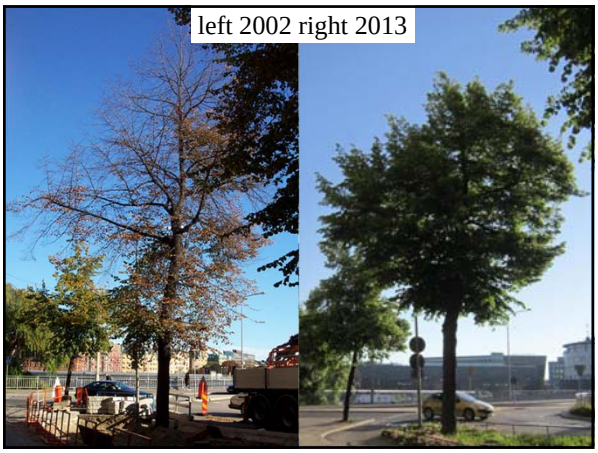
Precipitation Pervious Paving, High Water Tables, Sand & Compost

TREE RESCUE
Stockholm, Sweden
TYPE 1A Storms
USDA Zone 6
21" Annually
0 Days <0F & >80F
Cloud Cover 78%-94%
No Dry Season



Stockholm Method to Rehabilitate Existing Trees:
Demo Concrete, Air Spade Compacted Dirt, Replace Granite Aggregate, Wash-in Soil & BioChar, Install Inlets, Repave

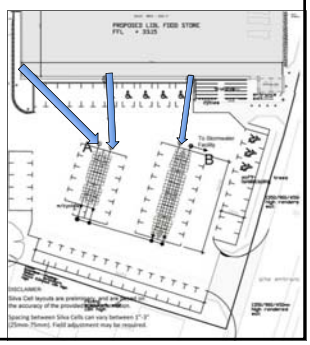
Stockholm, Sweden: TYPE 1A Storms; USDA Zone 6; 21" Annually
0 Days <0F & >80F; Cloud Cover 78%-94%; No Dry Season



Case Study: Lidl Grocery Store, New Milton, UK: 2010

Stormwater Trees with Roof and Parking Lot Runoff:
Rain-Leaders and Pervious Paver Bays; Silva Cells & Loam

- USDA Zone 8
- Type 1A Rain
- Annual Precipitation: 32"
- 0 Days <20F >85F
- Cloud Cover 70% - 90%
- No Dry Season
- Project Designer: lhc
- Technical Consultant Silva Cells and Rainwater: Kestrel Design Group
- Soil volume per tree: 19.98m3 (706 ft3)
- Catchment: 799.36 m2 (8,605 s.f., 0.2 acres)
- 5 Trees
- Total Silva Cells: 342 frames, 114 decks
- Installation: October 2010



Case Studies

Case Study: Lidl Grocery Store, New Milton, UK: 2010

Lidl Grocery Store, New Milton, UK
1 year after installation: 09/14/2011

Case Study: Ispwich UK

Zone 9; Type IA; 22" Annual Precipitation

Case Study: Ispwich UK

Zone 9; Type IA; 22" Annual Precipitation

Case Study: Leeds, UK.

Zone 7; Type IA Storms; 33" Annual Precipitation

Case Study: Bomber Command – London UK (2013)

London England:
Zone 9;
Type IA Storms;
24" Annual Precipitation

Vancouver Canada 2007

USDA Zone 8; Type IA Storms; 44" Annual Precipitation

SEFC: the site of the 2010 Olympic Village

Vancouver Canada 2007

USDA Zone 8; Type IA Storms; 44" Annual Precipitation

Athletes Olympic Village:

