Stormwater and Green Infrastructure in Boston Public Schools

Curriculum Appendix C

Print Materials for Lessons 7.1-7.4

Lesson 7.1

NUTRIENT POLLUTION: READINGS from the EPA

EPA text: https://www.epa.gov/nutrientpollution/problem

Nutrient pollution is one of America's most widespread, costly and challenging environmental problems, and is caused by excess nitrogen and phosphorus in the air and water.

Nitrogen and phosphorus are nutrients that are natural parts of aquatic ecosystems. Nitrogen and phosphorus support the growth of algae and aquatic plants, which provide food and habitat for fish, shellfish and smaller organisms that live in water.

But when too much nitrogen and phosphorus enter the environment - usually from a wide range of human activities - the air and water can become polluted. Nutrient pollution has impacted many streams, rivers, lakes, bays and coastal waters for the past several decades, resulting in serious environmental and human health issues, and impacting the economy.

Too much nitrogen and phosphorus in the water causes algae to grow faster than ecosystems can handle. Significant increases in algae harm water quality, food resources and habitats, and decrease the oxygen that fish and other aquatic life need to survive. Large growths of algae are called algal blooms and they can severely reduce or eliminate oxygen in the water, leading to illnesses in fish and the death of large numbers of fish.

Nutrient Challenges in the Charles River

EPA text: https://www.epa.gov/charlesriver/environmental-challenges-charles-river

Blue-green algae bloom along the banks of the Charles River in Boston.
Nutrients, primarily phosphorus, are a chief culprit for dramatic algae blooms that plague the River with blue-green algae during the summer months.

These "blue green" algae blooms, are a form of bacteria known as Cyanobacteria, whose cells may release a toxin when they die. Exposure to the toxin can cause skin rashes and irritate the nose, eyes or throat, and if ingested can lead to serious liver and nervous system damage. Other harmful effects of the algae include reduced water clarity, nuisance scum, and reduced oxygen in the water, which is necessary for a healthy fish habitat.

EPA's goal is to reduce phosphorus discharges to the lower Charles by 54 percent to restore the river to a healthy state. In order to meet that goal, EPA must reduce the amount of stormwater runoff entering the River.

EPA Finds: More Than Half of The Nations Streams and Rivers Will Not Adequately Support Aquatic Life

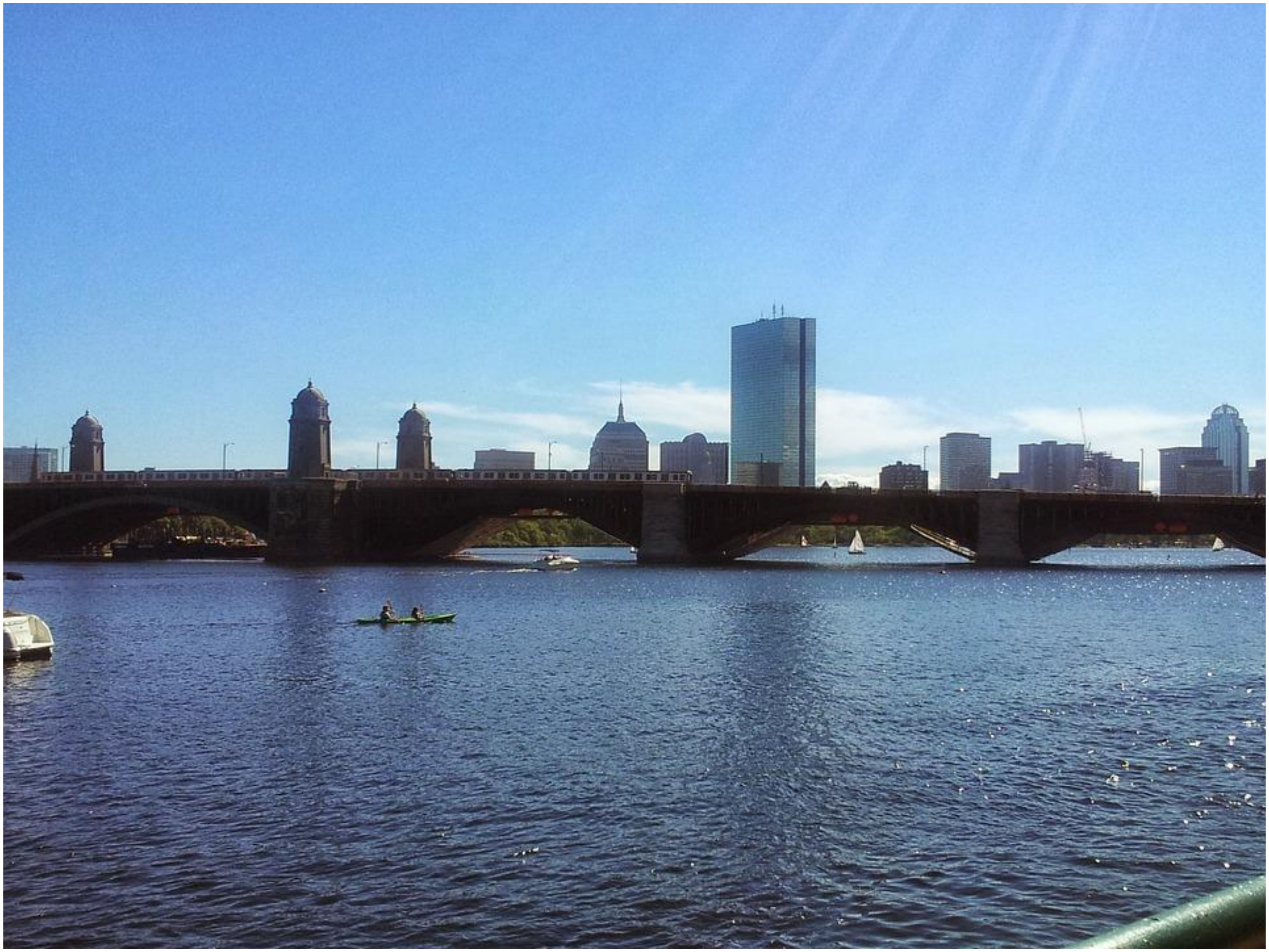
Ryan Locicero / April 23, 2013

A recent news release from the EPA finds that more than half, (55%) of the nations streams and rivers are in poor conditions for aquatic life. The major contributing factor: excess nutrients.

This comprehensive survey, collected with the help of university scientist, state, and local officials investigated the water quality of approximately 2,000 sites across the United States. They found twenty-seven percent of the nation’s rivers and streams to be significantly impacted as a result of excess nitrogen and forty percent to have high phosphorus levels.

Results from this study will be used to inform decision makers about the critical need for addressing the issue of nutrient over-enrichment and enhance the ability of states to manage water quality and protect sensitive ecosystems.

Photo Montage of Charles River Water Quality Over Time



Cars in river near Wellesley, near South Natick, April 22, 1966 Credit: Charles River Watershed Association

Dumping in Charles River at Cow Island-Flora Epstein and Arthur Brownell--H. Shippen Goodhue credit, 1963

West Medway Dye Co. Discharge

Credit: Charles River Watershed Association

Town Dump in Milford, Cedar Swamp Pond, July 1968

Credit: Charles River Watershed Association

Fish kill near Perkins School for the Blind, Watertown--June 1964

Credit: Charles River Watershed Association

Credit: Lamar Gore/USFWS

Credit: Charles River Watershed Association

Credit: Rob Lerman

Heron in nest, feeding young, Charles River, Millenium Park Credit: Rob Lerman

Millenium Park: What animal might have done this?

Credit: Rob Lerman

Credit: Lamar Gore/USFWS

Credit: Lamar Gore/USFWS

CHARLES RIVER--ALGAL BLOOMS

Credit: Lamar Gore/USFW

CAUTION

POSTED _______________: Based on counts of the cyanobacteria (blue-green algae), MDPH thresholds for recreational waters have been exceeded.

