SOVEREIGN CONSULTING INC.
AN ENVIRONMENTAL SERVICES FIRM

# Low Impact Development (LID)

Robert A. Cummings, PE, CFM
**Sovereign Consulting Inc.**
4 Open Square Way, Suite 307
Holyoke, MA 01040
(413) 540-0650
rcummings@sovcon.com

# Today's Discussion Goals

1. Storm Water Quality and Hydrology
2. Storm Water Pollution Prevention versus LID
3. LID Techniques:  Types and Functionality
4. LID Implementation
5. Costs:  LID versus Convention Construction
6. Maintenance Issues

# What's the Difference?

Storm Water Pollution Prevention Plan (SWPPP)

Erosion Control Plan

Construction Best Management Practices (BMPs)

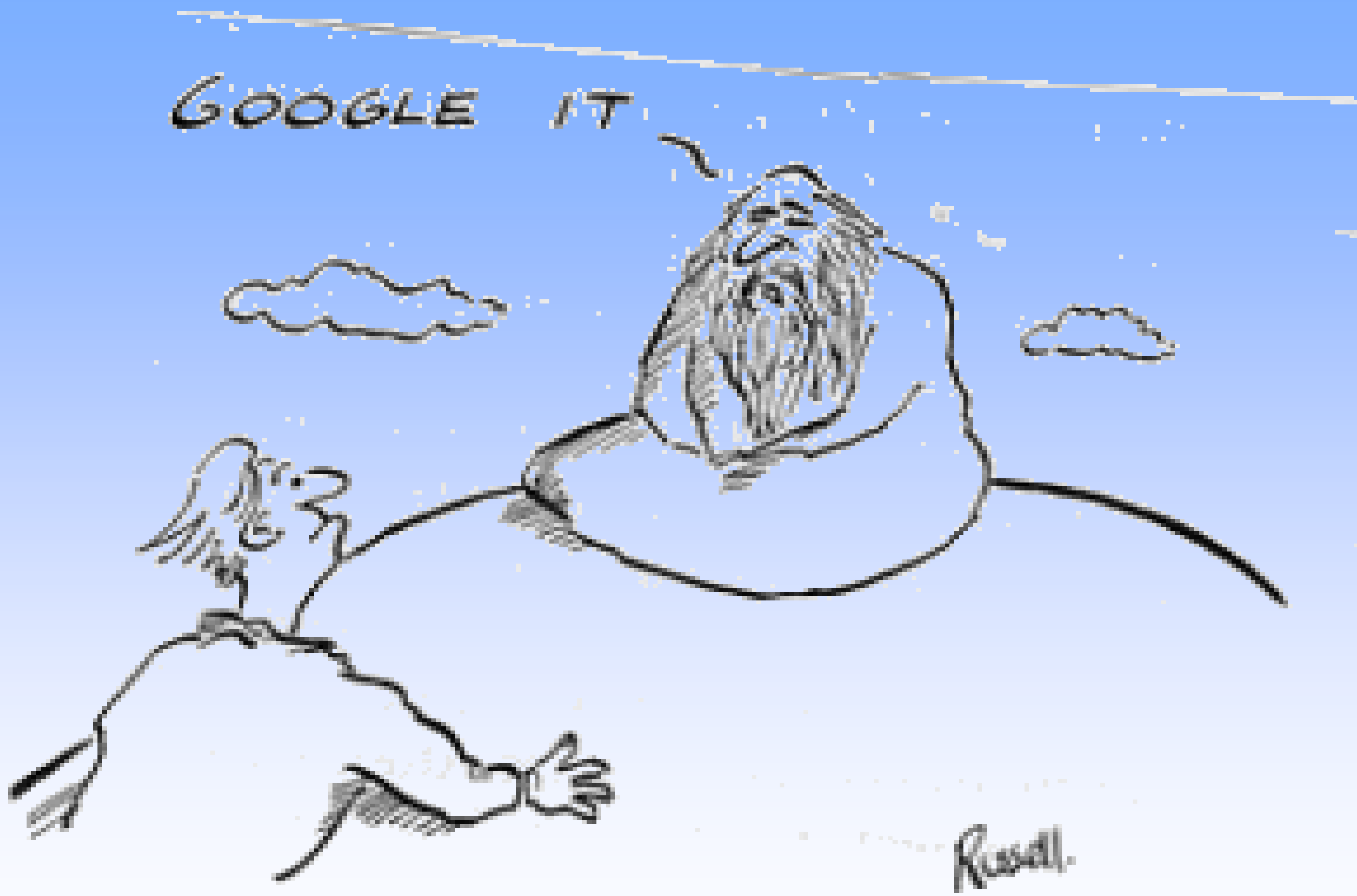
Soil Erosion & Sediment Control Plan

Low Impact Development

Spill Prevention & Control Plan

Best Management Practices

# Why Are We Here?



# Why Are We Here? Take 2

- The number of TMDLs nationally has increased exponentially over the past 15 years
- TMDL:  Total Maximum Daily Load
  - 1996 = ~0 TMDLs
  - 2009 = 42,500 TMDLs
- Approximately 40% of all waterways in the USA are considered impacted
- Chesapeake Bay has essentially been written off as “lost”
- Something isn’t working.  What’s not working?

# Old School vs. New School

# Unit Operations & Processes

- Physical Operations
- Biological Processes
- Chemical Processes
- Hydrologic Operations

# Old Methods vs. LID

| Then | Now |
|---|---|
| 1. Detention Ponds | Tree Filters |
| 2. Retention Ponds | Porous Asphalt |
| 3. Vegetated Swales | Porous Pavers |
| 4. Stone line Swales | Gravel Wetlands |
| 5. Berm Swales (Check Dams) | Rain Gardens |
| | Buffer Strips |
| | Green Roofs |
| | Rain Barrels |

