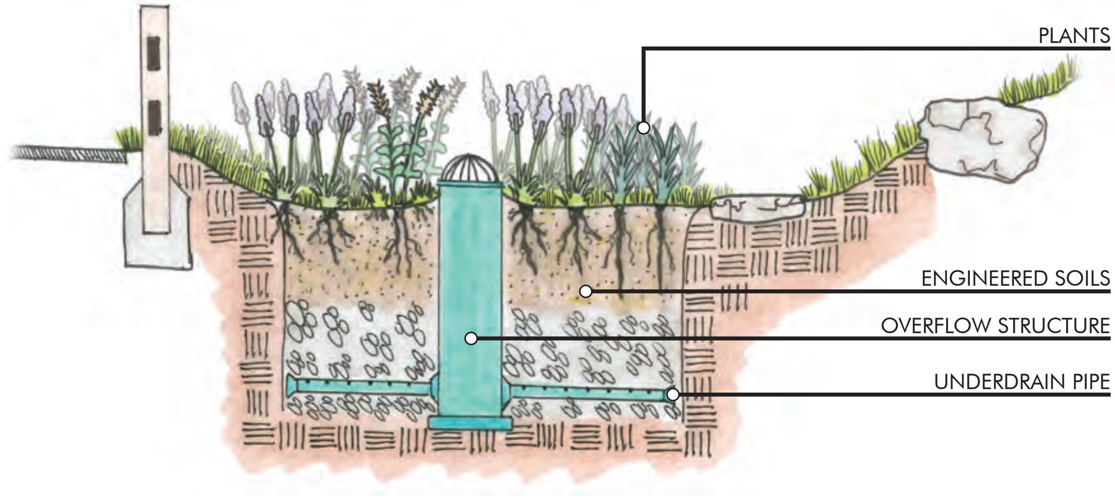
Stormwater and Green Infrastructure in Boston Public Schools

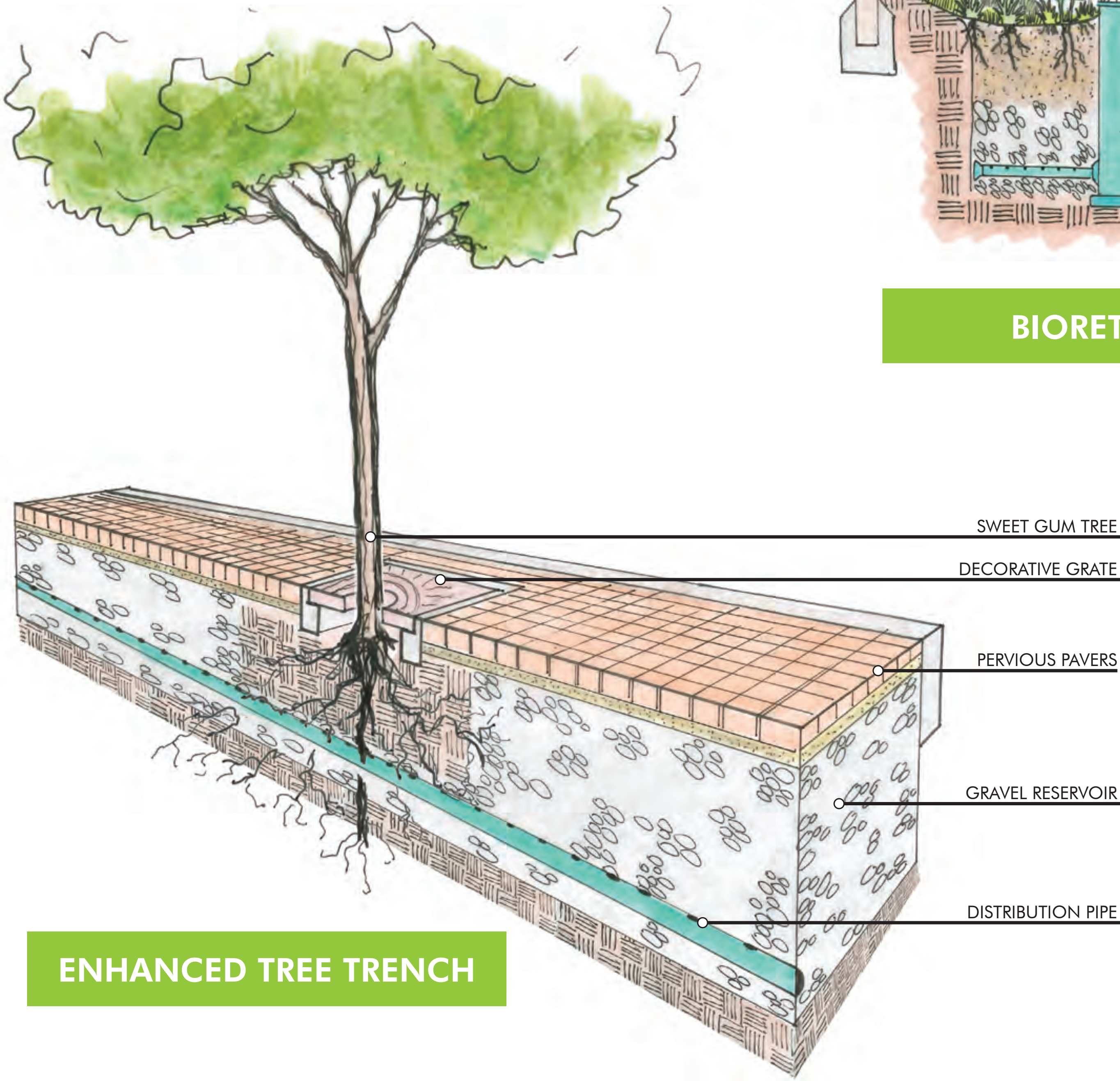
Curriculum Appendix B

GI Pilot School Resources

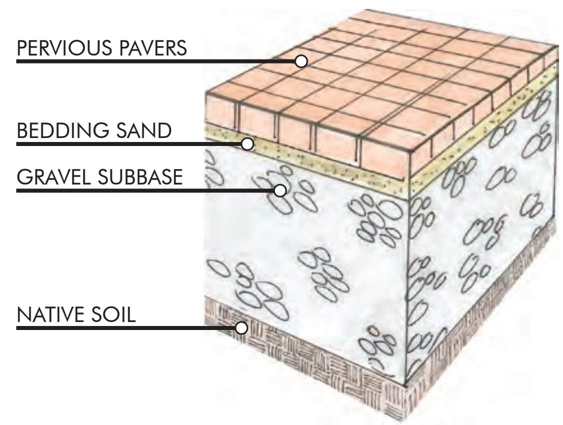
DAVID A. ELLIS ELEMENTARY SCHOOL



BIORETENTION



ENHANCED TREE TRENCH



PERVIOUS PAVERS

List of GI Features at the Ellis

1. Bioretention/rain garden
2. Porous pavers
3. Tree trench

Plantings at Ellis

A unique plant community was created at each of the 5 Boston Schoolyards to test and compare how various matrixes of plants would perform in green infrastructure at urban schoolyards. Each school's plant palette was designed differently, so the planting strategies can be compared over time. The plantings are designed to be an educational centerpiece for each school and additionally provide wildlife food and habitat in addition to stormwater cleansing benefits. The planting designs are entirely comprised of low-maintenance plants to minimize weeding, irrigation and long-term maintenance inputs over time once the plants established.

The Ellis school bioretention includes plant species that represent a wet native forest floor in New England. Water flows into the bioretention area that is filled with shade-tolerant native woodland plants common to the Boston area including many ferns species: *Polystichum acrostichoides, Osmundastrum cinnamomeum, Onoclea sensibilis, Dryopteris marginalis, Dennstaedtia punctilobula* and *Thelypteris noveboracensis*. White woodland flowering plants, *Anemone canadensis* and *Aster divaricatus* are included within the wet woodland fern planting. Three new native woodland tree species are also added in the schoolyard: *Amelanchier laevis* and *Hamamelis virginiana* provide early spring flowers, and *Liquidambar styraciflua* is planted within the tree trench that cleanses the stormwater.

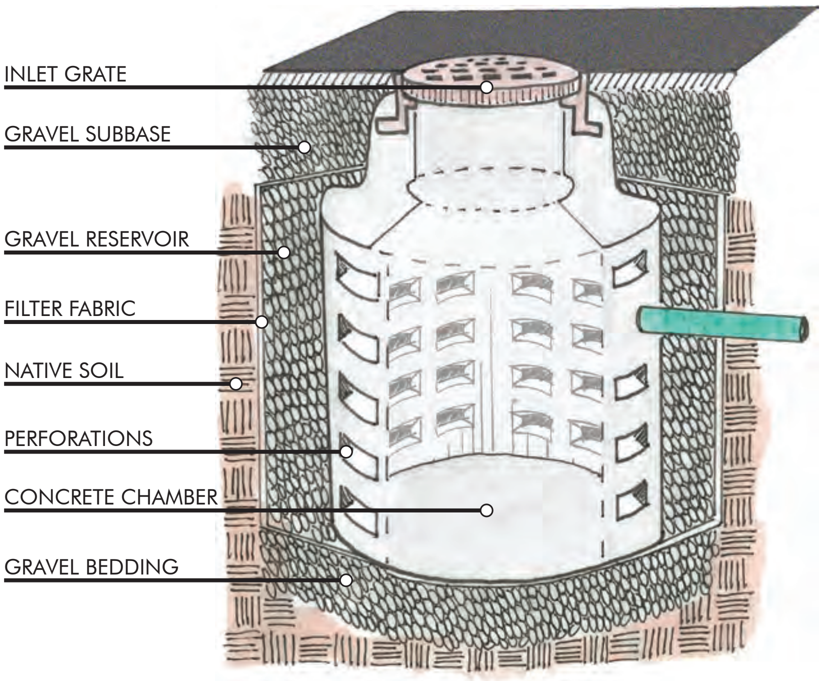
Ideas for how teachers/ students can engage with the plantings at Ellis:

- How many different kinds of ferns can you find in the bioretention planting? Look at the spore structures on the back of some of the leaves. How do fern plants reproduce that is different from other plants?
- What are the differences in the leaf shape in the garden? Use the various leaves in the garden to explain the difference between simple shaped and pinnate shaped leaves.

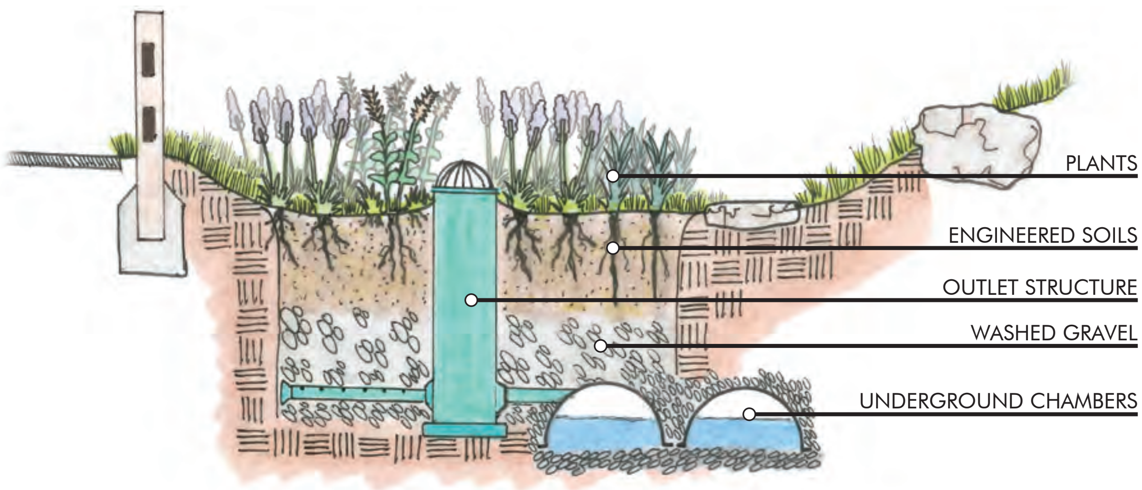
Suggested GI Activities

- ❑ Have general discussions about how different surfaces handle rain. surface runoff vs infiltration vs evapotranspiration
- ❑ Compare drainage on traditional pavement vs. porous pavers vs. landscaped areas. How does slope and tree canopy affect it?
- ❑ See activities by practice type at end of Appendix B.
- ❑ Delineate drainage area to bioretention inlet.
- ❑ Use rain paint in repaved area as an art project only visible when it rains.