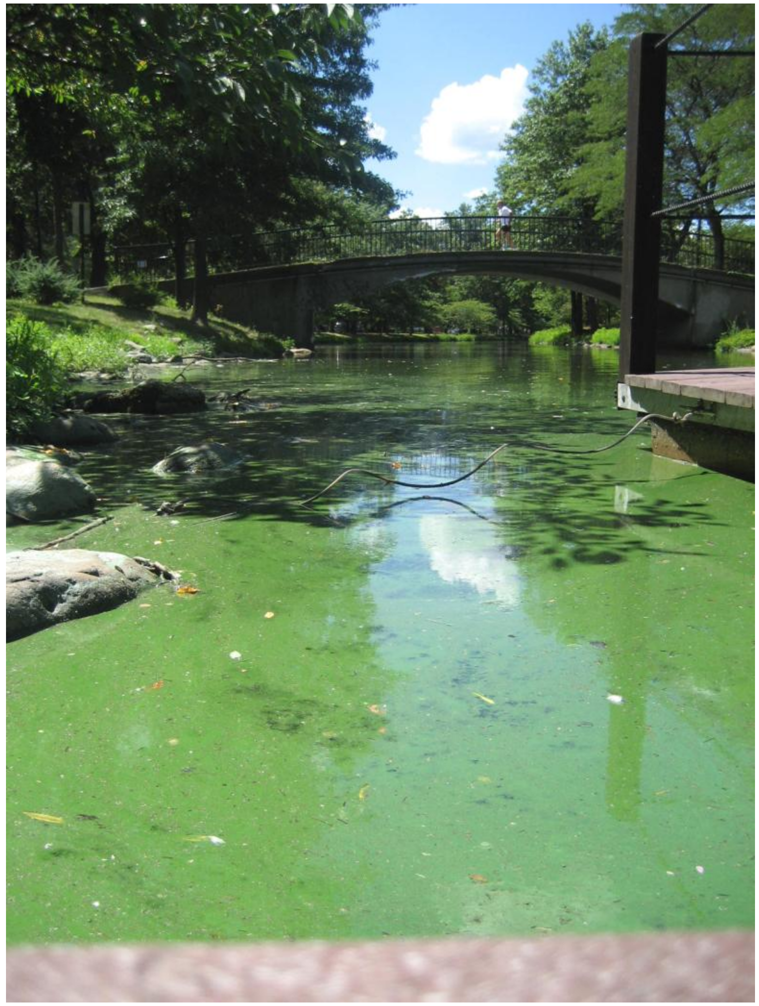
- Water which looks like the pictures above may contain algae capable of producing toxins that can be dangerous to humans and pets.

- People and pets should avoid contact in areas of algae concentration

- Do not swallow water and rinse off after contact

For further information call:

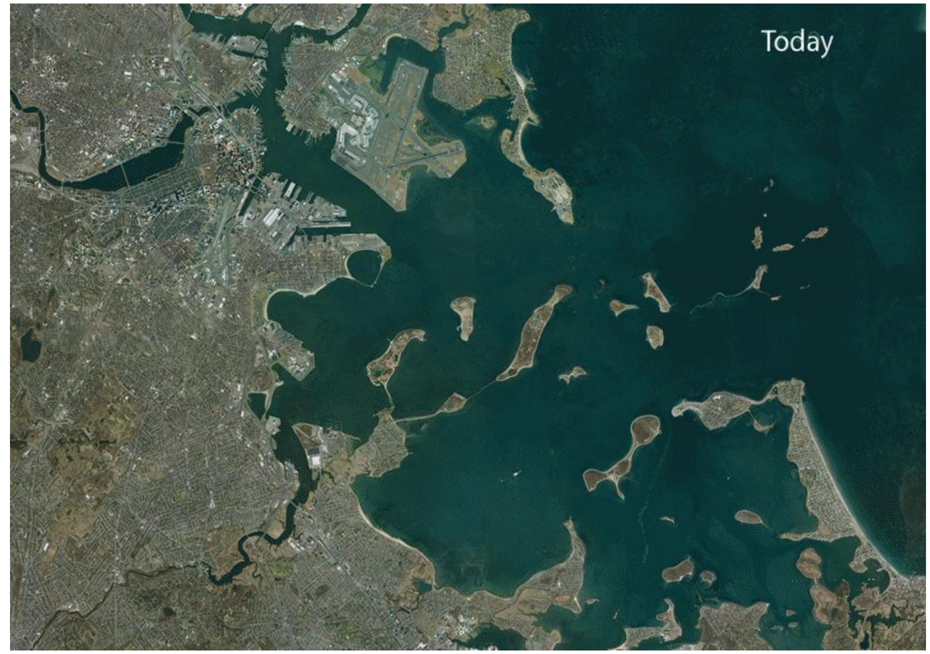
MA Department of Public Health at 617-624-5757



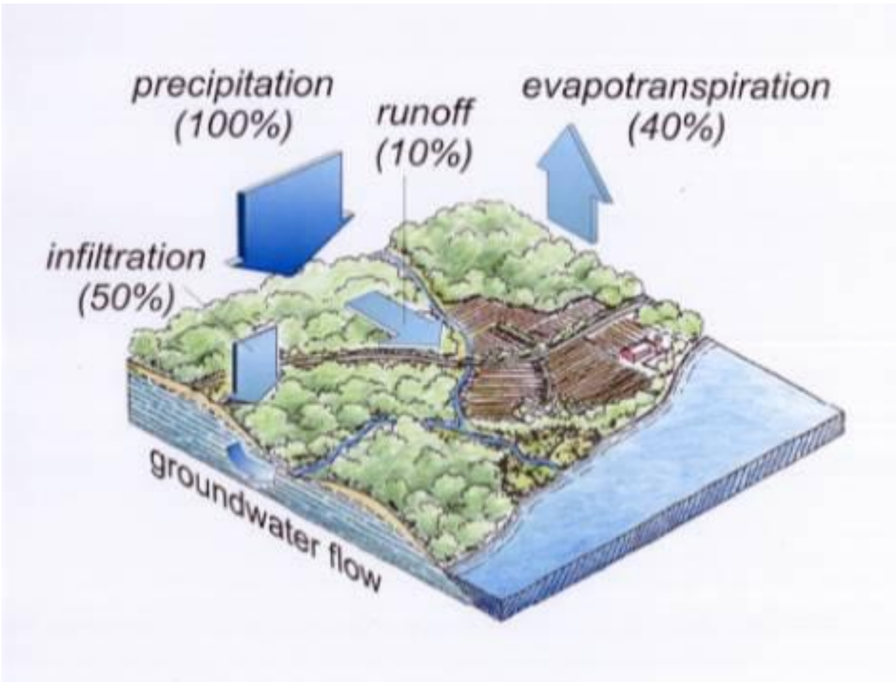
Algal Blooms Near the Esplanade, Credit: Charles River Watershed Association

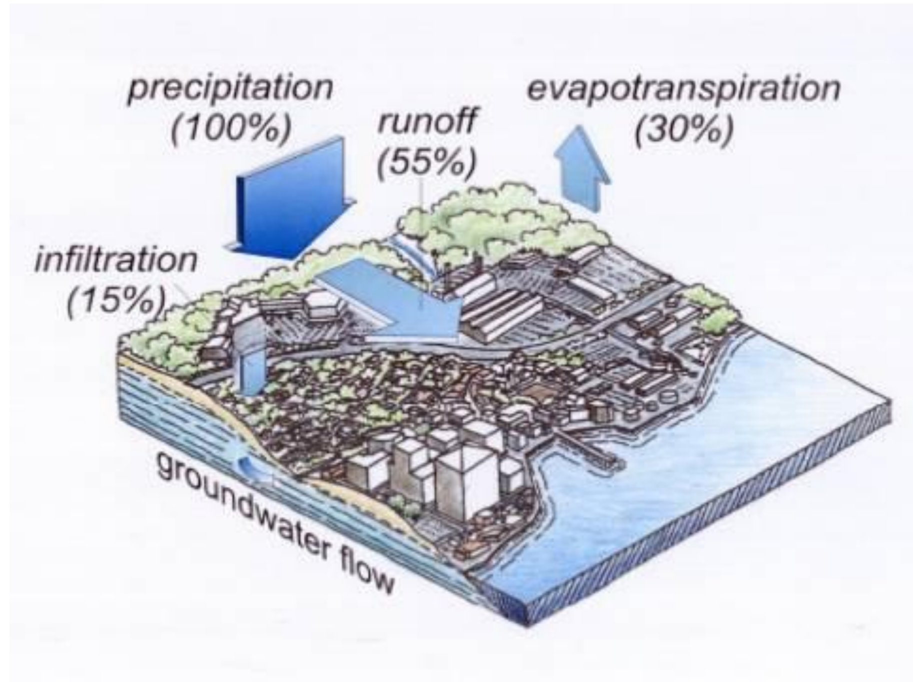
Algal Blooms Credit: Charles River Watershed Association,