## Manufactured Systems

1. Hydrodynamic separators (HDS)
2. In-ground detention or filtration systems (ADS, StormTech)
3. AquaFilter filtration systems (combination of HDS and detention/filtration systems)
4. Deep sump catch basins

LID measures (UOPs) typically have two components:

1. Structural measures
2. Plants

## Principles of LID:

10% Rule

Approximately 7% of the USA is industrial & commercial property

This 7% accounts for 63% of all nutrient loading in streams

# What Are We Trying to Remove?

| Pollutant | Target Removal Rate via SWQ |
|---|---|
| 1. Total Suspended Solids (TSS) | 80% |
| 2. Total Petroleum Hydrocarbons (TPH) | n/a |
| 3. Dissolved Inorganic Nitrogen (DIN) | 40% |
| 4. Zinc (Zn) and other heavy metals | n/a (5 mg/L for drinking water) |
| 5. Total Phosphorous (TP) | 60% |

# Observe the Patterns!

- The old system in the 1980s were failing due to lack of maintenance or poor construction.

- For years, the target has been to remove 80% of TSS from discharge stormwater but no one remembers why. Now, this number seems arbitrary, due to the absence of a target turbidity rate for discharged stormwater.

- The assumption was that pollutants (nutrients) in the stormwater runoff were hydrophobic and would adsorb to the TSS and thence settle out.

- This is a generally true; however, this does not address the dissolved pollutants which cause low dissolved oxygen (DO) in the stormwater runoff.

The general sense is to let developers develop, but **ensure that stormwater treatment is accomplished**. If poor soils or a shallow rock layer exists at the development site, work around it and **treat the runoff**.

