

Stormwater and Green Infrastructure in Boston Public Schools

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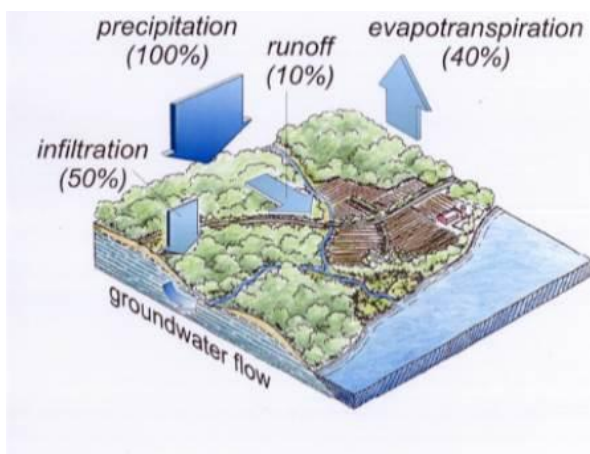
Background on Stormwater and Green Infrastructure

THE FATE OF PRECIPITATION IN THE URBAN LANDSCAPE

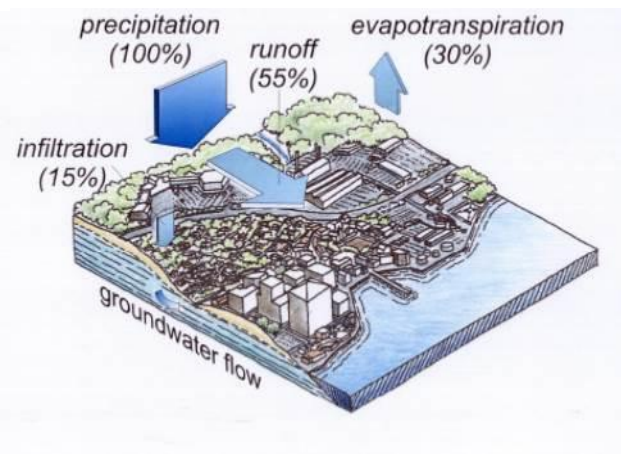
Water exists in the environment as vapor in clouds; as a liquid in precipitation, oceans, rivers and lakes, and groundwater; and as a solid in ice. **Precipitation** is the process by which water is released from clouds to the earth. Much of the rain and snow that falls on a natural, pervious landscape is recycled through infiltration and evapotranspiration. **Infiltration** is the process of rainfall soaking into the ground. Groundwater can feed rivers and lakes through subsurface flows or fill underground aquifers used for drinking water. Plants also take up a significant amount of rainfall, much of which is released back into the atmosphere through **evapotranspiration**. A small portion of precipitation is converted to surface runoff which drains directly to surface waters.

In the altered urban landscape, precipitation falls more frequently impervious surfaces such as pavement, which reduces the amount of infiltration that can occur. Also, there is less vegetation to take up precipitation and promote evapotranspiration. In an urban setting, a larger percentage of the precipitation becomes **stormwater runoff** that flows across the land surface to rivers, lakes, and oceans. Some surface water is recycled back into the atmosphere through evaporation. This alteration to the water cycle in the urban landscape leads to a number of problems, including increased flooding, water pollution, and loss of groundwater reserves.

The Fate of Precipitation in Natural Systems



The Fate of Precipitation in Altered, Urban Systems



Urbanization causes changes to the natural water cycle, specifically increases in the proportion of precipitation becoming surface runoff. Surface runoff leads to flooding, water pollution, and impacts to aquatic ecosystems.

THE PROBLEM WITH STORMWATER RUNOFF

Stormwater runoff is rainwater or snowmelt that flows over the land surface. In cities, most stormwater flows over pavement into a piped storm drain system that carries it into a body of water, such as a lake, river, or ocean. Although rain is basically clean as it falls from the sky, it can pick up anything from our streets, rooftops, and yards. Everything from oil, gasoline, pet waste, soap, fertilizers, pesticides, bacteria, and trash can be carried into storm drains and underground pipes that empty into local waterways like the Charles River. The growth of cities has had a major impact on the pollution of rivers, lakes, and oceans. Conversion of vegetated landscapes into buildings, roads, parking lots and other impervious surfaces has reduced the amount of rainfall that is taken up by plants (evapotranspiration) or absorbed into the ground (infiltration). These changes to the natural hydrologic cycle result a greater proportion of rainfall becoming surface runoff, which can lead to flooding, water quality impacts such as algal blooms, changes in river morphology, impacts to groundwater, as well as harm to aquatic ecosystems and wildlife habitats.

Because stormwater runoff in urban areas can cause flooding, engineers built drainage systems to get water quickly off of roads, sidewalks, and parking lots. The drainage network consists primarily of curbs, drain inlets, and underground pipes that carry flows away from buildings and roads to outfalls that discharge directly into waterways. This system of catch basins and pipes is called traditional or **gray infrastructure**. While gray infrastructure moves water away from roads and buildings quickly, it also takes away water that could be taken up by plants or infiltrated into the ground. Much of the time, pollutants in surface runoff do not get removed before dumping into the nearest waterway.