LAND COVER IN BOSTON: 1630 to TODAY

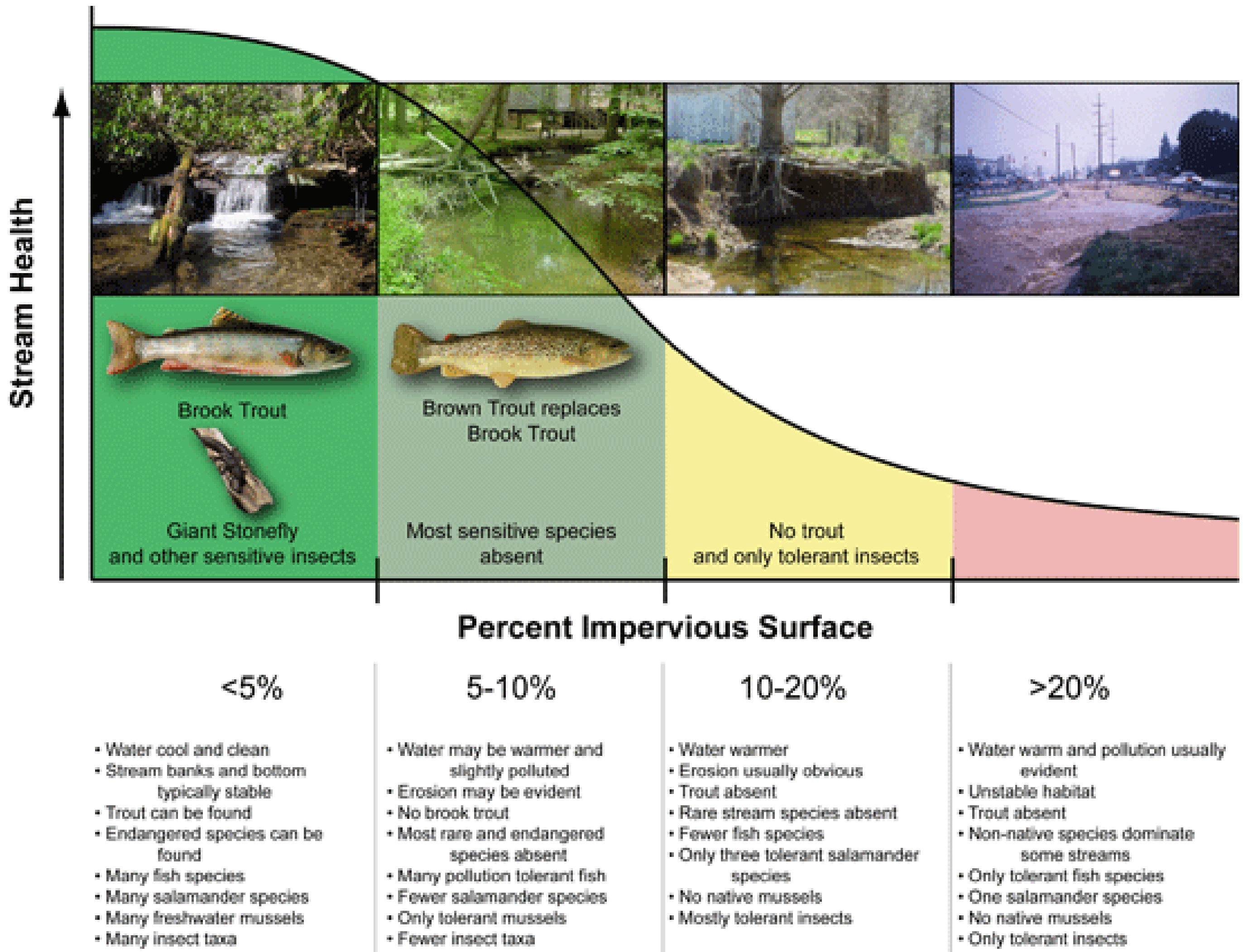


WATER CYCLE: PRE- AND POST-DEVELOPMENT





IMPERVIOUS COVER AND BIODIVERSITY IN STREAMS



Lesson 7.2

FOUR WATERSHED PHOTOS

Forest

Credit: Michael Roebbers

Farmland

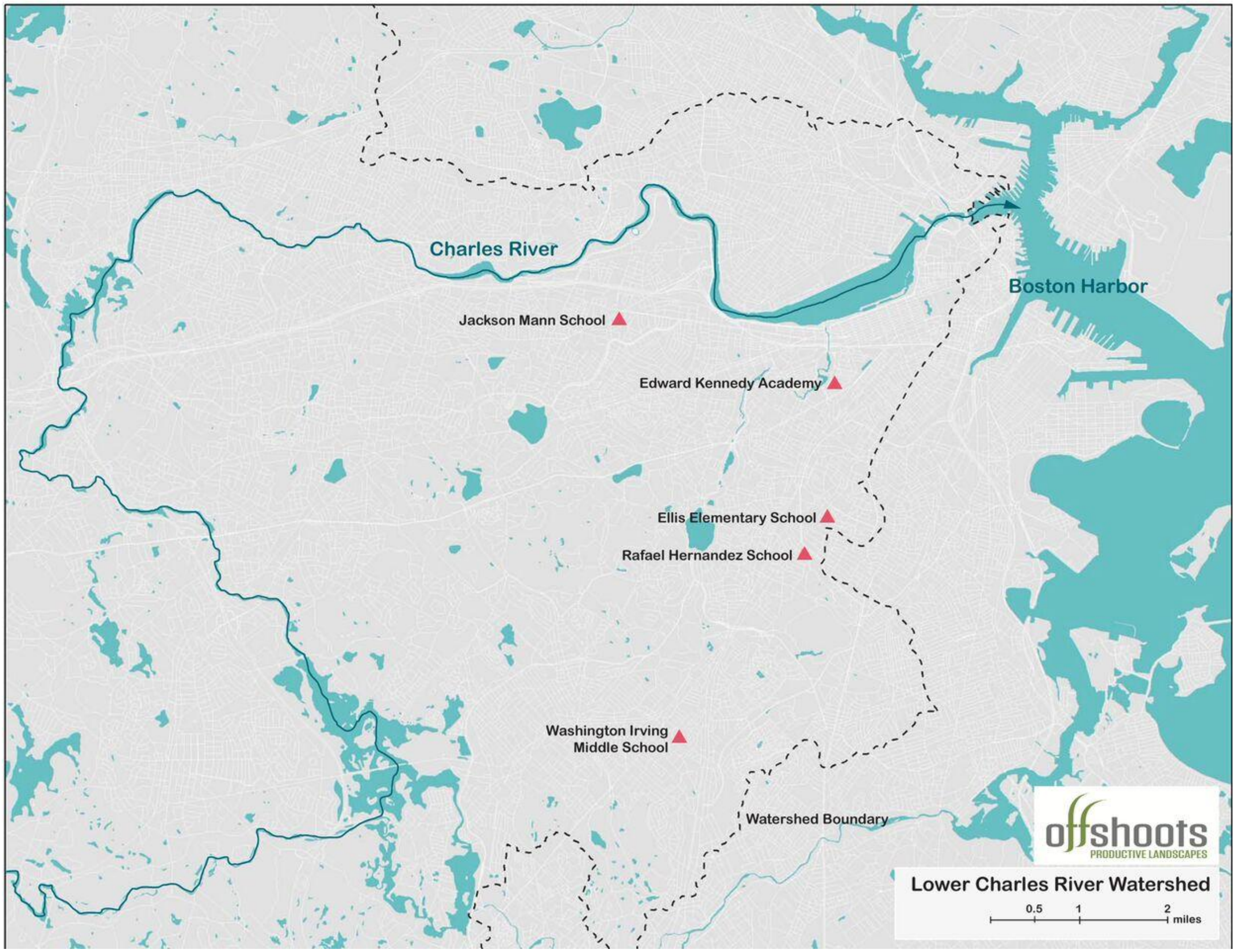
Town/Suburban

Credit: Max Pixel http://maxpixel.freegreatpicture.com/Inn-Old-Town-City-Historically-Passau-River-296797

Large City

Credit: Myrna Kassem

CHARLES RIVER WATERSHED MAP WITH GI SCHOOLS



IRVING SCHOOL PARKING LOT | "BEFORE" AERIAL VIEW

IRVING SCHOOL PARKING LOT | SCHOOLYARD WATERSHED MAP

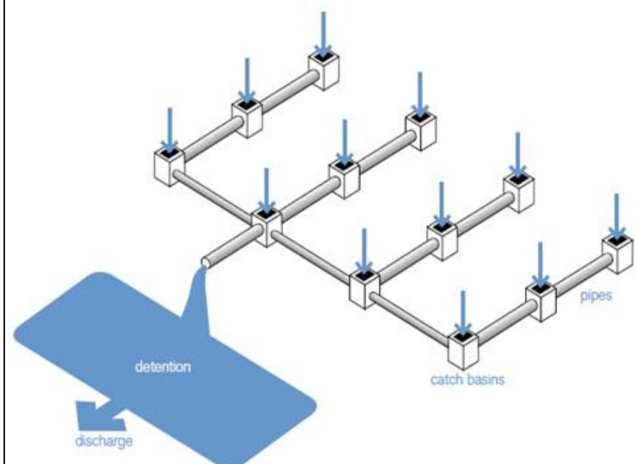
Grey Infrastructure

Grey infrastructure uses catch basins and pipes to quickly get runoff away from buildings and people; provides temporary storage in large ponds or underground storage tunnels/tanks; and carries stormwater to a single downstream location (pond or river outfall) while still carrying pollutants. It is the opposite of green infrastructure, which reduces runoff and promotes infiltration, evapotranspiration, and pollutant removal through small practices located close to where the actual rain falls.