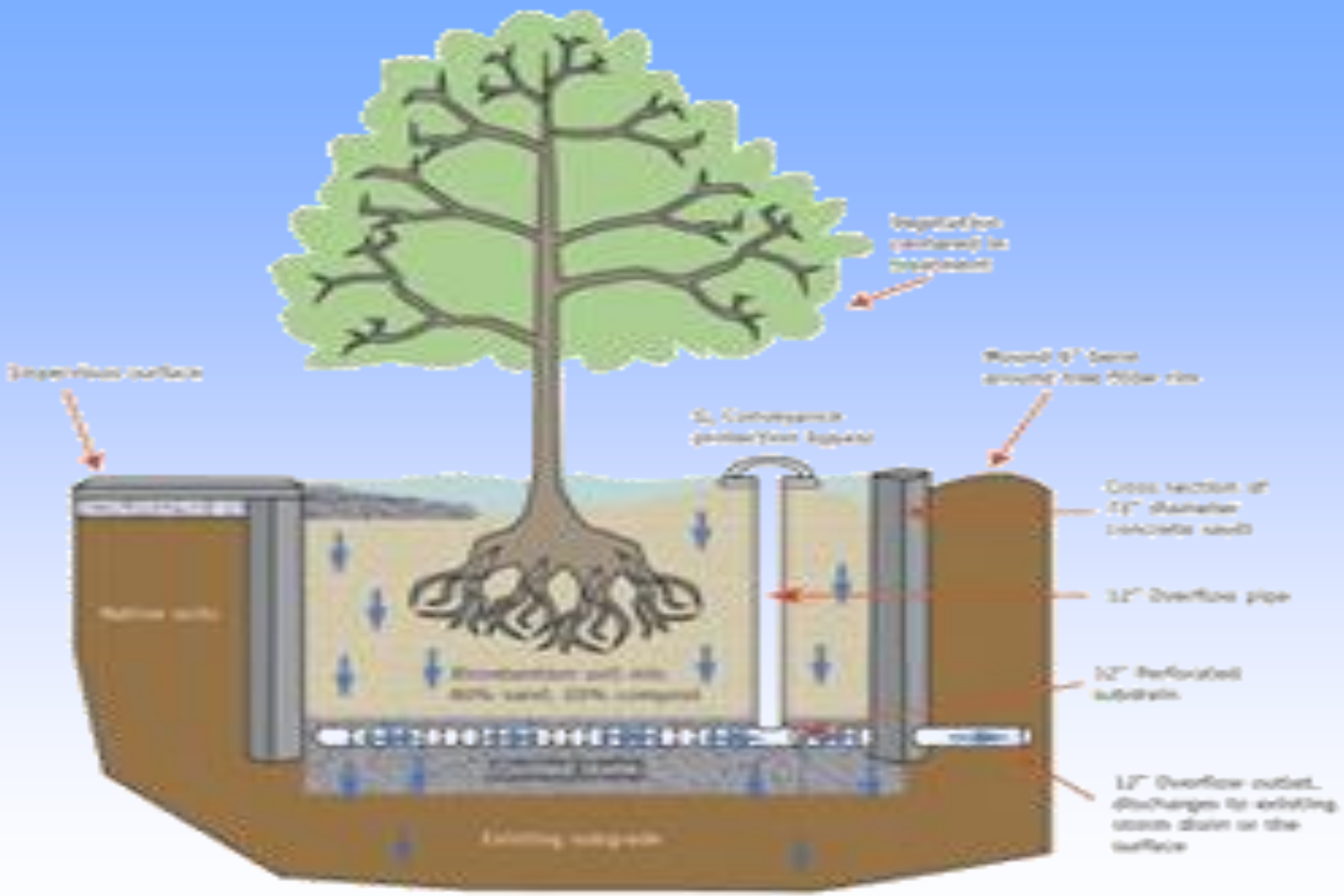
Filtration:

- Correctly designed detention ponds in accordance with Stokes' Law
- Filtration is far superior to sedimentation
- Addition of 5% floc to filtration media to meet 20 year lifespan
- Filtration is THE big push by the EPA right now

Planning:

- Use the site to your advantage:
  - Created wetlands
  - Floodplains

# LID Toolbox – Tree Filters



# Tree Filters: Advantages

1. Facilitates easy retrofits
2. Functions as designed in both summer and harsh winter conditions
3. Creates aesthetically pleasing landscape
4. Allows a developer to meet both SWQ and local landscape ordinances
5. Removes TSS efficiently (~92% removal)
6. Removes TPH very well
7. Removes zinc and metals well
8. Serves as low maintenance remedy
9. Can convey up to 425 cfs

# Tree Filters: Disadvantages

1. The effective SWQ process/treatment rate is only 0.1 cfs
2. Tree filters only treat small subbasins (~4356 square feet)
3. Finite lifespan on the tree
4. Low nitrogen (~5-8%) and phosphorous (0%) removal
5. Relatively small peak discharge reduction
6. No chloride removal
7. Effectiveness is greatly diminished during large runoff events