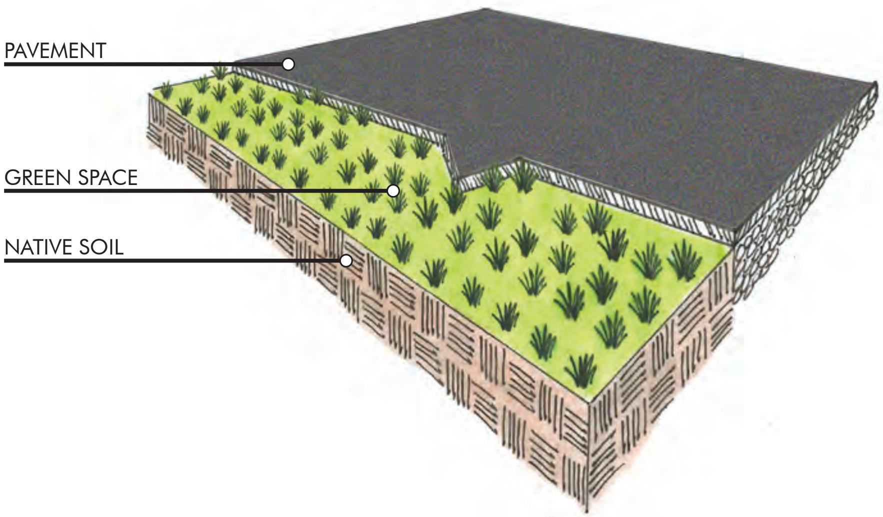
RAFAEL HERNANDEZ SCHOOL



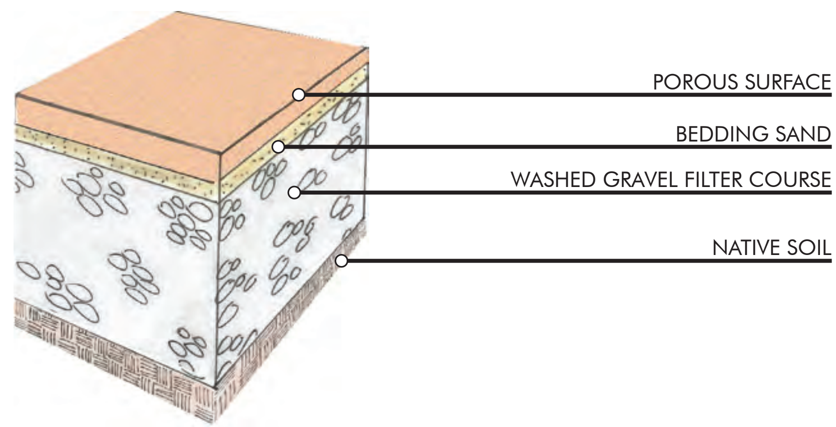
DRY WELL (RECHARGER)



BIOREтENTION WITH UNDERGROUND CHAMBERS



PAVEMENT REMOVAL



POROUS PLAYGROUND

List of GI Features at Hernandez:

1. Above ground Cistern/rain tank
2. Below ground Cistern (pump/tank)
3. Bioretention
4. Infiltration chambers (under bioretention)
5. Drywells
6. Porous playground surface

Plantings at the Hernandez School:
A unique plant community was created at each of the 5 Boston Schoolyards to test and compare how various matrixes of plants would perform in green infrastructure at urban schoolyards. Each school's plant palette was designed differently, so the planting strategies can be compared over time. The plantings are designed to be an educational centerpiece for each school and additionally provide wildlife food and habitat in addition to stormwater cleansing benefits. The planting designs are entirely comprised of low-maintenance plants to minimize weeding, irrigation and long-term maintenance inputs over time once the plants established.

The Hernandez school landscape is modeled after the movement of water within the Charles River Basin Watershed which is the "most densely populated watershed in New England" containing 35 towns within its 308 miles.[1] Urban watersheds typically suffer from non-point source pollution and warm water caused by stormwater runoff from parking lots and streets. Urban stormwater then inundates waterbodies in surges when a storm hits because it is all channeled away into drains. This process is on display at the Hernandez schoolyard.

The upper paved area of the schoolyard represents the urban and impervious watershed typical in much of the Charles River basin. Rain falls on the impervious paved urban condition and the watered is channeled through paved cobble swale. Small islands of planting throughout the paved schoolyard are planted with ornamental species commonly found in urban areas including *Pachysandra* and *Liriope* groundcovers, *Cornus sericea* 'Kelseyi', **Rhus aromatica** 'Gro-Low' and River Birch Trees.

The channeled water through the schoolyard then flows into the final raingarden planting bed designed with native plants common to a healthy riparian Charles River edge. These native plants include low-land, herbaceous species in the center of the planting that will survive both water inundation and drought events, including *Iris versicolor, Eupatorium dubium* 'Little Joe', *Aster novae-angliae, Asclepias syriaca, Carex muskingumensis and Carex amphibola*. Native woody upland shrubs and trees are found on the slopes, banks and upland areas of the rain garden including *Salix discolor, Viburnum dentatum, Vaccinium corymbosum, Clethra alnifolia, and Ceanothus americanu*s. These plants grow together to form a thick root zone and vegetated mat that stabilize steeper areas of soil preventing erosion. The roots of these species

[1] Charles River Watershed | Charles River Watershed Association. (2014). Retrieved November 22, 2016, from http://www.crwa.org/charles-river-watershed

additional perform rhizofiltration, helping to remove contaminants from the stormwater that infiltrates in the garden.

NOTE: Some of these plant species listed can be found in the schoolyard planting and final plant list, but they are not indicated on the original drawings/planting plan because some plant species were substituted during construction.

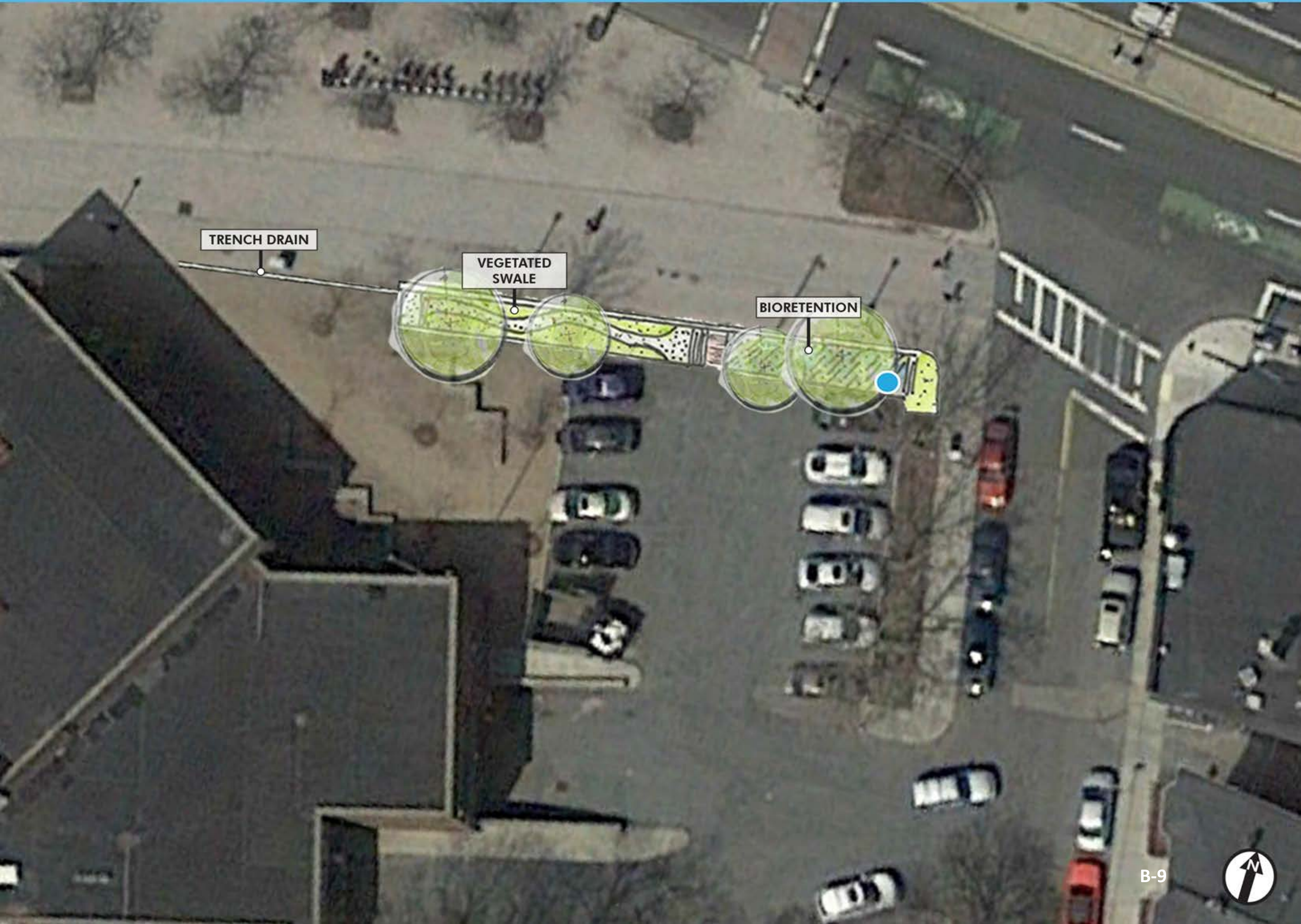
Ideas for how teachers/ students can engage with the plantings at Hernandez:

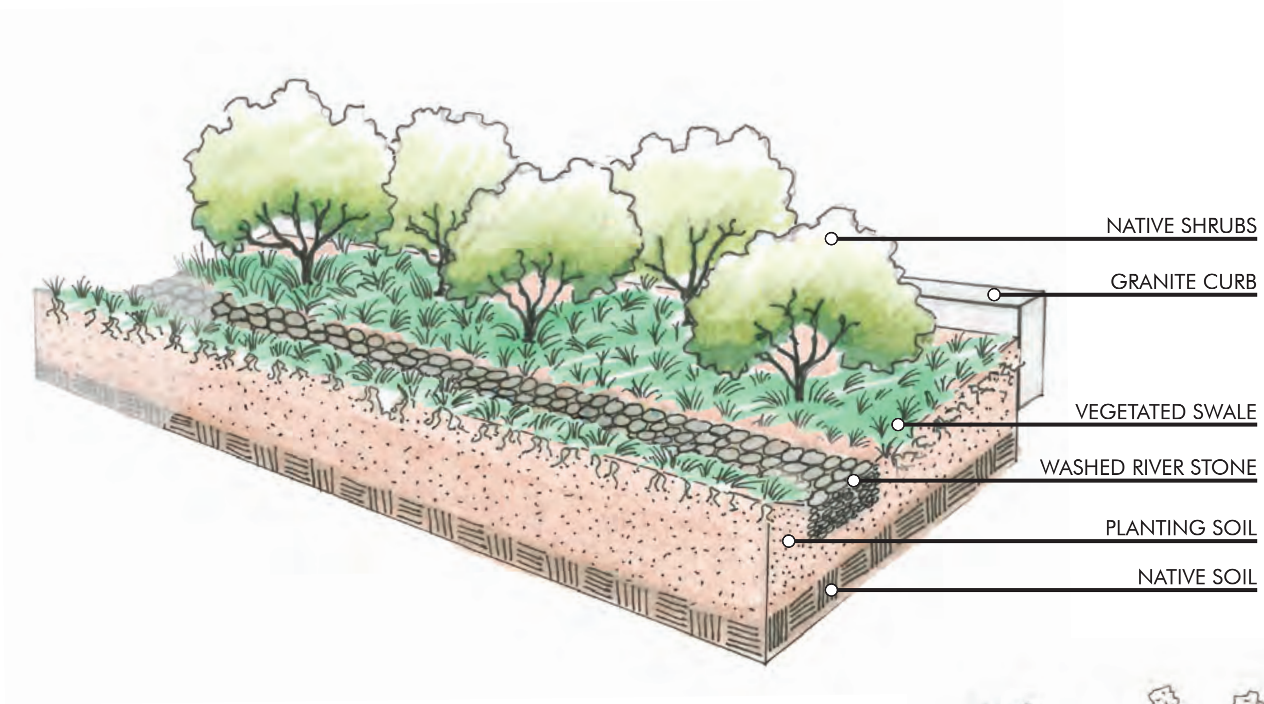
- What is the difference between a 'herbaceous' (non-woody plant species) and a 'woody' plant (shrub). Point out the herbaceous plant species in the rain garden and contrast those to the woody plants.
- Which of the plants in the rain garden look like "weeds?" Were they originally planted as part of the garden? What is the definition of a "weed?"
- *Amelanchier* (June Berry or Serviceberry) Trees & *Vaccinium* (blueberry) bushes: Harvest the June berries in June. Explain how these are edible and how they can be eaten and cooked with just like blueberries. Harvest the blueberries in July. Record observations and compare the taste, size and appearance of the berries. Discuss the different native animals that use these berries for food.