Large underground stormwater storage tunnel.

Considerations

- Mostly used to control flooding at a large, watershed-scale with catchbasins and pipe networks (see diagram on left).
- Goal is to move water away quickly and safely
- Pipes carry stormwater to storage (detention) ponds or tanks to be released at a later time (once flood concerns are over).
- Can be installed underground (see upper right photo)
- Not always designed to clean water or to encourage infiltration
- Does not use vegetation or increase evapotranspiration
- Can be expensive to construct.
- Out of sight, out of mind.



UACDC, 2010

Grey infrastructure uses catchbasins and pipes to collect rainwater and move it away from city streets and neighborhoods so they won't flood. Pipes carry stormwater to ponds and tanks for temporary storage or to outfalls into rivers.

Lesson 7.3

BIORETENTION PRACTICES

Shallow, landscape depressions that promote natural filtering, evapotranspiration, and infiltration using plants and soil. Stormwater flows into the bioretention practice and ponds for a short period of time. Plants absorb water and phosphorus, microbes around roots take up pollutants. The soil layer is designed to filter pollutants and, in some cases, can promote infiltration. There are different types of bioretention (e.g., simple rain gardens, bioswales, stormwater planters, green roofs, and tree filters).

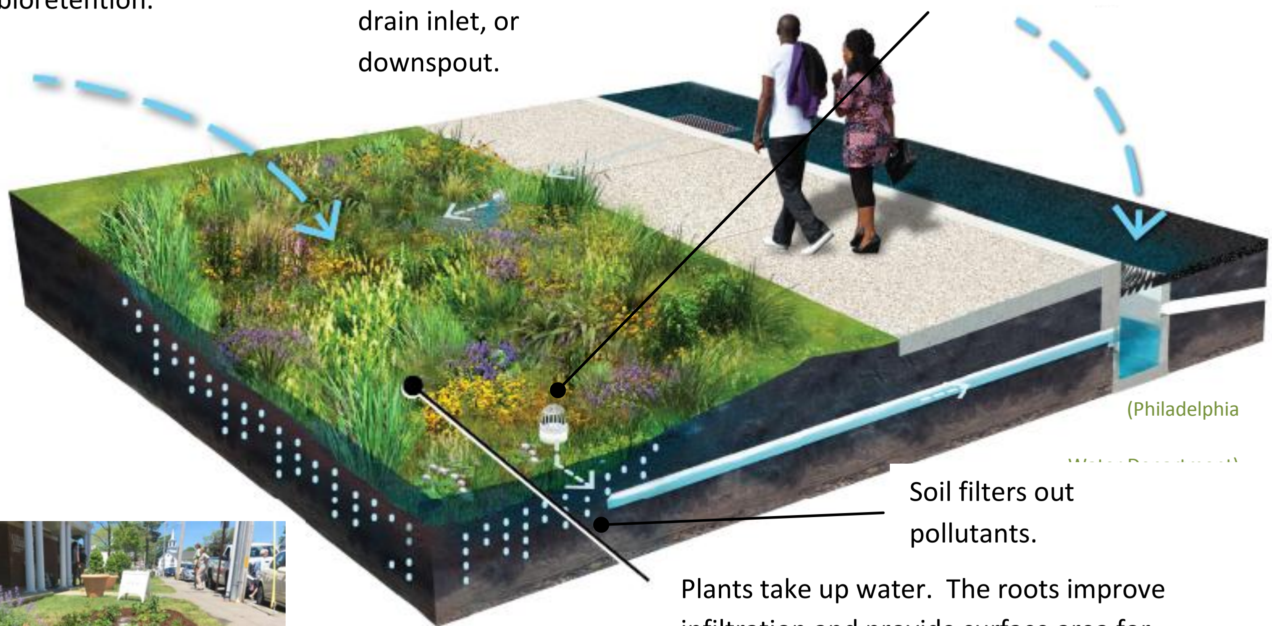
Siting Considerations

- Takes up surface space.
- Can be installed in existing landscaped areas such as lawn, parking lot islands, road medians, flower beds, etc. or can replace unused areas of impervious cover.
- Ponding is only temporary, generally less than 2 days.
- In general, do not eat the plants (unless only roof runoff going into practice).
- Need salt tolerant plants that can handle winter road salts if used to manage road or parking lot runoff.
- Green roofs can be expensive.

Benefits

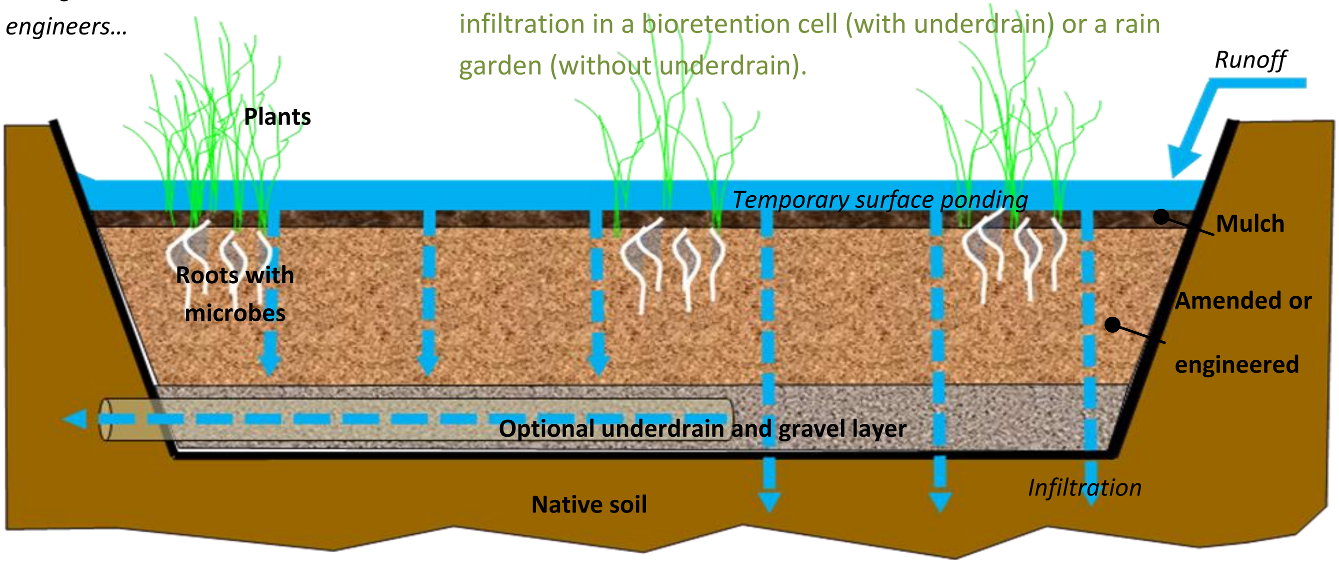
- 60% phosphorus removal from stormwater.
- Can be integrated with playspaces.
- High visibility for educational purposes.
- Promotes biodiversity.
- Can help provide shade and better air quality if trees are incorporated.
- Green roofs can help with building cooling
- Helps with water conservation by reducing need for watering.
- Can help provide infiltration (optional).

Bioretention/Rain Garden -planted depressions with modified soils. Rain gardens are generally smaller, have a simpler design, and include minor amendments to existing native soils. Bioretention facilities often treat larger drainage areas than rain gardens, have engineered soils, and include an underdrain pipe system.