# Tree Filters: Costs

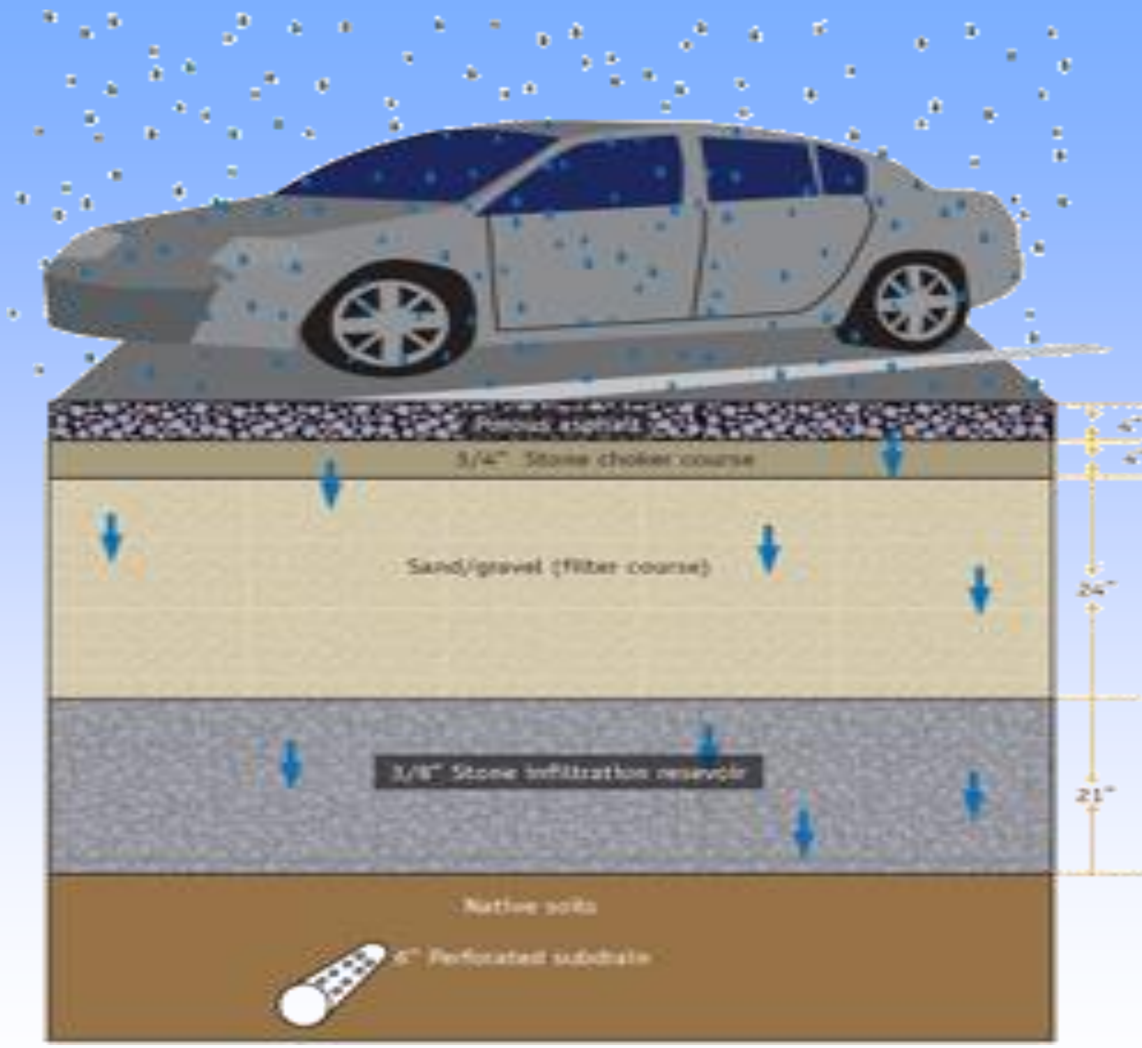
$3,000 per unit for materials
\+ <u>$3,000 for installation</u>
**$6,000** total per installation

- Thus about $3,000 per installation for municipalities
- $30,000 per acre treated
- Low maintenance cost:
  - Unclogging top 2” of soil via raking or vac-truck
  - Tree replacement
  - Manmade maintenance, e. g. car crashes
  - Floatables removal