Suggested GI Activities

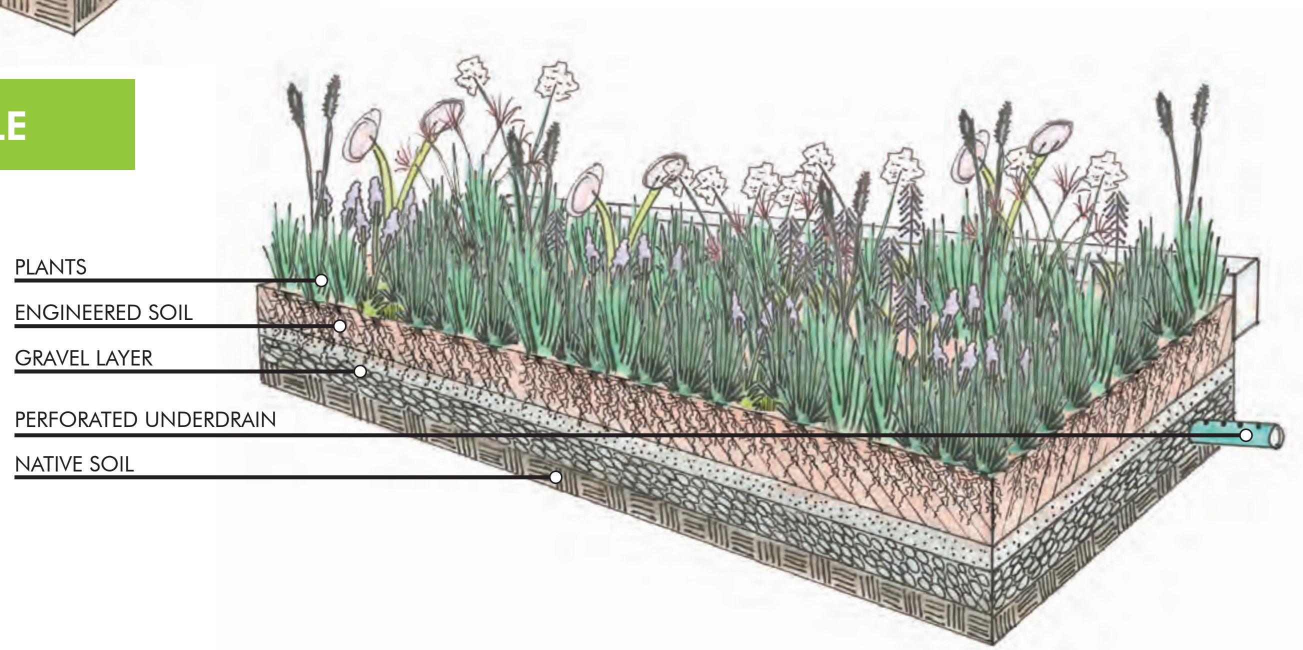
- ❑ Measure and compare water flow rates across different surfaces.
- ❑ During dry weather, use pump for tanks, and valve at cistern to generate water flow. Use sluice gate to temporarily back up flows into bowl area.
- ❑ Illustrate transport feasibility of floatables (trash and debris) by floating common city trash (e.g., styrofoam cups, plastic bags, and cigarette butts) down channel.
- ❑ Compare sediment and trash collected in weirs and gates.
- ❑ Open observation well in bioretention area to see how much water is sitting in chambers below and how long it takes to infiltrate.
- ❑ Open manhole for drywell and look at pipes. Where are they coming from and where are they draining to?
- ❑ Paint a watershed mural of the Charles River on the building wall facing the courtyard.
- ❑ Use rain paint on the concrete walkway as an art project that only appears when its raining.
- ❑ Calculate storage volume of cistern and tank. Delineate drainage area to each.
- ❑ Measure rainfall volumes from a storm.
- ❑ Compare level of water in the cistern before and after a storm.
- ❑ Experiment with the best way to manage cisterns (is it better to empty it before or after a storm?)
- ❑ Tank next to the ramp collects water drained off the impervious surface in the schoolyard through catch basins and pipes. Students determine ways to measure the amount of water they can pump out with hand pump. Test and compare water volume before and after a storm.
- ❑ Open manhole in pump tank. Why do you think there is a short weir wall inside?

JACKSON-MANN SCHOOL





VEGETATED SWALE



BIORETENTION

List of GI Features at Jackson-Mann:

1. Vegetated Swale
2. Bioretention

Plantings at the Jackson-Mann

A unique plant community was created at each of the 5 Boston Schoolyards to test and compare how various matrixes of plants would perform in green infrastructure at urban schoolyards. Each school's plant palette was designed differently, so the planting strategies can be compared over time. The plantings are designed to be an educational centerpiece for each school and additionally provide wildlife food and habitat in addition to stormwater cleansing benefits. The planting designs are entirely comprised of low-maintenance plants to minimize weeding, irrigation and long-term maintenance inputs over time once the plants established.

The green infrastructure improvements at Jackson-Mann school are split into two discrete treatment zones that mimic eco-systems - a river's edge and a wetland.

Water from the parking lot flows through the forebay and into a vegetated swale modeled after a riparian bank. Water flows through the center channel which is engulfed in a thick planting of shrubs with phytoremediation (pollution removal) capabilities (Native - *Cornus sericea,* non-native- *Cornus alba, Cornus sanguinea, Salix purpurea*)[2] underplanted with a dense mat of native sedges (*Carex platyphylla, Carex plantaginea*). The dogwood and willow shrub planting scheme is supplemented with non-native dogwoods and willows that will help ensure the swale has a diverse plant palette to handle urban conditions, provide year-round interest, and facilitate pollutant removal from the stormwater. Once the water has meandered through the swale, it flows through a second forebay before dropping into the second system.

Water that hasn't infiltrated or been taken up into the thick mat of roots stabilizing the riparian bank will flow into a bioretention area designed to mimic an herbaceous wetland planting. This system has two unique wetland mixes to create visual interest and diversity of plant species. The first mix, a large swath down the center of the system, is a mix of native Milkweed species (*Asclepias incarnata, Asclepias speciosa, Asclepias syriaca, Asclepias purpurascens*) creating a display of orange, pink, and purple flowers that will provide food and habitat value for pollinators. *Asclepia* is an especially important species to include since they are host plants for the Monarch butterfly, of which populations of this once-common black and orange iconic insect have plummeted by about 90% in just the last two decades[3]. Around the edges, the second native wetland mix (Amsonia 'Blue Ice', E*upatorium dubium, Pycanthemum muticum,* and *Veronicastrum virginicum*) provides additional seasonal blooms to provide pollinator food

[2] Kennen and Kirkwood 2015. P*HYTO: Principles and Resources for Site Remediation and Landscape Design*, Routledge, New York, NY
[3] http://blog.nwf.org/2017/02/new-numbers-show-monarch-butterfly-populations-still-in-trouble/

sources throughout the spring and summer. This portion of the system is designed to retain water and allow it to slowly infiltrate, the plants are all uniquely suited to this environment.

The Jackson-Mann green infrastructure system is in an exposed sunny area and will be supplemented with hybrid tree species that will provide shade, spring blooms, and fall color. The two shade trees, Acer x *freemanii* 'Jeffersred' (Autumn Blaze Maple), are a hybrid cultivar of the native Red Maple and Silver Maple which are commonly found along rivers and wetlands throughout the Northeast. The smaller ornamental trees, *Amelanchier x grandiflora* 'Autumn Brilliance', a hybrid of native Serviceberries will provide very early spring flowers, and berries that attract birds throughout the summer. These trees will be underplanted with a thick mat of Comfrey, a dynamic nutrient accumulator commonly used in organic gardening to both keep weeds down and provide pollution removal benefits.

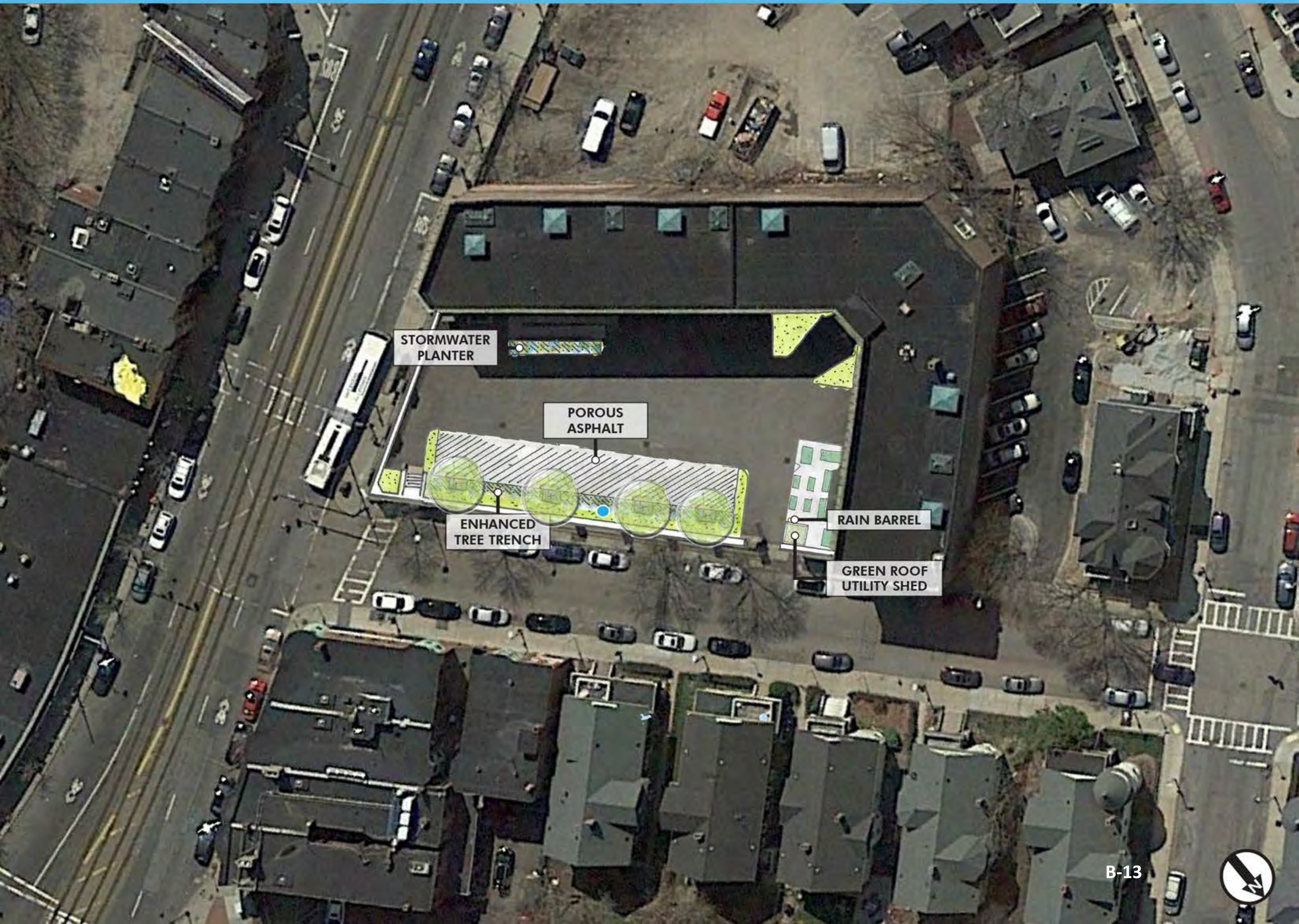
Ideas for how teachers/ students can engage with the plantings at Jackson Mann:

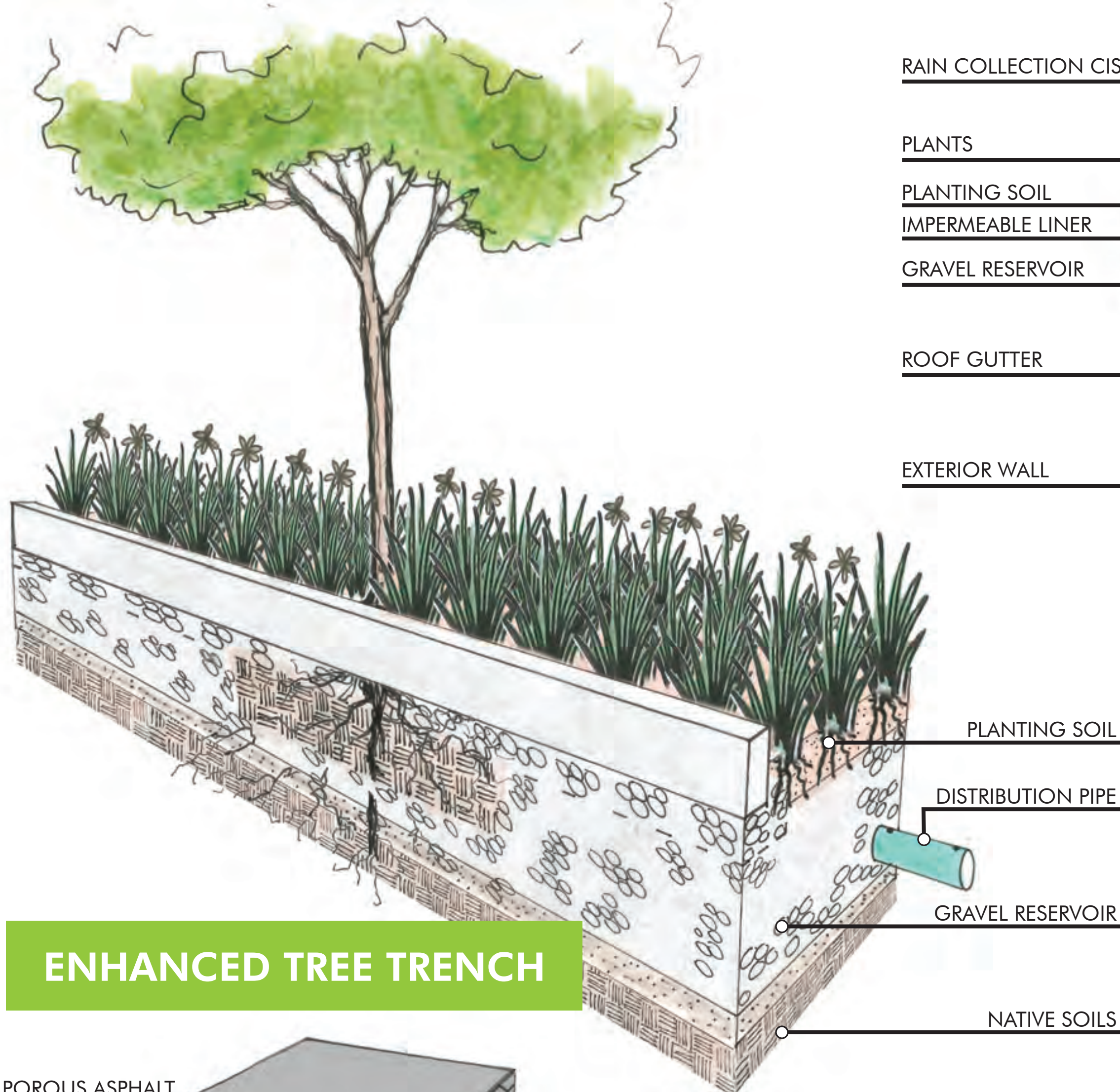
- Count the number of pollinator insects (butterflies, bees) on the plantings 1) in the Riparian Zone Areas 2) in the Wetland Zone area. How do they differ? Why? Are there more pollinators where certain plants are flowering? Complete this at different times of the year when different plants are flowering.
- Look carefully at the Asclepias species. Do any of they have Monarch larvae living on them or are adults eating the nectar of the plants? Explain the life-cycle of the Monarch and how it needs a specific species of plant for reproduction.
- Amelanchier (June Berry or Serviceberry) Tree: Harvest the berries in June. Explain how these are edible and how they can be eaten and cooked with just like blueberries. Try some/ make jam and explain how birds and wildlife use these berries for food.

Suggested GI Activities

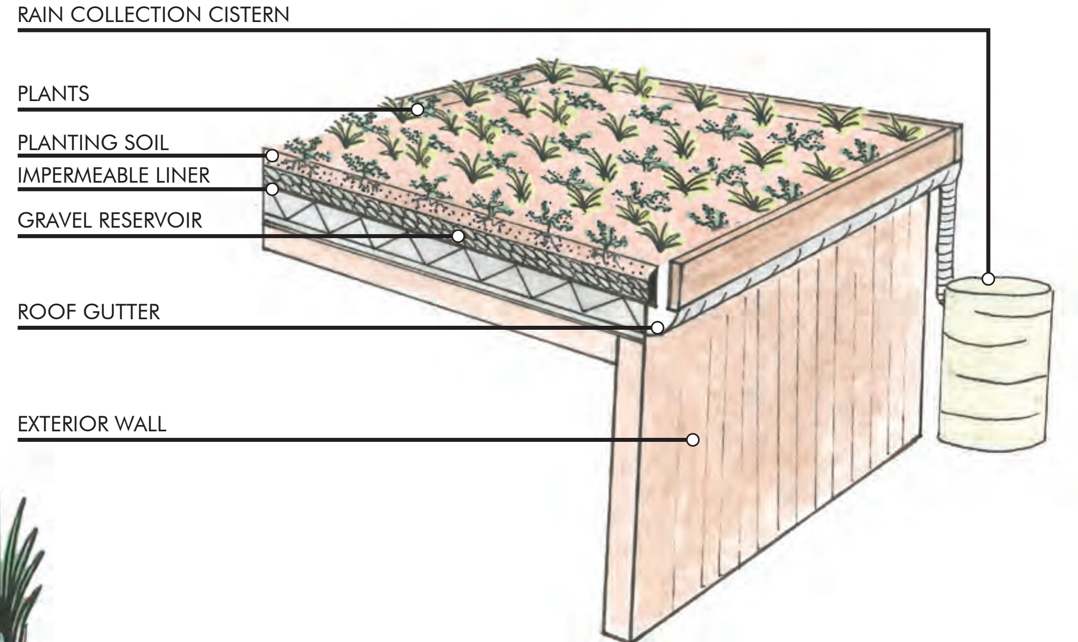
- ☐ Compare flows in trench drain vs. vegetated swale vs. gutter line on street.
- ☐ Delineate and measure drainage area to bioretention feature (two inlets).
- ☐ Measure sediment, organic and trash accumulation in sediment forebay, compare seasonally, because phosphorus binds to sediment, you can equate sediment to phosphorus.
- ☐ Measure chloride levels—compare summer to winter in runoff and soil.
- ☐ Compare authentic wetland edge in bioretention area to woodland stream in bioswale.

EDWARD M. KENNEDY ACADEMY

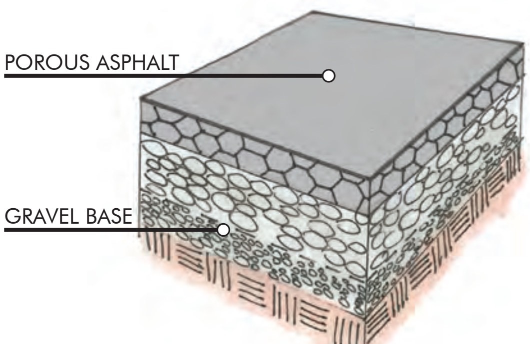




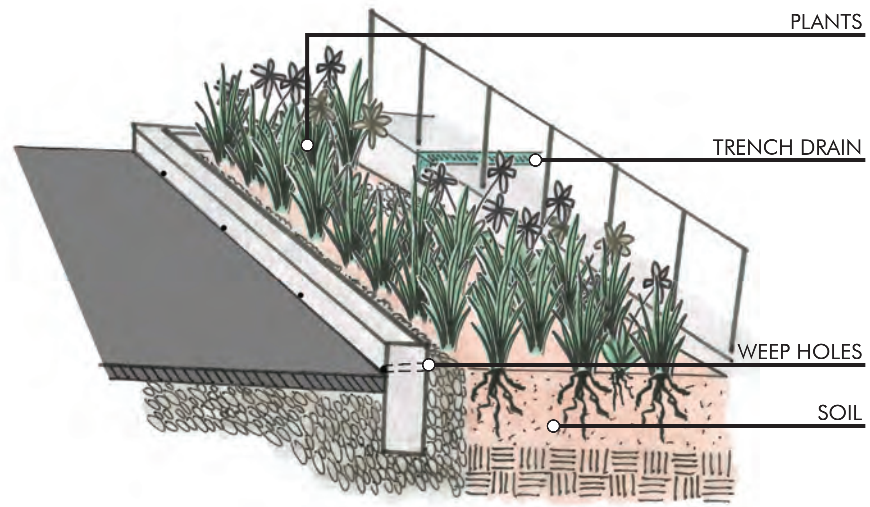
ENHANCED TREE TRENCH



GREEN ROOF & CISTERN



POROUS ASPHALT



STORMWATER PLANTER

List of GI Features at Kennedy:

1. permeable pavement
2. tree trench
3. stormwater planter
4. green roof
5. Rain barrel

Plantings at the Kennedy School:

A unique plant community was created at each of the 5 Boston Schoolyards to test and compare how various matrixes of plants would perform in green infrastructure at urban schoolyards. Each school's plant palette was designed differently, so the planting strategies can be compared over time. The plantings are designed to be an educational centerpiece for each school and additionally provide wildlife food and habitat in addition to stormwater cleansing benefits. The planting designs are entirely comprised of low-maintenance plants to minimize weeding, irrigation and long-term maintenance inputs over time once the plants established.

All of the plants installed in the new Kennedy School green infrastructure systems are medicinal plants and were at some point in history used for medicinal purposes. The planting design concept stemmed from the fact that the Kennedy High School is a college preparatory school for health careers, and that medicinal plants may be of interest to students. All of the plant species were also selected because of their ability to grow in harsh urban conditions, remove contaminants from stormwater, and survive adjacent to a parking lot that is salted during the winter months. The plant species utilized, and their medicinal uses are described below.