Rain gardens don't need engineers…

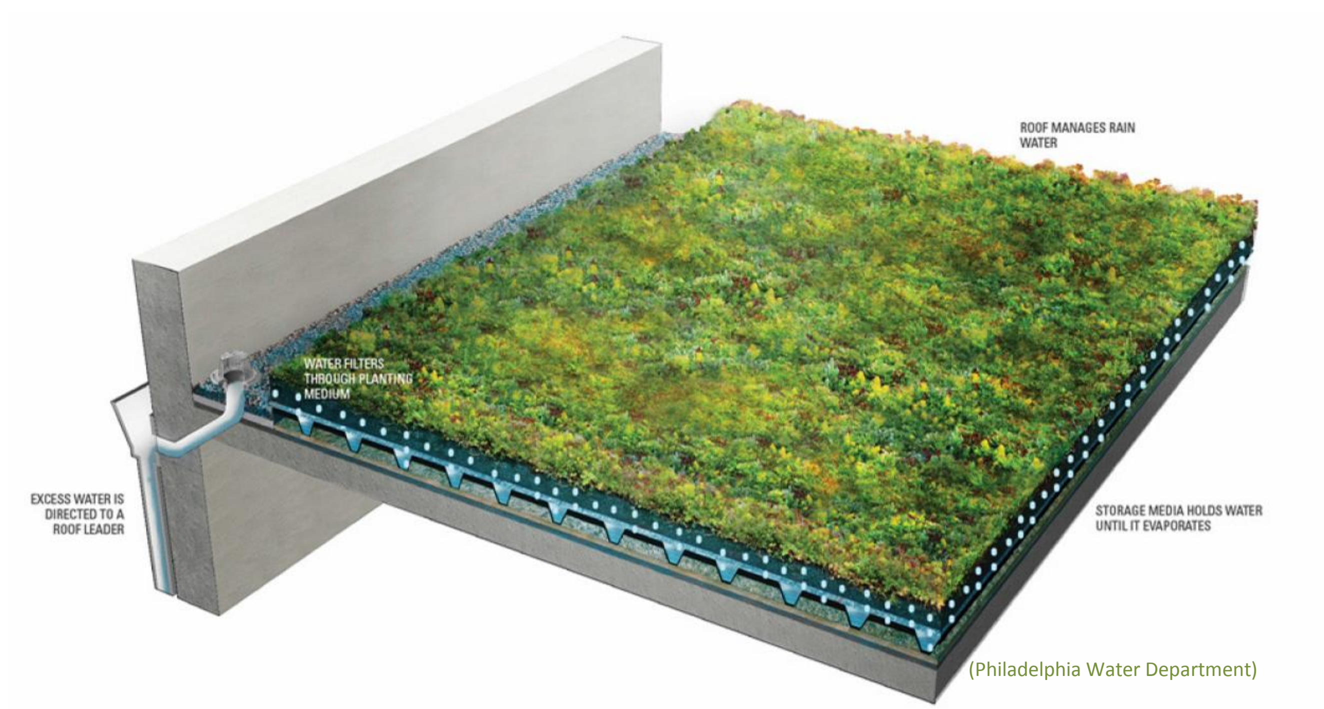
Cross section showing shallow ponding, cleaning, and infiltration in a bioretention cell (with underdrain) or a rain garden (without underdrain).



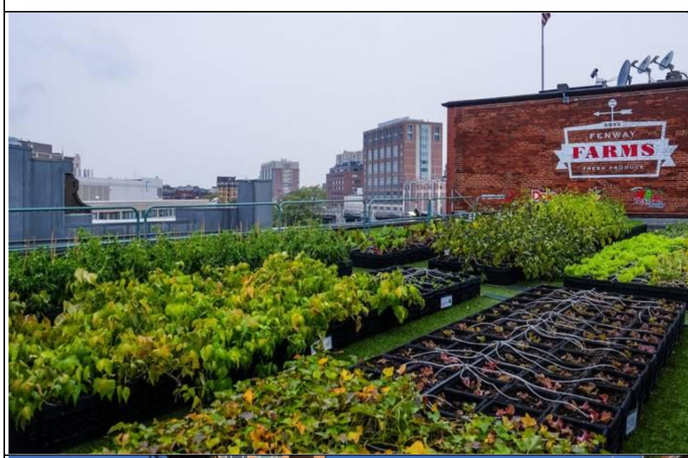
Bioswales- linear bioretention that also helps move runoff downhill. Commonly used in parking lot landscaped islands and between streets and sidewalks.

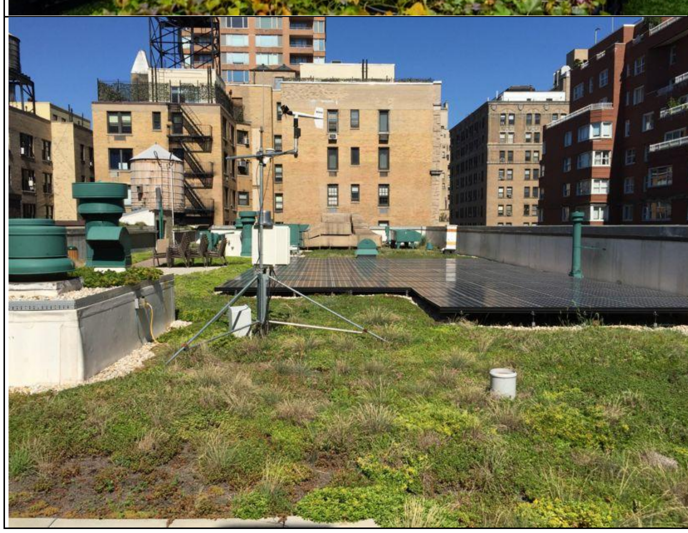
(Philadelphia Water Department)

Green Roof- using plants on the roof to manage runoff and cool buildings.



(Philadelphia Water Department)





Tree Filter- Street trees designed to accept stormwater runoff. They have large area of soil to hold runoff and promote root growth, uptake by the tree, and infiltration.

(Philadelphia Water Department)

Stormwater Planter-vegetated box installed next to buildings to intercept rooftop runoff.

(Philadelphia Water Department)

PERMEABLE PAVEMENTS

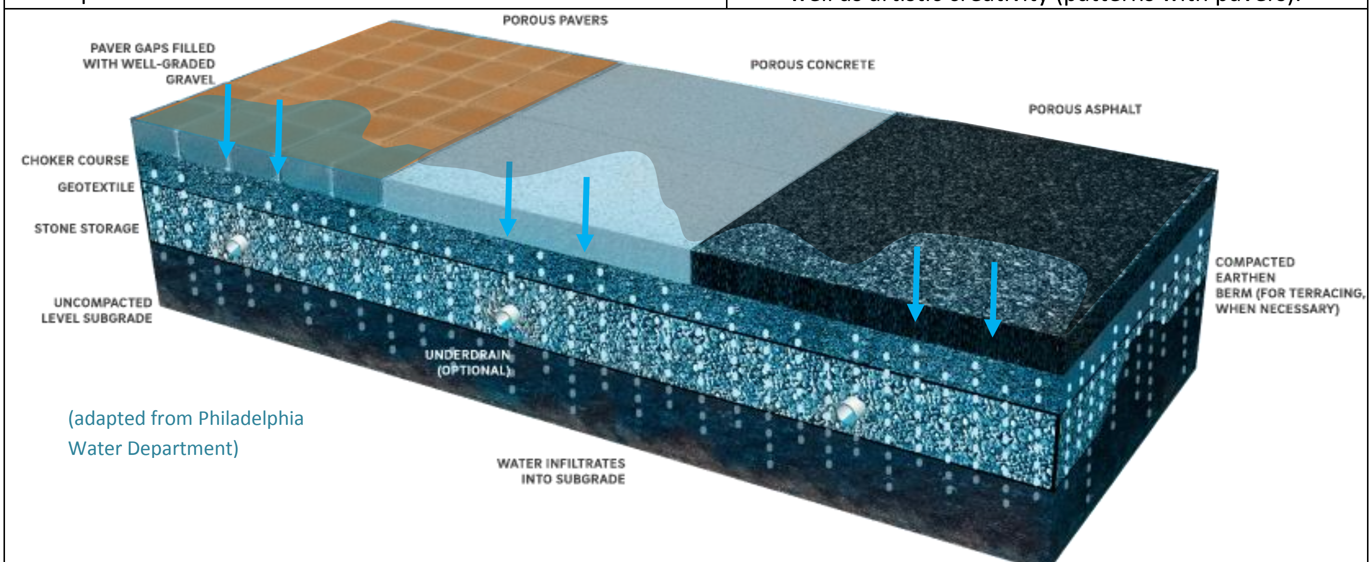
Hard surface materials used on roads, parking lots, sidewalks, basketball courts, etc. that allow water to pass through. These include permeable asphalt, concrete, and pavers. They can be made from a variety of recycled materials (rubber tires, glass, etc). You can still use the surface just like an impervious surface. The stone storage layer below the permeable pavement serves as a temporary reservoir to give water time to slowly infiltrate.