# LID Toolbox – Porous Paving

## Options:

- Porous asphalt
- Porous concrete
- Porous pavers



# Porous Paving: Advantages

1. Porous asphalt is resistant to the salts spread in icy conditions
2. Actually reduces the amount of salt needed during icy conditions by reducing snow and ice accumulation
3. Can handle massive amounts of rainfall without short circuiting (including rare storm events)
4. Requires little maintenance
5. Removes sediments, petroleum hydrocarbons, and heavy metals at a high rate
6. Removes phosphorous at a good rate
7. Reduces issues in developed parcels such as standing water in parking lots during heavy rain events
8. Does not take up development surface area like detention ponds
9. Reduces surface runoff flows to nearly zero
10. Assists and promotes groundwater aquifer recharge
11. If constructed correctly, will outlive conventional asphalt
12. Dramatically reduces peak runoff flows to receiving streams

# Porous Paving: Disadvantages

1. Has higher installation costs
2. Takes trained personnel to install it. Not many contractors are familiar with it.
3. Is easy to install incorrectly
4. Generally cannot be used atop shallow water tables, shallow rock layers, or low permeability soils
5. Performs poorly in heavy truck traffic or heavy traffic areas
6. Is susceptible to structure failure (consolidation)

# Porous Paving: Costs

## Materials

$2.80/ft$^2$ for porous asphalt
$2.25/ft$^2$ for conventional asphalt

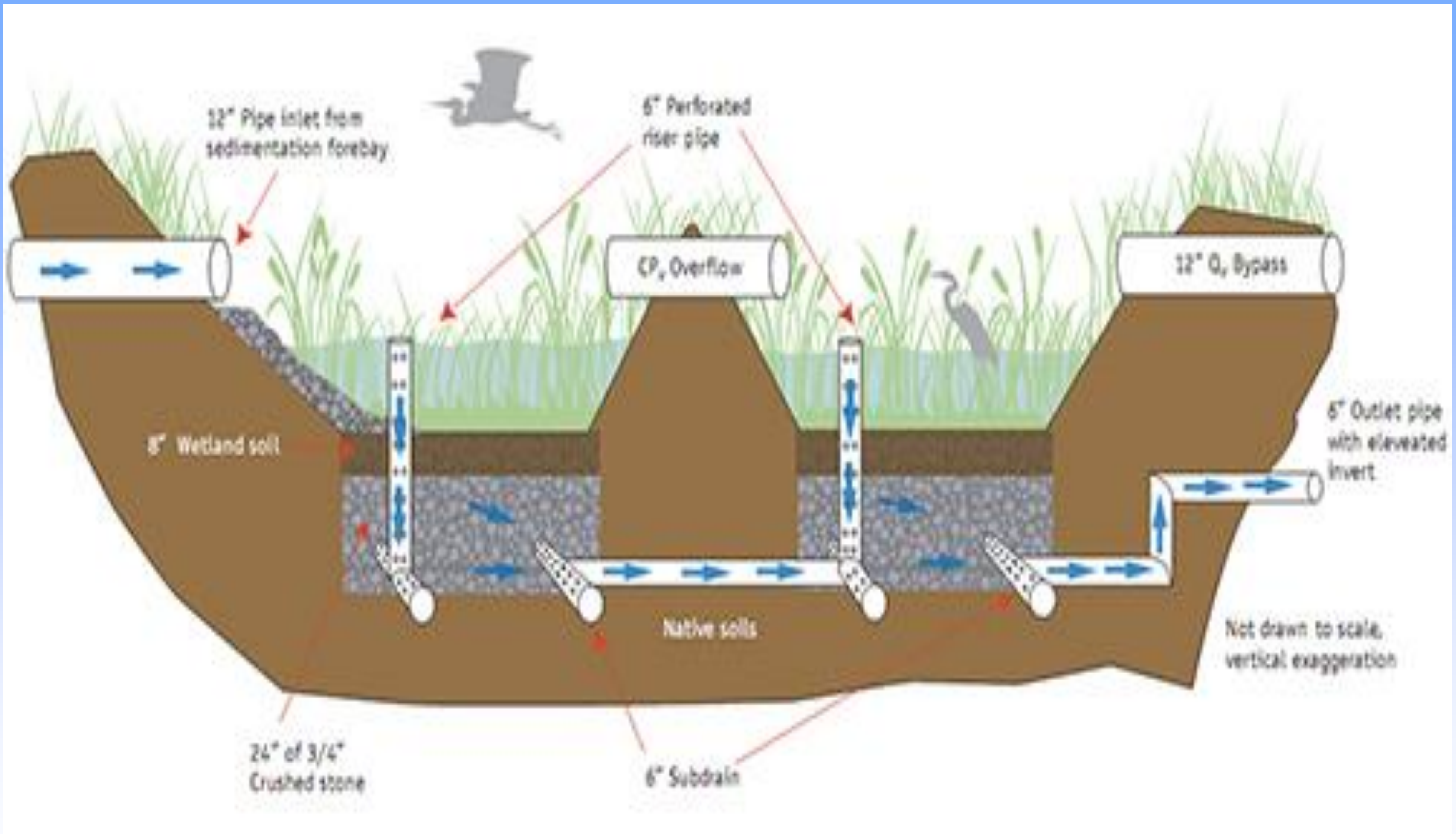
$2,300 per parking space for porous asphalt
$2,000 per parking space for conventional asphalt