SE False Creek Bike Path

Vancouver Canada 2007

USDA Zone 8; Type IA Storms; 44" Annual Precipitation

Jan.2008

Vancouver Canada

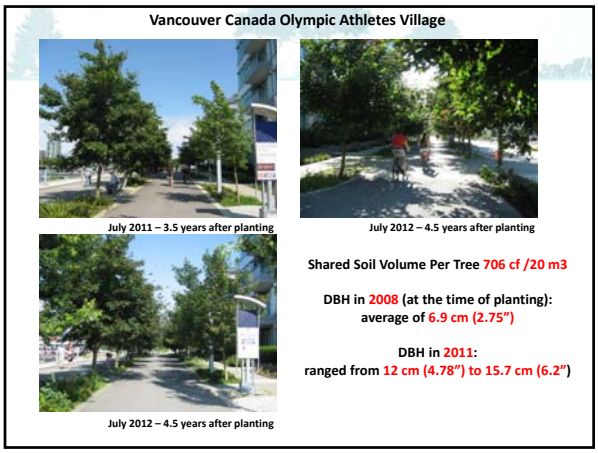
USDA Zone 8; Type IA Storms; 44" Annual Precipitation

January 2008 – just planted

June 2008 – 0.5 years after planting

July 2009 – 1.5 years after planting

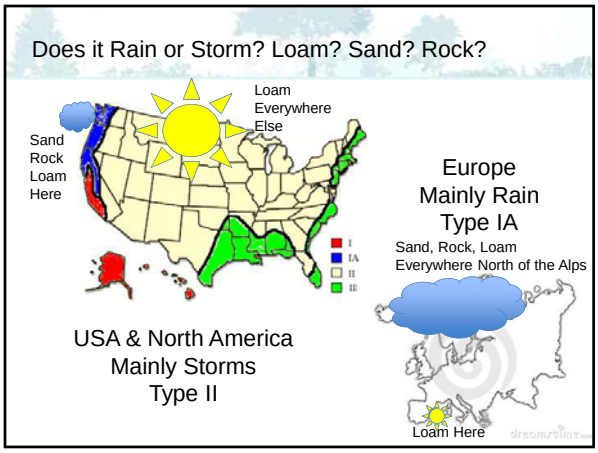
June 2010 – 2.5 years after planting

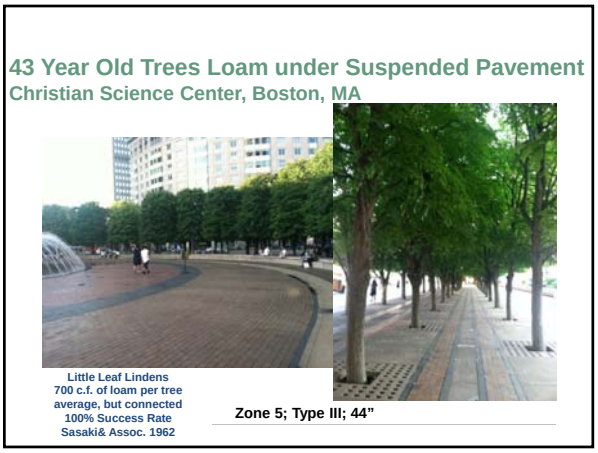

Vancouver Canada Olympic Athletes Village
July 2011 – 3.5 years after planting
July 2012 – 4.5 years after planting
July 2012 – 4.5 years after planting
Shared Soil Volume Per Tree 706 cf /20 m3
DBH in 2008 (at the time of planting):
average of 6.9 cm (2.75")
DBH in 2011:
ranged from 12 cm (4.78") to 15.7 cm (6.2")


2008 to July 2013
DBH - 2.7" to 7.9"


2014


2014


Does it Rain or Storm? Loam? Sand? Rock?
Sand
Rock
Loam
Here
Loam
Everywhere
Else
I
IA
II
III
USA & North America
Mainly Storms
Type II
Europe
Mainly Rain
Type IA
Sand, Rock, Loam
Everywhere North of the Alps
Loam Here