Siting Considerations

- Use in places where hard surfaces are needed (parking lots, playgrounds, sidewalks, basketball courts, etc).
- Needs adequate separation distance from groundwater table.
- Permeable native soils preferred.
- Do not allow off-site run-on to pavements. You really just want to handle the rain that falls directly on the surface.
- Can be an expensive alternative compared to other GI options.

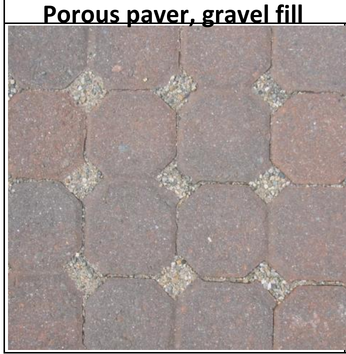
Benefits

- 70% phosphorus removal from stormwater
- Reduces the amount of stormwater generated by removing/replacing impervious cover.
- Allows for normal uses on surfaces (parking, basketball, etc)
- Promotes infiltration.
- Don't need to apply winter deicing chemicals.
- Good opportunities for stormwater education, as well as artistic creativity (patterns with pavers).



(adapted from Philadelphia Water Department)

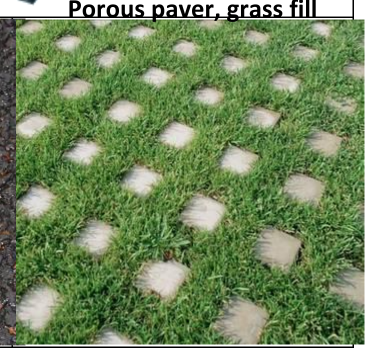
Porous paver, gravel fill

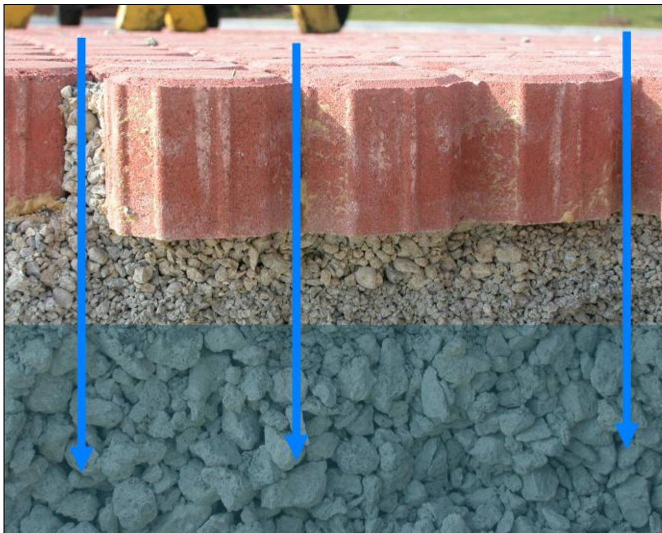


Porous concrete

Porous asphalt

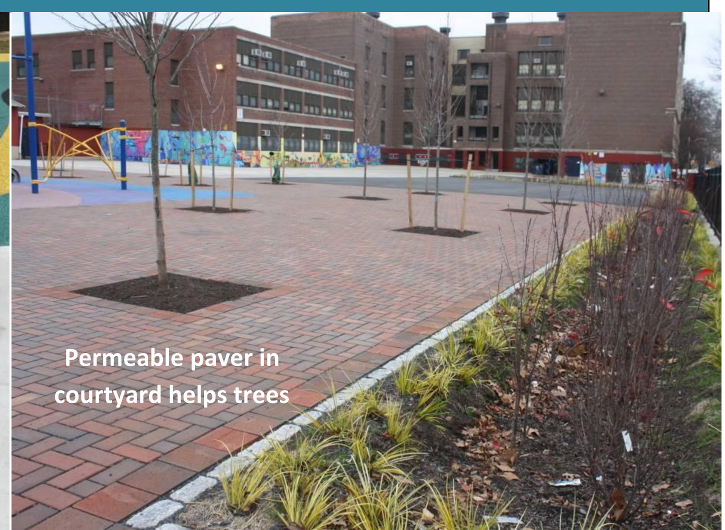
Porous paver, grass fill

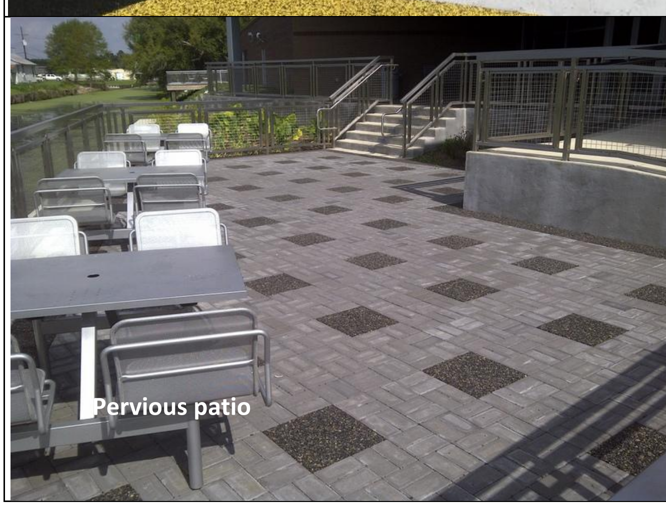




Runoff can pass through holes and gaps in the surface and drain down into and filling up the stone reservoir below.	Porous asphalt used here in parking stalls (on right) and traditional asphalt used in drive aisle (on left).

Examples of Permeable Surfaces at Schools





Pervious Turf Field

INFILTRATION PRACTICES

Group of engineered practices designed to hold runoff underground and slowly release it into the surrounding soils. This group of practices includes underground chambers, infiltration basins infiltration trenches, and dry wells. These practices only work if the underlying native soils are permeable. They typically are installed within a stone bedding layer, include internal pipes to help distribute flows evenly, and have a structure to trap sediment and debris that might otherwise clog the system.

Site Considerations

- Can be installed below parking lots, fields, or other locations where a change in land use is not desired.
- Needs adequate separation distance from groundwater table in order to infiltrate.
- Permeable native soils required. Avoid infiltrating into contaminated soils.
- Don’t want to be too close to steep slope, buildings, and underground utilities.

Benefits

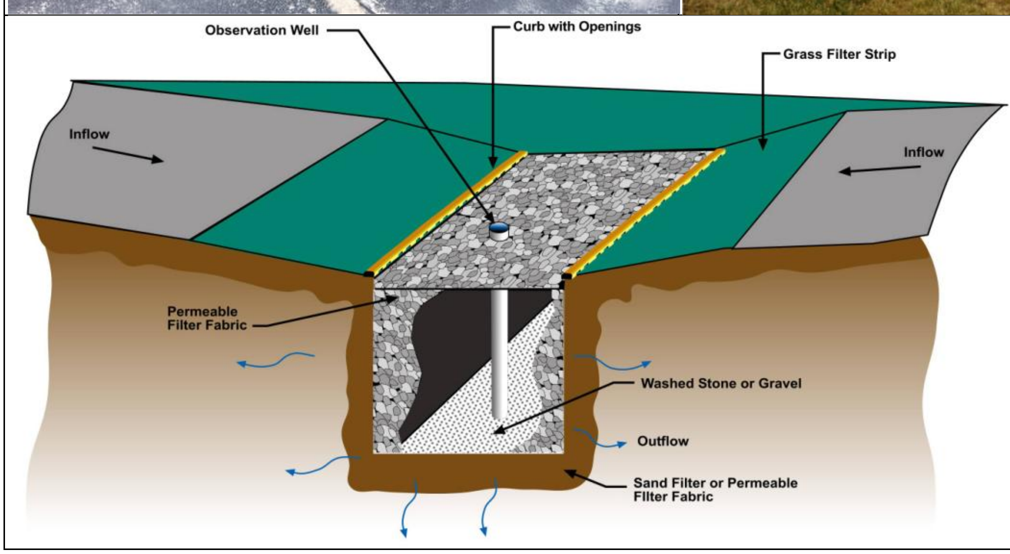
- 80% phosphorus removal efficiency.
- Promotes infiltration and can help recharge groundwater supplies.
- Can be used where parking or surface playspace cannot be lost for surface GI practice.
- Can provide some educational benefit, but not easily seen from surface.

(Philadelphia

Example of a dry well (also called a recharger) used to infiltrate water collected in a stormdrain inlet.

Infiltration Chambers—underground pipes, boxes, or other structure with an open bottom and perforated sides surrounded by stone. Chambers will fill up with runoff between storms and, slowly over time, infiltration out of the bottom and sides of the system into the native soils.