## Maintenance

$350 per vacuum cleaning, typically semiannually

Underdrains are recommended if low permeable soils exist. Otherwise, let runoff water infiltrate into the ground

# LID Toolbox – Subsurface Gravel Wetlands




Rule of Thumb: 1/8$^{th}$ of an acre of wetlands system treats 1 acre of land

# Subsurface Gravel Wetlands: Advantages

1. Probably THE most effective SWQ LID option currently available
2. Ninety-eight percent TSS removal is typical
3. Excellent at petroleum hydrocarbon removal (99%)
4. Good at removing dissolved nitrogen year round (>95%)
5. Phosphorous removal between 53%-70% (60% target)
6. **Get what you pay for!**
7. Great reduction of peak flow runoff discharges
8. Moderation of runoff temperatures
9. Aesthetically pleasing
10. Easy to retrofit into classical dry detention ponds
11. Unaffected by cold climates or freezing

# Subsurface Gravel Wetlands: Disadvantages

1. Not suitable for regions susceptible to long dry spells
2. Due to land requirements, often not practical in densely populated areas
3. Relatively new, therefore few design professionals have experience with them
4. No chloride removal
5. Phosphorous removal doesn't meet target removal efficiency year-round. Dips below target level in the summer
6. Expensive
7. Land hog