43 Year Old Trees Loam under Suspended Pavement
Christian Science Center, Boston, MA
Little Leaf Lindens
700 c.f. of loam per tree
average, but connected
100% Success Rate
Sasaki& Assoc. 1962
Zone 5; Type III; 44"

29 Year Old Trees in Suspended Pavement

Charlotte, NC – 1985
Trade & Tyron St. 29 years

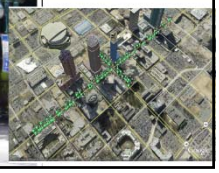
Bartlett Tree Labs; Tom Smiley 2014

Willow Oaks:
40mm (19 inch) DBH
21.7m (91 feet) Tall
19m³ (700ft³) of loam soil / tree

98% survival rate (167/170)

Designed by McSween

USDA Zone 8;
Type III Storms;
42" Annual Precipitation



Case Study:
Marquette & 2nd Avenues (MARQ2) Busway
Minneapolis, Minnesota
Stormwater Trees with Sidewalk Runoff to Pervious Pavers

- USDA Zone 4
- Type II Storms
- Annual Precipitation 30.5" No Dry Season
- 14 Days >90F, 11 Days <0F
- Cloud Cover 52% - 92%

- Average soil volume per tree: 650 ft3
- Catchment: 5.15 acres
- 167 Trees
- Total Silva Cells: 4,909 decks, 9,818 frames
- Installation: 2008-2009
- Project Designer: SEH and URS
- Technical Consultant: Kestrel Design Group

Case Study: MARQ2 Busway, Minneapolis, Minnesota

Stormwater Trees with Sidewalk Runoff to Pervious Pavers

Overview of Yearly Growth:
2010-2013: 4' taller, 5.4' wider

Marq2 Silva Cell Installation, tree monitoring images by Kestrel Design Group

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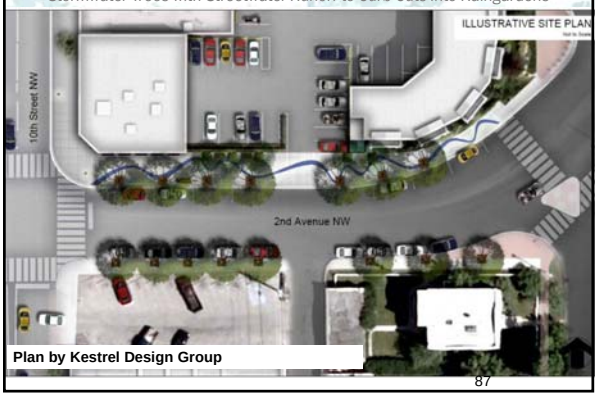
Case Study: 2nd Avenue Streetscape, Calgary, Alberta; 2013

Stormwater Trees with Streetwater Runoff to Curb Cuts into Raingardens



Plan by Kestrel Design Group

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Case Study: 2nd Avenue Streetscape, Calgary, Alberta

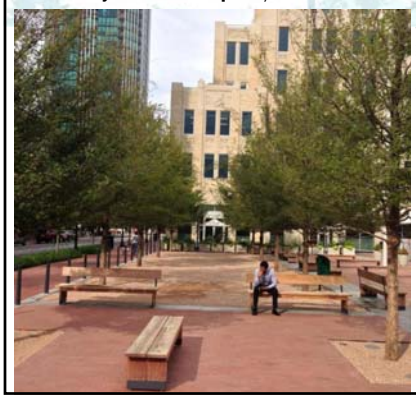
Stormwater Trees with Streetwater Runoff to Curb Cuts into Raingardens

- USDA Zone 3
- Type II Storms
- Annual Precipitation: 16.5" (422 mm)
- Dry Season
- 5 Days >90F, 17 Days <0F
- Cloud Cover 61% - 83%

- Average soil volume per tree: 19m3 (671 ft3)
- Catchment : 1,235 m2 (0.3 acres)
- 7 Trees
- Total Silva Cells: 470 frames, 270 decks
- Installation: June 2013
- Project Designer: Kestrel Design Group & Larson Engineering