SCIENTIFIC NAME	COMMON NAME	MEDICINAL USES
	TREES	
Hamamelis x intermedia 'Arnold Promise'	Arnold Promise Hybrid Witchhazel	Twigs & Bark - Astringent, tonic, sedative
Ginkgo biloba 'Autumn Gold'	Male Ginkgo Cultivars	Leaf- Memory disorders, asthma, allergies, bronchitis
Ginkgo biloba 'Halka'		Leaf- Memory disorders, asthma, allergies, bronchitis
Ginkgo biloba 'Magyar'		Leaf- Memory disorders, asthma, allergies, bronchitis
Ginkgo biloba 'Presidential Gold'		Leaf- Memory disorders, asthma, allergies, bronchitis

	SHRUBS	
Hamamelis x intermedia 'Diane'	Diane Hybrid Witchhazel	Twigs & Bark - Astringent, tonic, sedative
Juniperus sabina var. tamariscifolia	Tamarix Juniper	Young Shoots- Diuretic & used for skin ointments
Morella pensylvanica 'Morton'	Silver Sprite (Morton Female) Bayberry	Root Bark- Astringent & Emetic, Tea from Leaves- fevers & skin wash
Morella pensylvanica 'Morton Male'	Morton Male Bayberry	Root Bark- Astringent & Emetic, Tea from Leaves- fevers & skin wash
Rhus aromatica 'Grow Low'	Dwarf Fragrant Sumac	Root Bark- Astringent & treatment

SCIENTIFIC NAME	COMMON NAME	MEDICINAL USES
		of diabetes and kidney diseases
Rosa rugosa 'Purple Pavement'	Beach Rose	Rose Hip- High in Vitamin C, antioxidants
Salix purpurea 'Nana'	Dwarf Arctic Willow	Bark- Anti-inflammatory, Antiseptic, Ciuretic, Sedative
Sarcococca hookeriana var. humilis	Himalayan Sweet Box	Leaves- laxative, blood purifier and muscular analgesic

PERENNIALS		
Vinca minor	Periwinkle	Alkaloids- Treatment of leukemia, Hodgkin's disease, high blood pressure
Viola labradorica	Labrador Violet	Flowers- Respiratory problems
Viola odorata	Sweet violet	Flowers- Respiratory problems

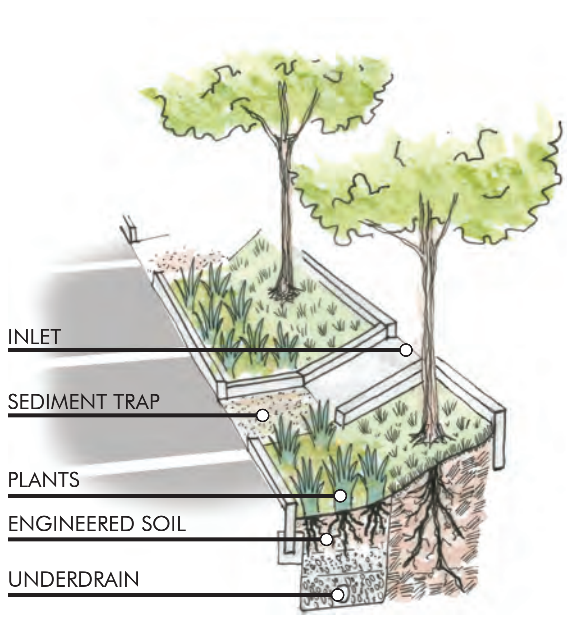
Ideas for how teachers/ students can engage with the plantings at Kennedy:

- Identify the different medicinal plants utilized in the landscape. What medicinal uses were they historically used for? What portion of the plant was utilized?
- How did each particular medicinal plant species arrive in the US? Why do you think it was brought here? Which plants are native to Massachusetts?

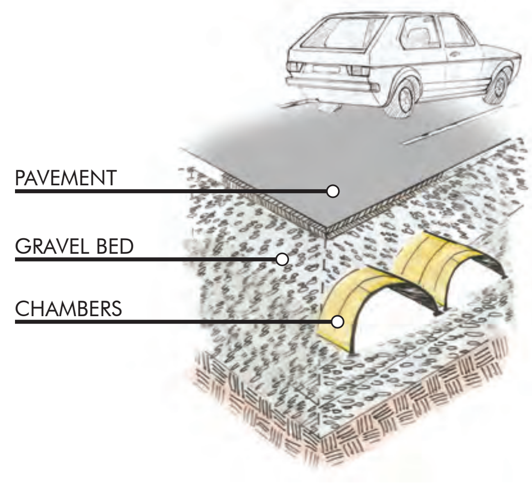
Suggested GI Activities

- ❑ ID plants and research medicinal properties of landscape plants and those in raised beds
- ❑ Rain paint to show underground pipes and flow paths
- ❑ Compare drainage on tradition pavement vs porous pavers
- ❑ Use rain gauge, gutter, and cistern to measure green roof runoff vs hardscapes area of similar size.

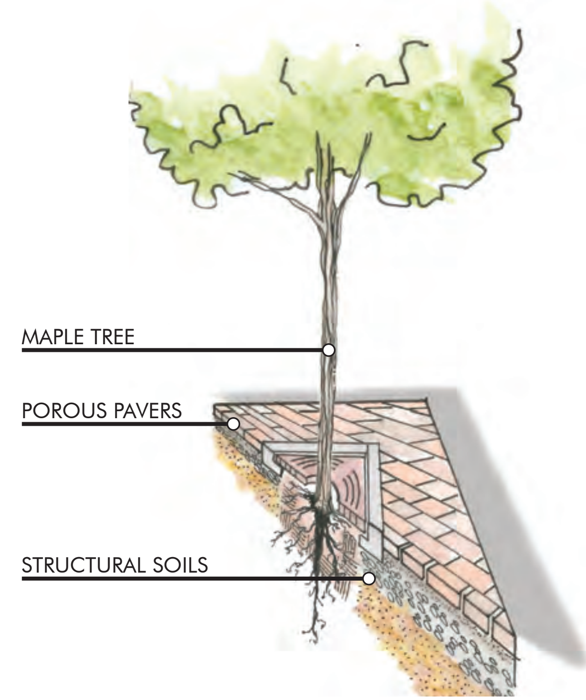
WASHINGTON IRVING MIDDLE SCHOOL



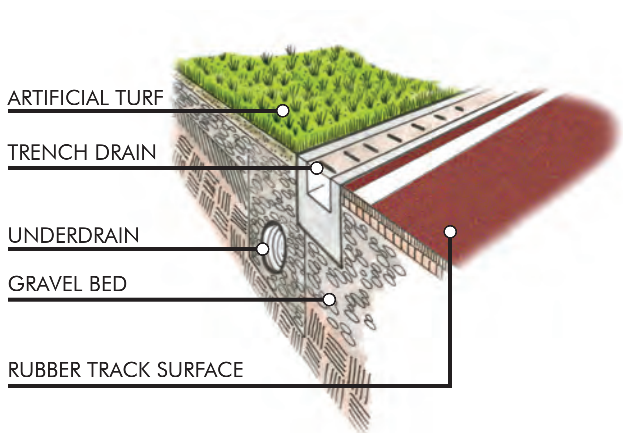
BIOSWALE



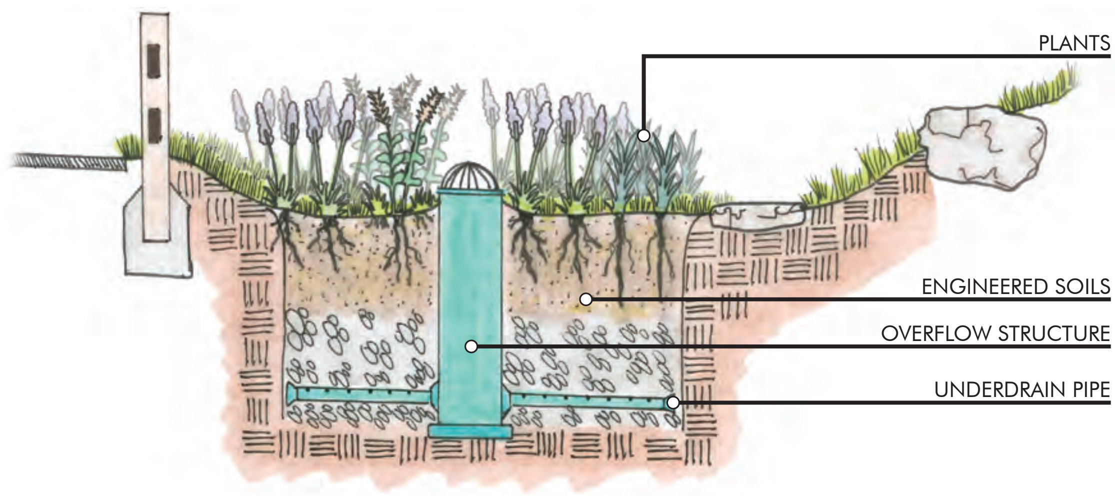
UNDERGROUND CHAMBERS



TREE PIT



ARTIFICIAL TURF



BIORETENTION


Infiltration Chambers
Bioswale
Tree Filter
Bioretention
Washington Irving Middle School
Permeable Turf Field

STORMWATER GREEN INFRASTRUCTURE
Curriculum Packet

WASHINGTON IRVING MIDDLE SCHOOL
105 CUMMINS HIGHWAY
ROSLINDALE, MA

Prepared for:
Kristin Metz

Prepared by:
Horsley Witten Group, Inc

November 2017

1.0 Introduction

The purpose of this report is to provide guidance materials for the 7th grade curriculum exercises related to site evaluation and stormwater practice selection for green infrastructure (GI) at the Washington Irving Middle School. GI were designed to:

1. Capture and treat the first 1-inch of stormwater runoff from contributing impervious surfaces, where practicable.
2. Maintain or improve runoff water quality when compared to existing conditions.
3. Reduce total impervious surface area if practicable to minimize runoff volumes.
4. Provide stormwater educational opportunities

We provide information from the engineering assessment and design of GI at the school that can be used to assist students:

- ☑ Delineate drainage areas;
- ☑ Calculate drainage area size and cover type;
- ☑ Evaluate site usage, constraints, and opportunities; and
- ☑ Select green infrastructure practices
- ☑ Interact with GI on site

2.0 Delineating Drainage Areas

Students can delineate general drainage area boundaries at their school using topographic maps and by walking around the property to identify low points (such as drain inlets, areas where water ponds) and the "watershed" that contributes to those points (i.e., high points creating the "rim of the bowl"). Once delineated, students will need to estimate the square footage of that drainage area in order to calculate annual phosphorus load and the volume of runoff generated by the first inch of rain. Stormwater practices are sized to manage this first inch of runoff. **Figure 1** is an example of the type of map that will be provided for each school showing the site aerial and topography. Students should use this map when they walk around outside. **Figure 2** shows what students might create as their drainage area map when they walk around the site. **Figure 3** is the corresponding engineering drainage area map showing catch basins and drainage pipe network for comparison.

3.0 Calculating Total Size of Drainage Area and Cover Types

Once the areas have been delineated on a map, students will need to estimate the size of each area. This can be done by pacing in the field and tapping into some geometry lessons, by using a scale on the map, or digitally on the computer in google earth (pro version allows you to calculate size of polygons). Adobe Acrobat also allows you to calculate the area of a polygon in PDF files. Just make sure you know the scale of the map. Students can also breakdown the total drainage area into impervious cover (roof or parking) or pervious area (trees or grass) if desired. Rough estimations of percent coverage can be used to generate a square footage (i.e., 50% of the area is grass, so divide total area in half to generate square footage of grass. **Table 1** provides the square footage information for each drainage area based on what was actually surveyed.