# Subsurface Gravel Wetlands: Costs

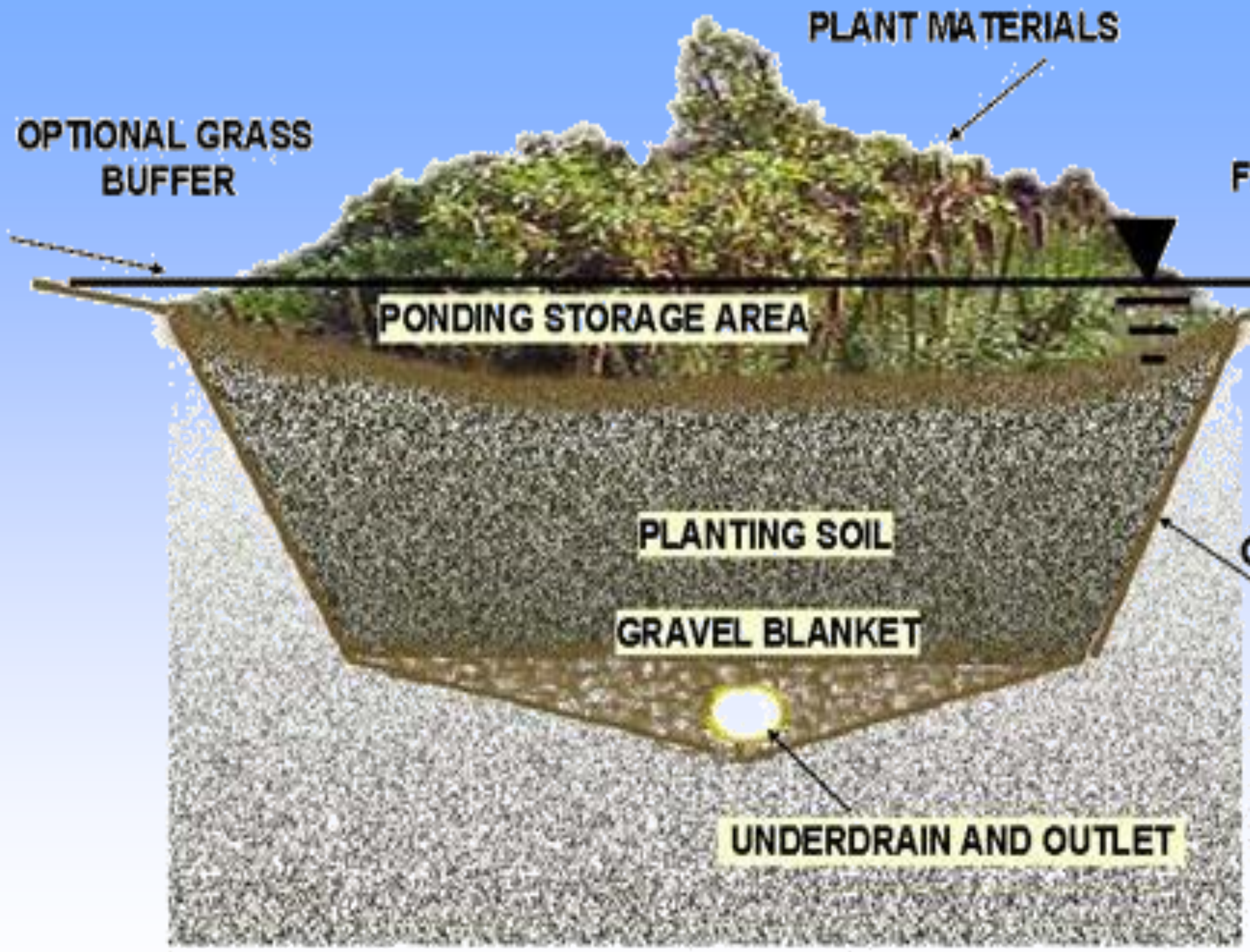
## Construction

A 1/8th acre subsurface gravel wetland costs about $22,500 to construct

## Maintenance

- Mow it once every three years
- Remove vegetation from the forebay and thin out or remove vegetation from the treatment cell(s) once every three years
- Biomass removal every three years is required or nitrogen release will increase
- Periodic sediment removal from the forebay will lengthen the lifespan and usefulness of the system
- Maintenance of the system helps the dinitrification process sustain itself
- Mowing the vegetation ensures that the water remains aerated before entering the $O_2$ limited environment of the subbase
- Maintenance of the forebay vegetation reduces the reintroduction of nitrogen and phosphorous to the water via the plants themselves

# LID Toolbox – Bioretention Pond or Rain Gardens



# Bioretention Systems: About

- Can come in many shapes and sizes
- Can be as simple or as complicated as the designer likes
- Works best when coupled with a forebay and treatment bay setup
- SWQ flow = 1 cfs
- A 272 $ft^2$ heavy duty bioretention area has been shown to treat a 1 acre area
- Among the most common LID systems used
- Success is dependent on the proper soil mix design
- Can be used as end-of-pipe treatment
- Most effective when treating small drainage areas
- Vegetation contributes to stormwater volume reduction through the process of evapotranspiration

# Bioretention Systems: Advantages

1. Ample research data on bioretention systems and proper soil mix designs
2. Seemingly unaffected by seasonal fluctuations, ice, and snow.
3. Can be used in areas of both good and bad percing soils
4. Very good TSS removal (97%)
5. Excellent TPH removal (99%)
6. Respectable Zn removal (99% for 36”-48” filter media)
7. Can attenuate peak chloride discharges
8. Excellent at substantially reducing peak runoff flow
9. Good retrofit to existing systems
10. Some nitrogen removal (44% for 48” filter media)
11. Phosphorous removal (up to 83%)

# Bioretention Systems: Disadvantages

1. Small changes in design from system to system can result in large variations of phosphorous efficiencies
2. Expensive
3. Not foolproof – requires a professional to help select a good bioretention soil design and the correct plants to use
4. Not the best at nitrogen removal. DIN removal can be as high as 44% or as low as 0%

## Overall

Usually around $14,000-$18,000 per acre treated (installed)