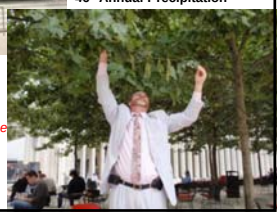
Case Study: Sundance Square, Fort Worth Texas: 2013

Case Study: Sundance Square, Fort Worth Texas: 2013



USDA Zone 8
Type II Storms
Annual Precipitation 37.8" 960mm
81 Rain Days
No Dry Season
74 Days >90F, 0 Days <20F
Cloud Cover 12% - 39%

Zone 6; Type III Storms;
46" Annual Precipitation



Manhattan NYC Lincoln Center: 2009

Trees in Loam Under Suspended Pavement……

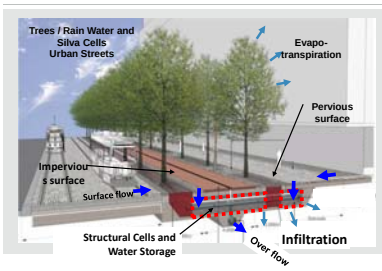
2.5 Years Old: 6" Caliper *Average 600 cf loam per tree*
No transplant shock
>8"/mm twig extension in 1st Season (2009)
>30"/762mm twig extension in 2nd Season
>35"/mm twig extension in 3rd Season

Manhattan NYC Lincoln Center: 2014

Manhattan NYC Lincoln Center: 2014

Urban Forest Canopy Planting at Scale

Waterfront Toronto: 2100 Acres On Lake Ontario: 2009
Largest Waterfront Project in the World



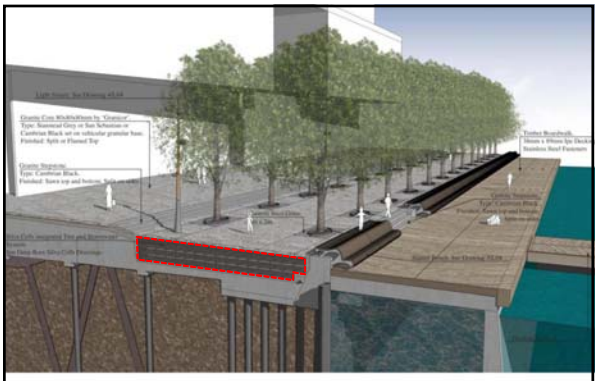
16 trees per acre capture
-1"/24 hour storm in: Soil

-16 trees @ 22" DBH capture
1.8"/24 hour storm in: Soil & Interception

Phase 1 Installed: 1,300 trees
All Phases: 16,800 trees

USDA Zone 6; Type II Storms;
33" Annual Precipitation

Courtesy: West 8 + DTAH



USDA Zone 6; Type II Storms;
33" Annual Precipitation

Waterfront Toronto

PERSPECTIVE/SECTION. WATER PROMENADE

Courtesy: West 8 + DTAH

Waterfront Toronto: Sugar Beach: 2009

5 KEYS to a SUCCESSFUL URBAN FOREST
Become Part of Stormwater System

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2. SPECIES DIVERSITY (UTC <5% GENUS)
3. DIRECT STORMWATER to TREES
4. SHOW STORMWATER VALUE of TREES
5. CALCULATE STORMWATER CREDITS for TREES

Request Portion of Stormwater Budget >$50

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Wolf, Kathy L. 2000. The Calming Effect of Green: Roadside Landscape and Driver Stress. Factsheet #8. Seattle: University of Washington, Center for Urban Horticulture. (Social Benefits).

Love Tunnel Railway, Klevan, Ukraine; Zone 5; Type II Storms; 26" Annual Precipitation

http://www.deeproot.com/products/silva-cell/case-studies

Urban Trees MN Manual:

http://stormwater.pca.state.mn.us/index.php/Trees

Q & A

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peter@tkdg.net