Table 1. Existing (Pre-GI) Drainage Area Summary (from Engineer)

Pre-GI Drainage Area ID	Total Area (sq ft)	Impervious Area (sq ft)	Impervious Area (%)	Pervious Area (sq ft)	Runoff Volume 1" storm (cf)
DA1	12,900	12,900	100%	0	1,075
DA2	18,230	15,660	86%	2,570	1,305
DA3	16,670	14,690	88%	1,980	1,224
DA4	17,140	15,400	90%	1,740	1,283
DA5	19,540	8,510	44%	11,030	709
DA6	9,240	7,640	83%	1,600	636
DA7 (6b)	5,080	2,560	50%	2,520	213
Roof	37,400	37,400	100%	0	3100
Front	12,880	6,725	52%	6155	560
Total	**149,080**	**121,485**	**81%**	**21,440**	**10,105**

1 cubic foot = 7.5 gallons; 1 acre=43,560 sf

It should be noted that post-GI, the individual drainage boundaries on site changed slightly due to rerouting and regrading. Overall site impervious cover was reduced by over 15,000 sf, which is 12% of total site impervious cover. This reduction also reduced the total volume of runoff that must be managed by 2,300 cf (or 17,200 gallons). Overall, almost 60% of the total impervious cover on the school property is now being managed by green infrastructure. The roof and the front of the school are not being managed. A final summary of the post-GI drainage area management is provided in **Table 2**.

In addition, the impervious cover area is reduced by over 15,000 sq ft (0.35 ac), which is equal to about 20% of the drainage area at the site. Furthermore, the volume of runoff needed to be treated has been reduced by 1,270 cf, also a 20% reduction.

Table 2. Post-GI Drainage Area Summary

Post-GI Drainage Area ID	Total Drainage Area (sf)	Impervious Area (sf)	Impervious Area (%)	Runoff Volume from 1" storm (cf)	GI	% 1" Runoff treated
DA1	26,740	16,420	61%	1,370	Tree Pits/Sports Field	100%
DA2	23,920	7,020	30%	600	Bioretention	100%
DA3	16,680	14,070	84%	1,150	Concrete Swale/ Underground Chambers	100%
DA4	17,140	14,390	84%	1,200	Bioswale	100%
DA5	14,320	10,200	71%	850	Underground Chambers (BPS)	100%
Roof	37,400	37,400	100%	3100	N/A	N/A
Front	12,880	6,725	52%	560	N/A	N/A
Total	**149,080**	**106,250**	**71%**	**8,830**	**--**	**59%**[1]

[1] 59% of the school is managed by green infrastructure for 1" of runoff from impervious surfaces. All of the paved areas where site improvements were made are now managed by green infrastructure (5,170 cf). The roof and the front of the school are not managed.

Figure 1. Washington Irving aerial prior to 2017 stormwater improvements, topography, and soils

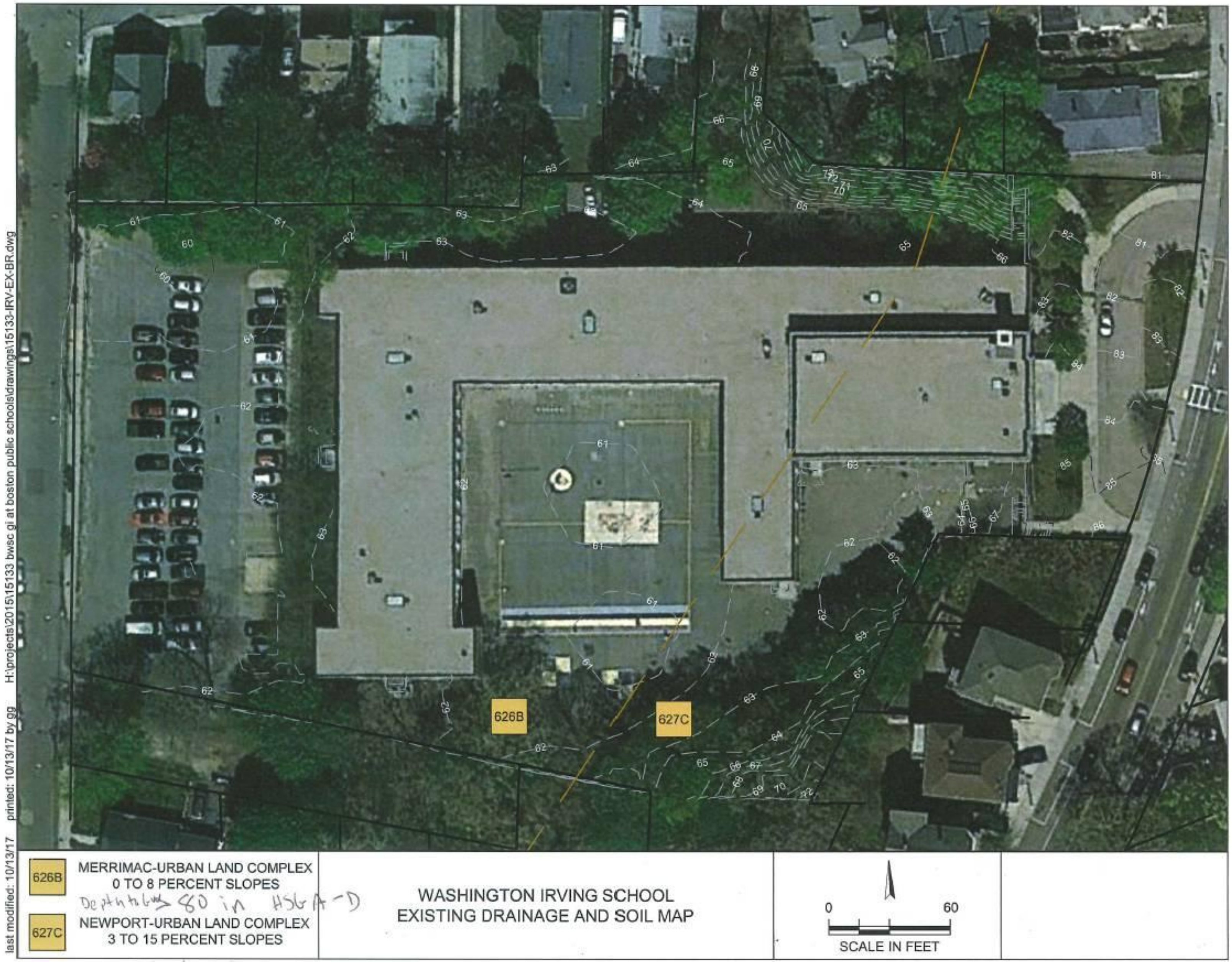


Figure 2. Field sketch of catch basins and drainage boundaries (THIS NEEDS TO BE TO SCALE FOR STUDENT USE)

Figure 3. Engineering drainage area map of pre-GI conditions

4.0 Evaluating Site Uses and Constraints

There was no existing stormwater management at this school. One of the most important parts of designing a new stormwater management approach at an existing building is understanding how different parts of the site are currently being used, what the constraints may be for stormwater improvement, and where the opportunities are. The students should document what is happening at the site including parking needs, areas where kids play, known flooding problems, and locations where snow is piled in the winter. They may want to interview the Principal, PE teachers, and maintenance staff. How can stormwater retrofits improve site uses?

To give you an idea of what site information is relevant, **Table 3** summarizes site usage, grounds maintenance, and parking information collected during the preliminary site assessment and in meetings with school officials. Based on this initial evaluation, three specific locations at the school were identified for focusing green infrastructure design efforts on: 1) the rear parking lot; 2) the interior courtyard; and 3) the existing low point on the east side of the school between the stage and the interior courtyard. Each of these locations was then evaluated based on site constraints and opportunities:

- Adequate available space for siting surface and/or subsurface practices;
- Safety
- Aesthetics
- Educational opportunity and public visibility;
- How site is currently used by students and staff;
- Existing drainage pathways;
- Existing utilities, buildings and other structures;
- Potential disruption to existing facilities, adjacent land uses/activities and traffic; and
- Operational or maintenance conflicts (e.g. snow removal) or opportunities for improvement.

Table 4 summarizes the land use constraints, the potential space improvements through the use of green infrastructure, and the potential educational opportunities for each of three locations.

Other key data include soils and floodplain information. Based on the USDA web soil survey the two major soil types at Washington Irving include:

- 626B Merrimac-Urban Land Complex: 0-8 % slope, HSG A-D, with >80 inch depth to groundwater.
- 627C Newport-Urban Land Complex:3-15% slopes, HSG B, with 18-30 inch depth to groundwater

Soil type and depth to groundwater is important to determine if increasing stormwater infiltration is feasible and are included in **Figure 1**. In real life, the Engineer dug test pits to actually classify soil type and measure depth to groundwater, but for concepts and for this exercise, the web soil survey is fine. BWSC will be providing these maps for all schools.

Table 3. Preliminary Site Assessment for Washington Irving

Assessment Parameters	Comments
Existing "available" space–documenting unused or underutilized land, either unpaved or paved, that does not currently have a building or other structure (i.e. play equipment).	• Opportunities exist for pavement removal in the back. The area is used mostly for play and is not typically accessed by vehicles (except medium-sized bus pickups/drop offs). • For PE classes, the school can have 70 students in courtyard at one time playing soccer, kickball etc. Home plate is in western corner. The majority of the courtyard space should remain open for running kids and flying balls. • Tenacity currently has 16 students in the program with 3 to 4 courts set up at 60-ft lengths with 18-ft wide portable nets. The setup uses about half the available courtyard space. Tenacity would prefer a hard surface
Parking lot configuration/traffic flow – documenting current existing parking and traffic flows to evaluate whether GI practices can be installed with minimal or no impact on existing parking and traffic.	• One entrance exists from Hawthorne St. and one on Sycamore St. The co-principals indicated that parking is not a problem and could reduce available parking spaces if lot was to be reconfigured. BPS noted that a loss of up to 8 spaces would be acceptable. Compact parking stalls acceptable. • Need to maintain fire access and handicapped accessibility, particularly from sidewalk to ADA-compliant door into building. Easy access should be maintained in multiple locations with proposed parking lot reconfiguration. • Snow disposal area is currently on north side of rear parking lot. • Full-sized buses use front of school for pickup/drop-offs. Half buses load in interior courtyard. Moving bus pickup from interior courtyard to the rear building entrance will improve safety. Buses need to have approximately 300 ft to line up, with space to pull around. Bus dimensions are 26ft long x 8 ft wide. Students exit from multiple doors and load onto buses during the same time that Tenacity is meeting in interior space. The school is open to rerouting suggestions. • Reconfiguration of the rear parking lot could be considered, including new curb cuts to Hawthorne Street and access to Sycamore Street. However, there was not much support from the school or BPS for a new curb entrance on Hawthorne. Exiting out of the side onto Sycamore Street would be viable—delivery trucks go that way. • Must maintain firetruck access to interior courtyard area
Site visibility and viewsheds – identifying educational opportunities and evaluating whether GI practices can be readily observed by most individuals entering/leaving the site and/or buildings.	• Parking lot may not be easiest spot for classes to be out looking at GI unless there is a "viewing platform" or sidewalk space • Interior courtyard visible from classrooms. Evaluate way to incorporate trees or other perimeter vegetation without blocking light into windows. • Consider bioretention in low point in the back. Karen discussed her vision of the outdoor classroom—20 kids at a time, distributed area where kids can all walk around and not be clumped together. Suggested elements: visible line of sight; opportunities to interact and observe; water quality testing.
Site context – identifying unique site features, elements, vegetation and assess the context of the surrounding neighborhood.	• Soils indicate relatively high potential to infiltrate. Groundwater Adjacent community is walkable neighborhood. • At low capacity right now, likely to be identified for additional growth. • Community group may be interested in landscape maintenance.
Existing Landscaping and grounds maintenance—documenting the types of vegetation and level of care currently provided.	• Floods in the back by the stage due to clogged catchbasin • Fix the stairs back by the stage when redoing that area. • Minimal existing landscaping (small grass area out front and in back by main entrances). • School co-principal asked about maintenance of surface GI practices and classroom areas. BPS is adding the GI pilots to their outdoor classroom maintenance list, which is a 3 times/yr maintenance plan. BWSC will maintain GI for first few years.