Infiltration basins/trenches—underground stone bed below a depressed area with vegetation (top right) or stone surface (top left). Basins are generally wider than they are long. Trenches are linear (longer than they are wide). Both use a perforated pipe system to help distribute flows evenly underground (bottom right). Both practices are designed to temporarily store runoff until it is able to infiltrate out into the into surrounding native soils.



RAIN WATER HARVESTING

A storage structure, such as a rain barrel, cistern, or rain tank used to hold runoff for subsequent reuse--primarily for non-potable purposes such as irrigation or washing cars. Generally includes a filtering mechanism and a pump for distribution. In Massachusetts the plumbing code is very restrictive when it comes to rainwater reuse inside buildings. In other places, if treated with chlorine or UV light, rainwater can be used for washing clothes/dishes, toilets, showers, sprinkler systems, and even drinking.

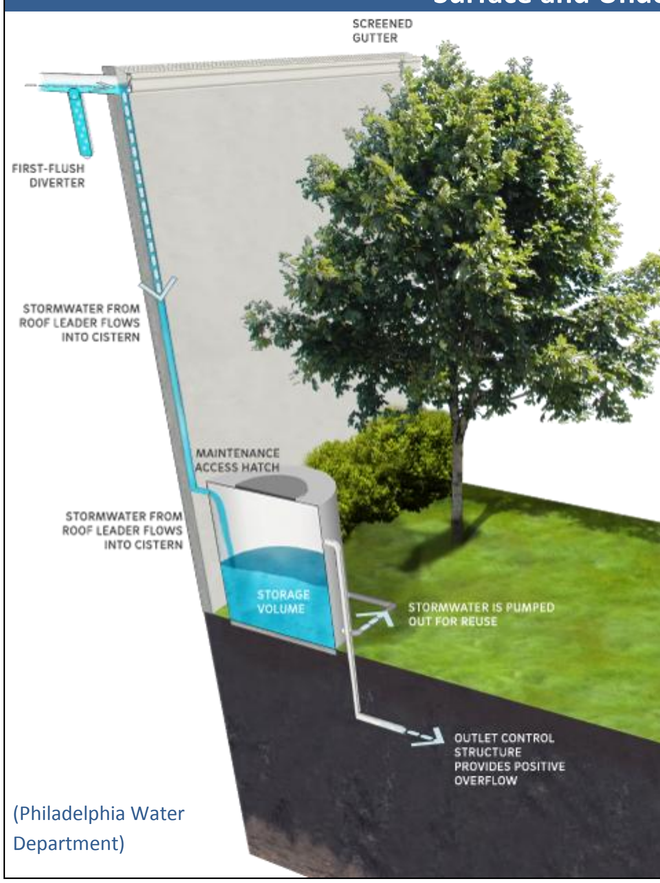
Site Considerations

- Great for collecting rooftop runoff (can be installed above ground and water is relatively clean for reuse).
- Depending on where located, it may require pumps to move water.
- Be careful when reusing to water edible plants.
- Underground storage is generally more expensive than aboveground storage.

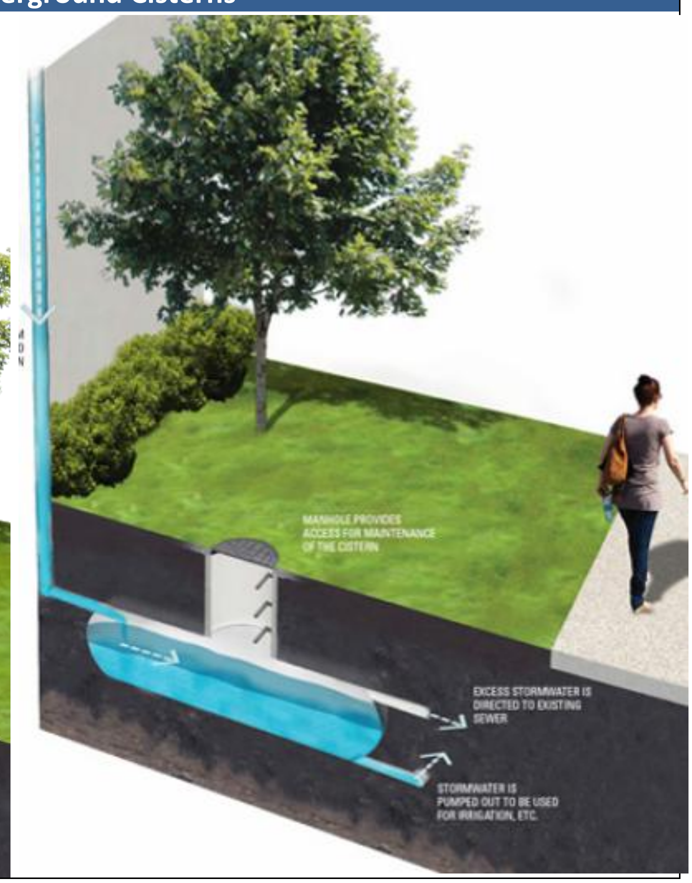
Benefits

- If completely reused, then 100% phosphorus reduction.
- Water reuse helps meet water conservation goals and provides cost savings on water bill.
- Could be used to help plants grow (irrigation), which could contribute to greater evapotranspiration and infiltration.
- Great educational opportunity.

Surface and Underground Cisterns

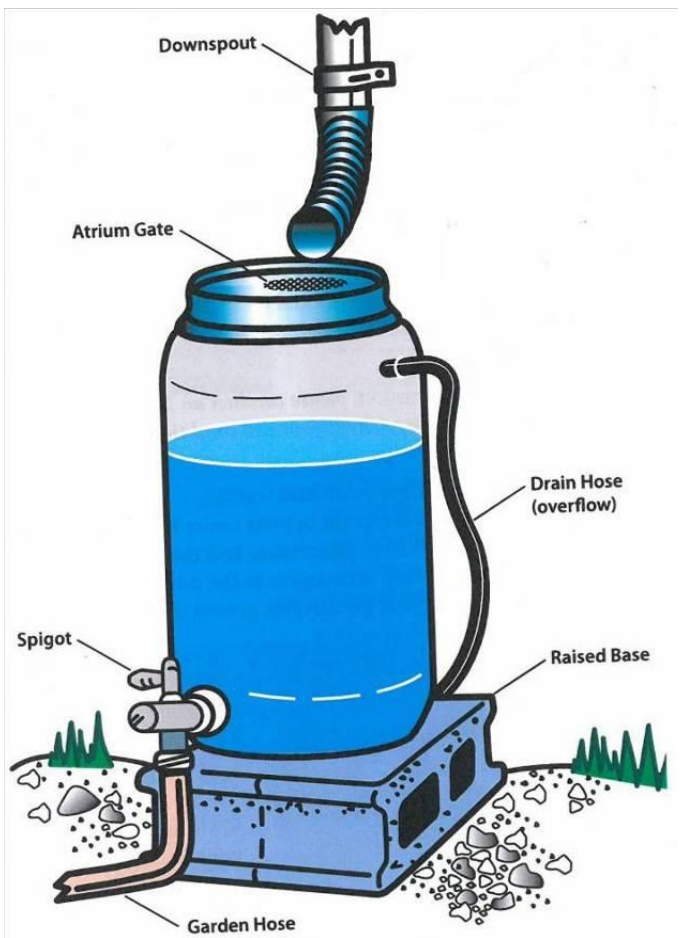


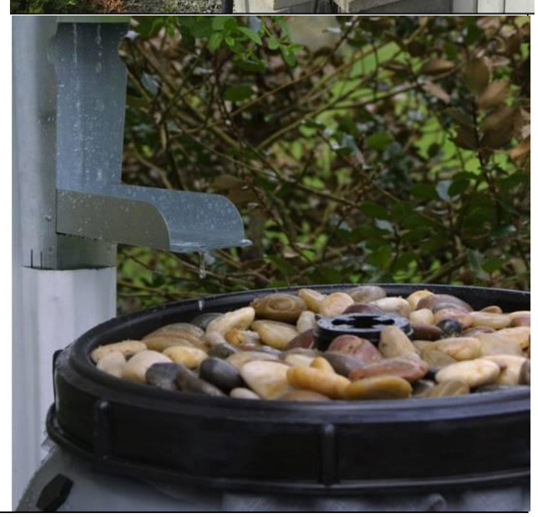
(Philadelphia Water Department)



Rain Tank—underground modular, plastic cells surrounded by impermeable liner to prevent loss of water through infiltration. Water is pumped from tank to watering lawn.