## Installation

Municipalities can install these for $5,500 for materials and plants

## Maintenance

- Generally maintenance free
- Highest maintenance is for the first 3-4 months as the plants need to be carefully maintained to get them to establish a root system
- After plants establish their roots, bioretention systems require no more maintenance than a lawn (occasional mowing and raking)
- Long-term maintenance may include scarifying the top 2” of the filter media

# LID Toolbox – Subsurface Infiltration Systems

# Subsurface Infiltration Systems (ADS): About

- ADS is a manufactured system, one of the few with a high performance rate
- Infiltration is the major push right now for stormwater management by the EPA through various state environmental agencies
- By using isolater header pipes and overflow weirs, subsurface infiltration systems can serve as filtration alone or detention AND filtration
- Several manufacturers of subsurface infiltration systems on the market
- Research has shown that subsurface infiltration systems are good at phosphorous removal due to an aerobic film developing atop the geotextile at the bottom of the excavation
- A “brute force” way to achieve SWQ

# Subsurface Infiltration Systems (ADS): Advantages

1. Can do double duty for detention AND infiltration
2. Assist in groundwater aquifer recharge
3. Low maintenance (jet once every 5-7 years)
4. High TSS removal (99%)
5. High TPH removal (99%)
6. High Zn removal (99%)
7. Good phosphorous removal (81%) which increases with time
8. Space efficient - excellent for use in high land value area
9. Unaffected by snow or icy conditions
10. Easy to install
11. Greatly reduced peak flows to receiving streams

# Subsurface Infiltration Systems (ADS): Disadvantages

1. Expensive
2. Does not perform nitrogen removal, which is typical of non-vegetated, aerobic systems
3. Can only be used in areas of high permeability soils
4. Cannot be used in areas of seasonal high water tables
5. In high pollutant areas, requires extensive changes to the system design
6. Does not provide chloride removal

# Subsurface Infiltration Systems (ADS): Costs

## Overall

Costs approximately $34,000 per acre of treated drainage area.

The cost is usually offset by the ability to use more surface area

## Maintenance

- Extremely low maintenance cost
- Jet the system once every 5-7 years to a manhole or inspection port and vacuum sediment up.

# Number of UOPs that ***alone*** will solve your problem?

# 0

# Low Impact Development: Recommendations

- Use a combination of systems
- Always use UOPs in series, not in parallel
- Use the UOP(s) that target your problem
- Remember that to remove DIN, use vegetative uptake or microbial processes

# LID Costs vs. Conventional Costs: Case Study I

| | Low Density Residential | Med. Density Residential | Shopping Center | Office Park |
|---|---|---|---|---|
| Conv. Design | $1,539,000 | $143,000 | $782,000 | $948,000 |
| LID Design | $1,239,000 | $126,000 | $746,000 | $78,000 |
| Cost Savings | $300,000 | $17,000 | $36,000 | $160,000 |
| Percent Savings | 19.49% | 11.89% | 4.6% | 16.88% |

LID designs can range from 5.5% more than conventional designs to 20% under. Why?

# LID Costs vs. Conventional Costs: Case Study II

| | Paving | Stormwater | Combined |
|---|---|---|---|
| Conventional | $1,539,000 | $143,000 | $782,000 |
| LID | $1,239,000 | $126,000 | $746,000 |

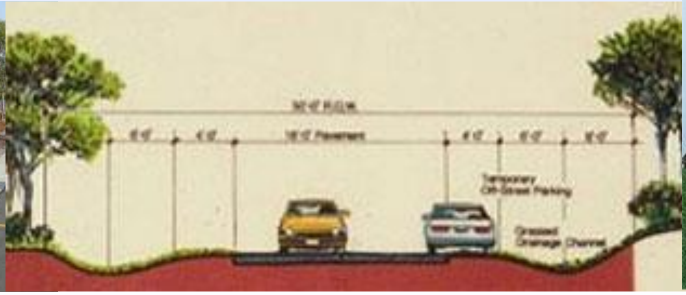
- LID was 5.5% more
- Lease space goes from $65/sf to $68.56/sf
- It is cheaper to design in a UOP to an LID than it is to retrofit a UOP to an existing development
- Streams: 8 mg/L to 3 mg/L of DIN costs $65M - $13M/mg/L

# Other Options

- Green roofs
- Rain barrels
- Cisterns
- Curbless parking lots
- Infiltration trenches
- Swales
- Narrow roads
- Buffer strips








# Any Questions?