Table 4. Summary of Site Constraints, Improvements and Opportunities

GI Location	Constraints	Potential Improvements	Educational Opportunities
1. Parking Lot in the Rear	• BPS proposing to manage this area; potential to reduce size of underground storage chambers • Full sun • No utility conflicts; can use existing drainage infrastructure • Highly visible • Not particularly safe for kids to be standing around GI without dedicated space • Reduction of existing parking count (56 stalls); requires designated on-street parking • 300 ft line up length for buses may not be easily met in rear lot • Snow disposal may result in temporary loss of additional spaces. Snow storage along eastern boundary.	• Safety benefit to reconfiguration for busing that makes sense with building access • Add landscaping and canopy cover to open parking lot; Potential for air quality improvement in location where vehicles idle. • Potential to disconnect drainage from sewer (not as currently proposed)	• Observe stormwater runoff across paved and vegetated cover • Compare BMP performance • Comparable drainage areas
2. Interior Courtyard	• BPS proposing to manage this area; • Partial shading • Visible from all interior facing classrooms (three sides of 3-story building) • Main drain line • Limited potential for landscaping (e.g., trees potential hazards to running children)	• Safety benefit to reconfiguration for busing-makes sense with building access • Improving the play space and aesthetics is primary driver • Surfacing and sizing should be compatible with PE classes and Tenacity program	• Some related to permeable vs impervious surfaces • Arboretum
3. Low point in eastern back corner	• Shady, integration potential with sloped, treed area • Poor drainage at low point • Utility poles	• Improve drainage conditions • Opportunity for pavement removal • Need to maintain fire access • Close to door	• Outdoor classroom space • Transition between paved and natural area

5.0 Practice Selection

Once site constraints and opportunities are known, students will next identify the type of green infrastructure they want to use for a given drainage area(s). There is a fun spreadsheet that can be used for this activity that groups typical practices into 5 groups and assigns a generic TP removal efficiency (**Table 5**). While design and sizing of these practices varies greatly, this complexity can be ignored at the 7th grade level.

Table 5. Simplified groupings of stormwater practices

GI Group	Practices	Assigned % TP removal efficiency	Assigned 20-yr $ per acre treated	Comments on selection criteria
Infiltration practices (subsurface)	basin, chambers, dry well/leachers, trench	80%	$160,000	Need permeable non-contaminated soils and sufficient distance to groundwater
Biofilters (surface, vegetated)	bioretention, bioswale, tree pits, organic filters	60%	$150,000	Acceptable landscape area, understanding of sun vs shade for plant selection
Pervious pavement (surface with subsurface base)	porous concrete, permeable pavers, porous asphalt, pervious synthetic turf	70%	$280,000	Replacement for impervious hardscapes; no deicing
Ponds/wetlands (surface)	constructed wetlands, wet ponds, gravel wetlands	50%	$50,000	Take up a lot of space. Considerations for standing water on site. Could be cool for habitat
Cisterns	above ground, underground tanks, rain barrels	--	--	

The proposed green infrastructure practices at Washington Irving include a bioswale and underground chambers in the parking lot and alley; tree pits and pervious synthetic turf field in the interior courtyard; and a large bioretention in the eastern corner. Specific GI components are shown in **Figures 4** and **5** and described below. **Table 5** summarizes the benefits of the GI used. **Figure 6** shows the new, post-GI drainage boundaries from engineer's modeling.

Table 5. Summary of GI practices

GI	Post-GI DA managed	Benefits
Bioswale	half of rear parking lot (DA4)	• Some phosphorous removal capability • Increase biodiversity- phytoremediation • Some infiltration • Helps with improved traffic flow • Educational comparison with concrete swale
Underground chambers	half of rear parking lot (DA3) and alley (DA5, *formerly DA6*)	• Good phosphorus removal • Increased infiltration • Can drive/park on top, allows for traffic reconfiguration • Reduces ponding issues
Tree Pits/Synthetic Field	Interior courtyard (DA1, formerly DA1 and DA2)	• Reduced impervious cover • Some phosphorus removal • Improved recreation • Increased biodiversity and shade • Some infiltration
Bioretention	Eastern corner between stage and courtyard (DA2, formerly DA5)	• Reduced flooding • Some phosphorous removal capability • Increase biodiversity-pollinator meadow • Some infiltration • Educational

Figure 4. Green infrastructure at Washington Irving

Figure 5. Cartoons of GI practices used at Washington Irving

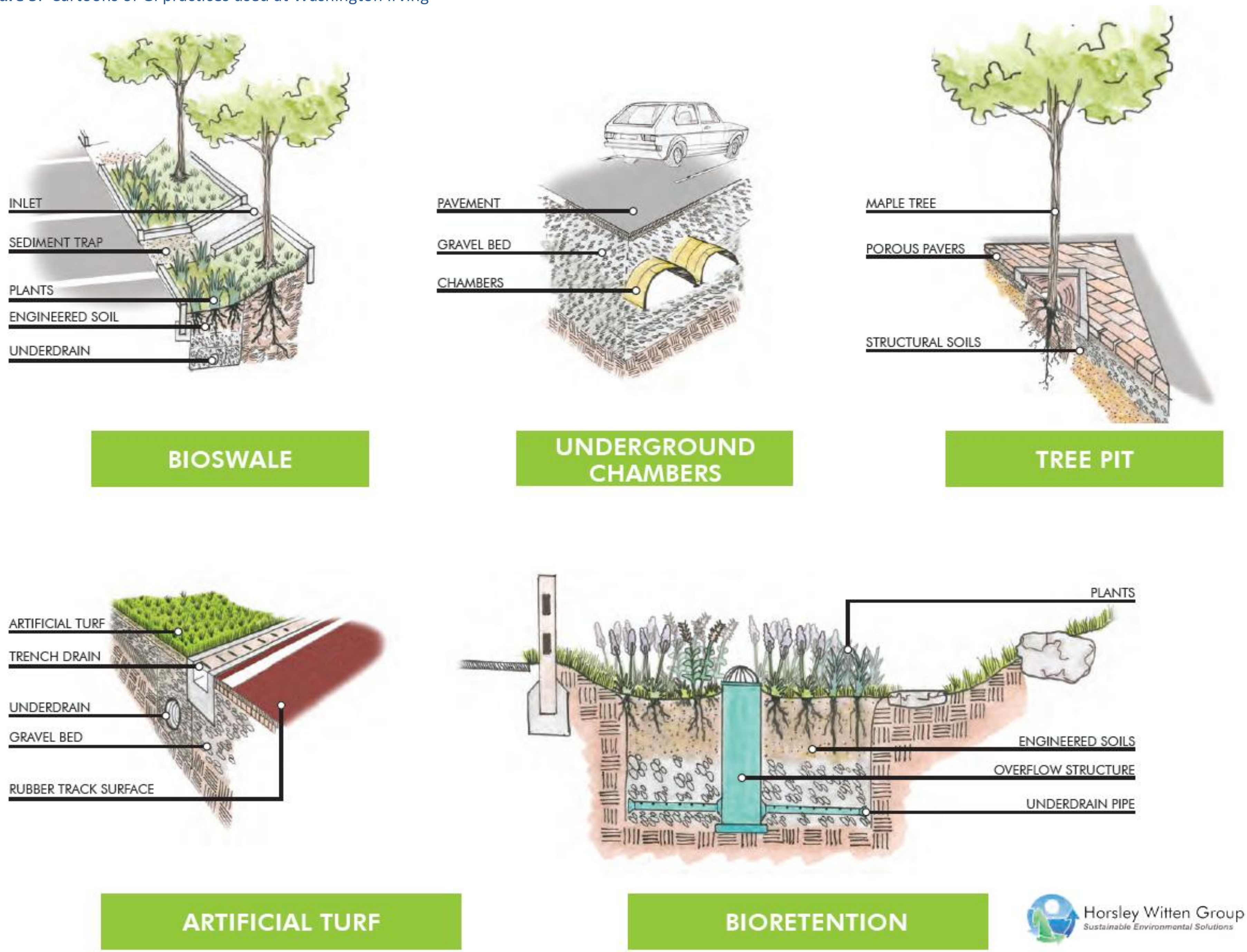


Figure 6. Engineering drainage area map of post-GI conditions (note slight changes from original drainage boundaries in courtyard and eastern corner)

Rear Parking Lot
The green infrastructure was designed to manage stormwater runoff from DA3 and DA4. The design splits the parking lot in half. Half of the lot drains to a concrete swale and underground chamber system, and the other half drains to a bioswale. This split was done explicitly to provide an educational opportunity to compare stormwater runoff between traditional (concrete channel) vs the "green infrastructure" approach (bioswale). The chambers used actually provide treatment for the runoff from the concrete swale. The total number of parking stalls was reduced, however the parking lot was reconfigured to create a designated bus loading zone to improve safety (rather than using the interior courtyard). Pedestrian access between the parking lot and the school is provided through a sidewalk crossing between the two swales, and buses now exit through the alley on the north side of the building to Sycamore St. See **Figure 7** for photos and illustrations of the GI in the parking lot. The Washington-Irving school has three unique interventions with plant communities suited to each application. There is a bioswale at the parking lot, shade trees at the sports field, and a pollinator meadow at the outdoor classroom.

<u>Bioswale Design</u>
The parking area drains to the bioswale through curb inlets while the designated loading zone and drive aisle drains to the bioswale through concrete inlet channels. Runoff to the bioswale is managed for the first 1-inch of runoff from impervious surfaces for water quality; excess runoff enters the existing drainage system through an overflow structure. Due to limited infiltration capacity in the soils, the bioswale is under-drained to ensure the practice will drain within 40 hours. The bioswale uses bioretention soil media and vegetation to promote infiltration, filtering and uptake of pollutants. A ponding depth of no more than 4-inches is used to maximize management of stormwater runoff, but minimize any safety concerns for students, teachers or staff.

The bioswale is planted with salt tolerant species as well as species that provide air quality benefits to minimize impacts from bus idling. The selection of plants is diverse to maximize water quality benefits through pollutant uptake and minimize required maintenance. Plants include Creek and Ice Dance Sedges, Blue Flag Iris, Slender Rush, Creedping Lilyturf, and Varigated Liriope. Trees (Sycamore, London Plain Tree, Tulip Poplar, and Little Leaf Linden) provide shading for the parking lot and pedestrains.

<u>Concrete Swale and Underground Chambers Design</u>
Similar to the bioswale design, the concrete swale manages stormwater runoff from the parking area through curb inlets while runoff from the designated loading zone and drive aisle would enter through concrete inlet channels. Unlike the bioswale, the concrete swale design is for conveyance only; runoff would ultimately be conveyed to underground storage chambers that would manage the 1-inch water quality event. The underground system includes 30, 16-inch StomrTech chambers laid out in two rows sitting in a 34-inch bed of gravel. It is equipped with an overflow mechanism to safely convey runoff from larger storm events to the existing catch basin that will be converted to a drain manhole structure.

Figure 7. Before and after photos of bioswale and underground chambers in the rear parking lot.

Interior courtyard

The green infrastructure in the interior courtyard involved replacing pavement with a porous sports field and tree pits that manage stormwater runoff from both original drainage areas DA1 and DA2 (see **Figure 8** photos). The sports field was specifically selected to improve recreational uses of this space. Five tree pits were added around the perimeter to improve aesthetics, shade, and to create an educational opportunity related to comparing different types of maple trees. The tree pits maintain a 10-ft setback from the building to avoid impacts to the building foundation and to allow access around the perimeter of the courtyard. The surface of the tree pits are a permeable paver block. Tree pits are spaced to avoid blocking windows and sightlines, minimize interference with PE class activities (e.g., kickball).