Rain barrels—small storage tanks used by homeowners to collect rainwater for watering plants





IRVING SCHOOL PARKING LOT | AFTER--DIAGRAM WITH GI

IRVING SCHOOL PARKING LOT | "BEFORE" GROUND VIEW

IRVING SCHOOL PARKING LOT | CONCRETE SWALE

IRVING SCHOOL PARKING LOT| BIOSWALE

Claims, Evidence, Reasoning Template

Question:

Claim:

Evidence:

Evidence:

Evidence:

Reasoning:

Reasoning:

Reasoning:

Fill in the order you prefer.

Lesson 7.4

Stormwater Runoff Table

Land Cover	Catchment Area (sq ft)	Runoff Volume from 1-inch Storm (gallons)	Phosphorus (lb/acre/yr)
Roofs	-	-	-
Pavement	27,000	16,830	0.806
Trees/landscaping/gardens	-	-	-
Lawn/grass field*	3,000	224	0.014
Total	**30,000**	**17,054**	**0.820**

Washington Irving Case Study Scenario A

Scenario Name (optional)	Washington Irving Scenario A
Location	parking lot
Priority Co-benefits	education, parking, and groundwater

Decision Matrix

GI Practice Options	Catchment Area (sq ft)	Runoff Volume (gallon)	Phosphorus (lbs/acre/yr)		Construction Cost ($/cu ft)	Co-benefits Score
			Before GI	Remaining After GI		
No GI	30,000	17,054	0.82	0.82	N/A	N/A
Infiltration practices	30,000	17,054	0.82	0.16	$ 73,000	70
Bioretention practices	30,000	17,054	0.82	0.33	$ 61,600	10
Permeable pavements	30,000	17,054	0.82	0.25	$ 228,000	70
Rainwater harvesting	30,000	17,054	0.82	0.00	$ 45,600	0

Priority Co-Benefits

Co-benefits of GI	Explain Your Ranking	**Rank** (out of 100 points)	Considerations
Parking	teachers and parents generally complain about finding enough parking, so we don't want to reduce the number of spaces	30	*If parking is limited or there are traffic issues with bus loading and parent pickup, you don't want your GI installation to make things worse. Maybe it can make it better!*
Impervious Cover			*If you have wasted areas of impervious cover (not really used by cars or buildings or people), then maybe you can remove it and convert to a bioretention or other landscaping. This would reduce the amount of stormwater runoff generated.*
Playspace			*If playspace is limited or unattractive, you don't want to make it worse. Opportunities to expand playspace or improve existing areas as part of GI construction could be great!*
Groundwater	recharging groundwater is a priority for us since our schoolyard is almost 100% impervious area, meaning we have NO infiltration at our school anymore.	30	*A main goal of GI is to get water back into the ground rather than discharing it offsite in a pipe. (This is an especially good choice If you know that the soils on your site have a high permeability, i.e. HSG A and B soils.)*
Biodiversity			*If your schoolyard or neighborhood lacks vegetation or habitat areas for birds, insects, etc., then you may want to use GI to help bring some biodiversity back to your school. Using native plants that flower and fruit in GI features is a good start.*
Tree Canopy			*Trees promote evapotranspiration and provide shade during the summer which helps reduce air temperatures in the city --for people and parked cars.*
Air Quality			*Trees can help clean pollutants out of the air and can make a measureable difference at the city-scale. At the school site, consider planting trees in locations where car or bus exhaust is most concentrated.*
Stormwater Education	Has to be good for educational purposes	40	*Since it is a school, maybe providing opportunities for stormwater and watershed education with your GI feature is a priority for you. Look for locations with high visibility (e.g., front of school) and choose GI practices you can see.*
Total		**100**	

Co-benefit Scores for GI Practices

Infiltration practices

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	30	No change to parking count	0
Impervious Cover	0	None Selected	0
Playspace	0	None Selected	0
Groundwater	30	Increases infiltration a lot	30
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	0	None Selected	0
Education	40	Excellent teaching opportunity	40
Total	**100**		**70**

Bioretention practices

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	30	Reduces number of parking spaces	-30
Impervious Cover	0	None Selected	0
Playspace	0	None Selected	0
Groundwater	30	Increases infiltration a little	0
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	0	None Selected	0
Education	40	Excellent teaching opportunity	40
Total	**100**		**10**

Permeable pavements

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	30	No change to parking count	0
Impervious Cover	0	None Selected	0
Playspace	0	None Selected	0
Groundwater	30	Increases infiltration a lot	30
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	0	None Selected	0
Education	40	Excellent teaching opportunity	40
Total	**100**		**70**

Rainwater harvesting

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	30	No change to parking count	0
Impervious Cover	0	None Selected	0
Playspace	0	None Selected	0
Groundwater	30	Increases infiltration a little	0
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	0	None Selected	0
Education	40	Some teaching opportunity	0
Total	**100**		**0**

Washington Irving Case Study Scenario B

Scenario Name (optional)	Washington Irving Scenario B
Location	parking lot
Priority Co-benefits	education, air quality, and impervious cover reduction

Decision Matrix

GI Practice Options	Catchment Area (sq ft)	Runoff Volume (gallon)	Phosphorus (lbs/acre/yr)		Construction Cost ($/cu ft)	Co-benefits Score
			Before GI	Remaining After GI		
No GI	30,000	17,054	0.82	0.82	N/A	N/A
Infiltration practices	30,000	17,054	0.82	0.16	$ 73,000	40
Bioretention practices	30,000	17,054	0.82	0.33	$ 61,600	100
Permeable pavements	30,000	17,054	0.82	0.25	$ 228,000	65
Rainwater harvesting	30,000	17,054	0.82	0.00	$ 45,600	35

Priority Co-Benefits

Co-benefits of GI	Explain Your Ranking	Rank (out of 100 points)	Considerations
Parking			*If parking is limited or there are traffic issues with bus loading and parent pickup, you don't want your GI installation to make things worse. Maybe it can make it better!*
Impervious Cover	Convert some impervious cover to landscape islands where we can separate cars from where kids walk into the school or wait to be picked up	25	*If you have wasted areas of impervious cover (not really used by cars or buildings or people), then maybe you can remove it and convert to a bioretention or other landscaping. This would reduce the amount of stormwater runoff generated.*
Playspace			*If playspace is limited or unattractive, you don't want to make it worse. Opportunities to expand playspace or improve existing areas as part of GI construction could be great!*
Groundwater			*A main goal of GI is to get water back into the ground rather than discharing it offsite in a pipe. (This is an especially good choice If you know that the soils on your site have a high permeability, i.e. HSG A and B soils.)*
Biodiversity			*If your schoolyard or neighborhood lacks vegetation or habitat areas for birds, insects, etc., then you may want to use GI to help bring some biodiversity back to your school. Using native plants that flower and fruit in GI features is a good start.*
Tree Canopy			*Trees promote evapotranspiration and provide shade during the summer which helps reduce air temperatures in the city --for people and parked cars.*
Air Quality	Bring in plants that can help clean the air where all the cars are	35	*Trees can help clean pollutants out of the air and can make a measureable difference at the city-scale. At the school site, consider planting trees in locations where car or bus exhaust is most concentrated.*
Stormwater Education	Has to be good for educational purposes	40	*Since it is a school, maybe providing opportunities for stormwater and watershed education with your GI feature is a priority for you. Look for locations with high visibility (e.g., front of school) and choose GI practices you can see.*
Total		**100**	

Co-benefit Scores for GI Practices

Infiltration practices

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	0	None Selected	0
Impervious Cover	25	No change in amount of impervious cover	0
Playspace	0	None Selected	0
Groundwater	0	None Selected	0
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	35	No improvement	0
Education	40	Excellent teaching opportunity	40
Total	**100**		**40**

Bioretention practices

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	0	None Selected	0
Impervious Cover	25	Reduces impervious cover (e.g. removal of some pavement)	25
Playspace	0	None Selected	0
Groundwater	0	None Selected	0
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	35	Improves air quality (e.g., trees planted at bus loading zone)	35
Education	40	Excellent teaching opportunity	40
Total	**100**		**100**

Permeable pavements

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	0	None Selected	0
Impervious Cover	25	Reduces impervious cover (e.g. removal of some pavement)	25
Playspace	0	None Selected	0
Groundwater	0	None Selected	0
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	35	No improvement	0
Education	40	Excellent teaching opportunity	40
Total	**100**		**65**

Rainwater harvesting

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	0	None Selected	0
Impervious Cover	25	No change in amount of impervious cover	0
Playspace	0	None Selected	0
Groundwater	0	None Selected	0
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	35	Improves air quality (e.g., trees planted at bus loading zone)	35
Education	40	Some teaching opportunity	0
Total	**100**		**35**