Sports Field Design

The sports field design includes a porous, synthetic playing surface (e.g., artificial turf) with a shallow gravel storage area to manage runoff from rainfall that falls on the field itself, the surrounding track, and asphalt. A small portion of the asphalt areas surrounding the sports field would also be captured through individual tree pits. The sports field's storage will be directed to trench drains which will then connect into existing 54-inch drain line.

Tree Pits

The tree pits manage stormwater runoff from surrounding impervious surfaces and allow for filtering of pollutants using a structural based soil. The trees at the sports field showcase a gradient of native tree species and their cultivars to create a visualization of the differences between Red Maples, Fraser Maples and Silver Maples.

Low Point on East Side (Between Interior Courtyard and Stage Area)

The green infrastructure manages runoff from the original drainage area DA5 and a portion of DA2. It involved removing portions of existing pavement and installing a large bioretention facility with a pretreatment sediment forebay. The practice was specifically selected and designed to eliminate flooding. The bioretention area and surrounding landscaping are configured to provide an outdoor space for teachers and students to observe drainage, bees, and plants. A section of existing pavement was cut and planted to mimic a river pattern. Site features, such as stepping stones, allow students to interact with the space. There is a sampling port cut into the inlet flume that allows for the collection of water samples if needed. The area is configured to ensure fire access between the rear parking lot and the stage area and protect existing overhead utilities along the edge of the existing asphalt area. See **Figure 9**.

Bioretention Design

The bioretention area includes a curb cut to a sediment forebay with paver stones that can be easily shoveled. From the sediment forebay, flows overtop a weir structure into a vegetated swale that discharges into the bioretention. Flows are then directed through a spillway to the bioretention area, which uses engineered soil media and vegetation to promote infiltration, filtering and uptake of pollutants. Runoff to the bioretention area manages 1-inch of rainfall on contributing impervious surfaces; excess runoff would enter the existing drainage system through an overflow structure. Due to limited infiltration capacity in the soils, the bioretention is under-drained to ensure the practice will drain within 40 hours. The bioretention has a maximum ponding depth of 4-inches to maximize management of stormwater runoff while minimizing safety concerns for students, teachers and staff that will be observing and interacting with the practice. The plants selected for the bioretention area mimic a small pollinator meadow comprised of primarily MA native Little Bluestem, joe pyweed, and Creek Sedge, and supplemented with additional North American native meadow species (e.g., yarrow, hyssop, milkweed, asters, indigo, coneflowers, sunflowers, spike gayflower, iron weed, and little bluestem) to create a pollinator garden to provide food and habitat to butterflies and bees throughout the growing season.

Figure 8. Before and after photos of the interior courtyard conversion to field with perimeter tree pits.

Figure 9. Before and after photos of the eastern corner conversion to bioretention.

In addition to these GI practices, pavement was also removed around the side door entrance in the interior access lane. These areas were planted with Red chokeberry, spurge, and little leaf linden (**Figure 10**).

Figure 10. Before and after photos of the side entrance.

6.0 Additional Activities

This pilot site will be set up with real-time monitoring equipment, including

- Two monitoring panels powered by solar (one in front bioswale and one in back bio)
- 4 or 5 flow measuring devices (using weirs and pressure transducers) will be located in the outlet structures for concrete and bioswale so you can compare, and one at recharge chamber. Also one in the bio in the back. Not sure they will be measuring inflow into systems, so it would be great to be able to have kids go actively measure surface flows so they can compare with what is leaving.
- Two soil saturation sensors, one will be placed in the bio in the back and one in the swale in the front.
- Not sure if there are multiple rain gauges at the site. We put a post in the back by fence, but they may opt to put it out front.

Activities suggested for interacting with the GI on site include:

1. At bioswale: Paired catchment study. Delineate drainage areas. Compare traditional drainage vs GI features and how each works. Measure volume, rate, quality of inflow and outflow from each system. See opti on-line, real-time measurements.
2. At recharge chambers: Apply rain paint on surface to show location of recharge chambers and underground pipes/flow direction. Open observation port/maintenance cleanout and measure height of water in system.
3. At bioretention: Apply rain paint to showing actual or representative watersheds and flow paths to each bio inlet. Could paint Charles River on wall of building. Students could use street chalk to draw and calculate drainage areas. Can sample inflow,

measure how much rain it takes to overflow system via under drains or overflow pipe. Open maintenance cleanout port and see if there is water in the system. See opti on-line, real-time measurements.

4. All GI: Plant identification and co-benefits: in pollinator meadow garden; trees in tree pits; pollution reduction by plants in bioswale
5. Impervious cover reduction- calculate how much impervious cover was removed from the site (measure footprint of field, landscape islands, and bio).

List of GI Features at Washington Irving:

1. Bioswale/concrete channel in parking lot
2. Infiltration chambers (underneath parking lot managing drainage from concrete swale)
3. Tree pits
4. Turf Field
5. Bioretention

Plantings at the Washington-Irving

A unique plant community was created at each of the 5 Boston Schoolyards to test and compare how various matrixes of plants would perform in green infrastructure at urban schoolyards. Each school's plant palette was designed differently, so the planting strategies can be compared over time. The plantings are designed to be an educational centerpiece for each school and additionally provide wildlife food and habitat in addition to stormwater cleansing benefits. The planting designs are entirely comprised of low-maintenance plants to minimize weeding, irrigation and long-term maintenance inputs over time once the plants established.

The Washington-Irving school has three unique green infrastructure interventions with plant communities suited to each application. The bioswale plantings at the parking lot are designed to both cleanse the stormwater from the parking lot and remove large particulate matter from any air pollution generated from idling cars and buses. Around the sports fields/ track, several varieties of maple trees were planted in the tree filter boxes so that students can compare and contrast different species of maple leaves. Lastly, a pollinator meadow was created at the outdoor classroom to provide both stormwater infiltration benefits while providing food and habitat for bees and butterflies.

<u>Parking Lot Bioswale:</u> The bioswale that runs along the parking lot is planted with a cohesive mix of low maintenance, spiky textured plants including *Iris versicolor*, *Liriope*, Iris "Caesar's Brother' and *Carex morrowii* 'Ice Dance' among others. The aggressive plant varieties selected will grow together, mix and spread by seed or rhizomes creating very little visible soil at ground level and thereby smothering out weeds and creating a lower-maintenance planting. The leaves of all the native and non-native plant varieties selected are vertical and spiky in appearance, creating an overall pleasing aesthetic composition, even when the species are mixed together. The idea is for the planting to have a neat, unified appearance, but to be comprised of many different plant species to maximize the variety of microbiology present in the bioswale root zone. Different varieties of plants support different kinds of microbiology in the root zone and the microbes help mitigate contaminants introduced with the stormwater. The row of trees along the edge of the parking lot swales consists of species selected for their ability to remove large particulate matter from the air[4]. The intention is for these trees to help mitigate the air pollution impacts caused by buses and cars idling at the drop off circle. These tree species, including *Tillia cordata, Platanus occidentalis, Liriodendron tulipifera* and *Platanus* hybrids all have waxy leaf surfaces or leaf hairs that help remove particulate matter from the surrounding air.

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[4] Kennen and Kirkwood 2015. P*HYTO: Principles and Resources for Site Remediation and Landscape Design*, Routledge, New York, NY

<u>Sports Field/ Track:</u> The trees planted in the tree filter pits around the sports field/ track area showcase two native maples and a hybrid that has the best attributes of each: *Acer rubrum* (Red Maple), *Acer x fremanni* (Freeman Maple, a hybrid of red and silver) and *Acer saccharinum* (Silver Maple). These maples can survive in harsh urban growing conditions and the roots help remove contaminants from stormwater. A gradient of different types of maples was utilized so students can compare the different leaf shapes and consider the physical differences in the shape, color and size of the tree canopy between multiple varieties of the same kind of plant.

<u>Bioretention:</u> The plantings in the bioretention are all native species and create a pollinator meadow garden to provide food and habitat to butterflies and bees throughout the growing season.

The primary grass species in the meadow is *Schizachyrium scoparium* (Little Bluestem) which is paired with supplemental flowering North American perennial species. These forbs, including but not limited to, *Agastache* 'Blue Fortune', *Achillea millefolium, Baptisia, Helenium* and *Helianthus* provide flowers throughout the entire spring and summer so that pollinators have a constant source of high-quality nectar. Various seed pods will develop on the plant species for student collection and exploration.

Ideas for how teachers/ students can engage with the plantings at Washington-Irving:

- How many different kinds of plants do you see in the parking lot bioswale? Many of the plants have a similar leaf-shape, but the kinds of plants are actually different. Which plants do you think were planted as part of the original planting? Which do you think might have invaded as 'weeds'?
- Compare and contrast the different varieties of maple trees around the sports field/ track area. Which trees are similar? Which are different? How are the leaf shapes of the different varieties of maples different even though they are the same species? How are the cultivars different? Explain the difference between plant family, species, variety and cultivar.
- Count the number of pollinator insects (butterflies, bees) on two different kinds of flowering plants in the outdoor classroom area. How do they differ? Why? Are there more pollinators on certain kinds of plants? Why do you think this is? Complete this at different times of the year when different plants are flowering.

Suggested GI Activities

- ❑ See 7^{th} grade lesson plans and case study.
- ❑ Paired catchment study between bioswale and concrete channel. Delineate drainage areas. Compare traditional drainage vs GI features and how each works. Measure volume, rate, quality of inflow and outflow from each system. Visit BWSC website for link to real-time monitoring.
- ❑ Apply rain paint in parking lot to show recharge chambers and underground pipes/flow direction and watershed divide.
- ❑ At bioretention: Apply rain paint to showing actual or representative watersheds and flow paths to each inlet. Could paint Charles River on wall of building. Students could use street

chalk to draw and calculate drainage areas. Can sample inflow, measure how much rain it takes to overflow system via under drains or overflow pipe.

- ❑ Rain gauge measurements, compare open vs canopy area
- ❑ Impervious cover reduction- calculate how much impervious cover was removed from the site (measure footprint of field, landscape islands, and bio.

Suggested Activities for GI Schools by GI Feature

Bioretention Feature

- ❑ Measure soil saturation: how much water comes into a bioretention feature and how much is taken up by plants compared to how much is taken up by the soil?
- ❑ During or immediately after a rain, compare water flow on impervious surfaces aimed at moving water out as fast as possible to water flow in bioretention features which mimic the natural hydrologic process: slowing water down so plants, soil and microbes can remove phosphorus and the water can slowly absorb into the ground.
- ❑ Look for patterns in the types of plants that are used in the bioretention features. Can you find plant species that you think typically grow in wet areas? Compare riparian (on or near river banks) vs upland transition zones.
- ❑ Research the plants on your site to identify the species, and learn about what plants were chosen and why. Each species has a different function.
- ❑ Look for evidence of biodiversity in different areas of the schoolyard. Compare number of species in grassy areas to bioretention features.

Infiltration Practices

- ❑ Underground so hard to see, unless you can open manholes or observation wells/clean outs.
- ❑ Open observation well and look down inside. If there is water in the chambers, you should be able to see it. You can use measuring sticks and fishing bobbers to keep track of the water level to see how quickly it fills after a rain event and how long it takes for water to infiltrate (dry out).

Permeable Pavement

- ❑ Look for evidence of ponding water on street or in parking lot (impervious surfaces) compared to pervious surfaces (permeable pavers, bioretention features) used in GI.
- ❑ Poor water on different surfaces and see what happens.

Rain Gauge

- ❑ Collect and record data over time to compare volume of rainfall from: rain gauge in the schoolyard, online real time data, and weather reports.

Tree Pits

- ❑ Analyze how much water trees uptake when they're leafed out to compared to when they're bare.
- ❑ Measure canopy density of different tree species and make correlations with canopy interception rates and shade.