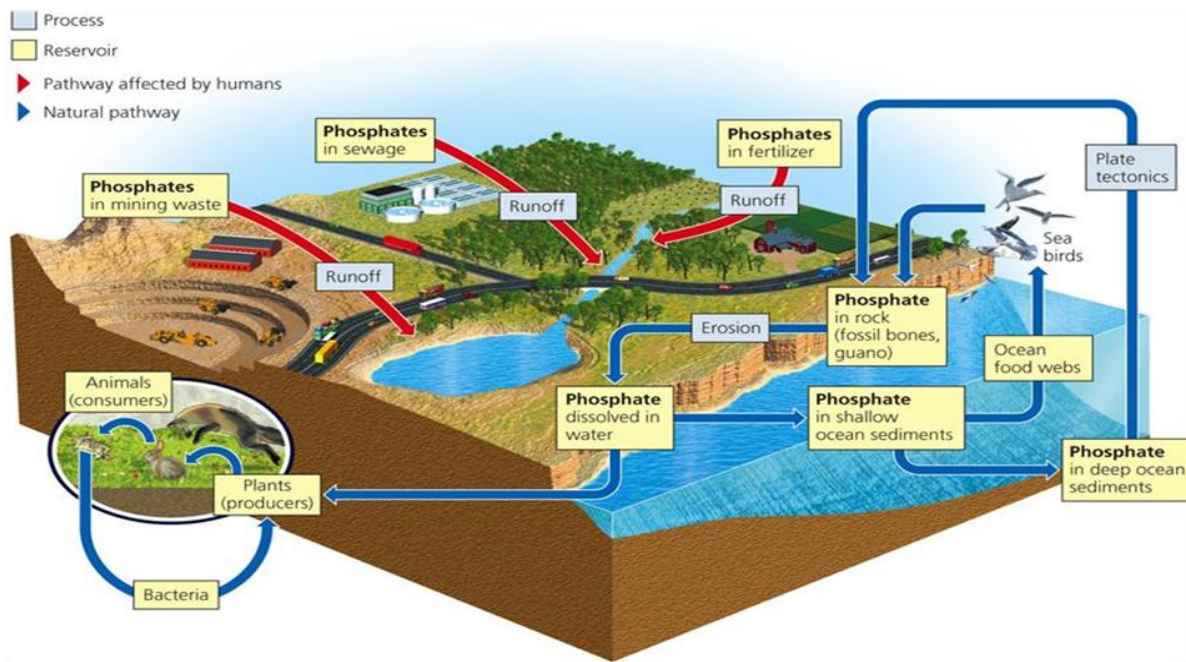
Traditional drainage management includes pipes and other grey infrastructure to get water away from buildings and roads. This leads to discharges of polluted water directly to oceans, lakes, and streams.

A BIT ABOUT PHOSPHORUS

One of the problems that stormwater contributes to is phosphorus pollution in major waterways. **Phosphorus** is a naturally-occurring chemical element that is abundant in sedimentary rock and is used by all living things to help them grow. It is normally released into the environment slowly by physical and chemical weathering or erosion. In urban environments, however, phosphorus derived from detergents, sewage, fertilizers, and oil/gas products can overload waterways. For example, when vehicles burn gasoline, they release phosphorus pollution into the air that settles onto impervious surfaces. Phosphorus pollution settling on impervious surfaces is washed off when it rains, and is eventually carried through stormwater runoff into lakes and rivers like the Charles River. An overabundance of phosphorus can trigger cyanobacteria growth, algal blooms, and hypoxia (oxygen depletion), which can be detrimental to the health of humans and animals. Some cyanobacteria can produce toxins that can be harmful to people and animals who touch or drink the water. Stormwater runoff that enters our waterways before it is cleaned can also make its way into drinking water sources, swimming areas, and fishing areas, polluting them with pathogens and other bacteria and making them unsafe for humans and wildlife to use.



Excess phosphorus in a waterbody can lead to algal blooms, oxygen depletion, and fish kills.



Phosphorus cycle (Living in the Environment 17th ed., Miller, 2012)

MORE ON THE CHARLES RIVER

Most of the stormwater in Boston and the towns to the north and west of Boston flows into the Charles River. The Charles River runs for 80 miles from Echo Lake in Hopkinton to Boston Harbor. Historically, the river has been used as a source of power for mills as well as a way to dispose of waste products such as chemical dyes and sewage. Groups such as the Charles River Watershed Association and laws like the Clean Water Act have helped protect the Charles River from these threats. Although the water isn't clean enough to drink, fish, or swim in, it is safe for boating most of the time. Today, there are restrictions on the amount of phosphorus that can be discharged into the river. The Boston Water and Sewer Commission is tasked with reducing phosphorus loads from the wastewater and stormwater drainage system in the City. Some sewage still gets into the river during heavy rains a lot, because there are a few places in Boston that still have a combined sewage and stormwater system that can overflow to the Charles. Most of the drainage system in the City has been separated and the Commission, along with other City agencies, is investing in green infrastructure to better manage stormwater contributions.

The U.S. Environmental Protection Agency has given the Charles River a water quality report card every year since 1995. The first grade was a D, which meant that the river was not safe for boating most of the time. Recently, the river has been getting B's, B+'s, and even an A- for its low levels of bacteria pollution, making phosphorus pollution from stormwater runoff one of the biggest threats the Charles River faces.

HOW CAN WE REDUCE STORMWATER

POLLUTION? What if urban stormwater was managed in a way that better mimicked the natural cycle of water? What if we could bring vegetation back to our cities to promote more evapotranspiration? Could we create more opportunities to infiltrate stormwater and reduce the amount of polluted surface runoff going to our waterways? We can and we are through the use of Green Infrastructure (GI). Unlike the conventional grey infrastructure approach to stormwater management, GI relies less on pipes and more on plants, soil, and other engineered materials to reduce runoff volumes and filter out pollutants. Bioretention, pervious pavements, infiltration practices, and rainwater reuse/harvesting are different types of GI being used throughout the City to re-establish the balance of the natural water cycle. GI is incorporated into parks and open space, roadways, parking lots, schools, and backyards.

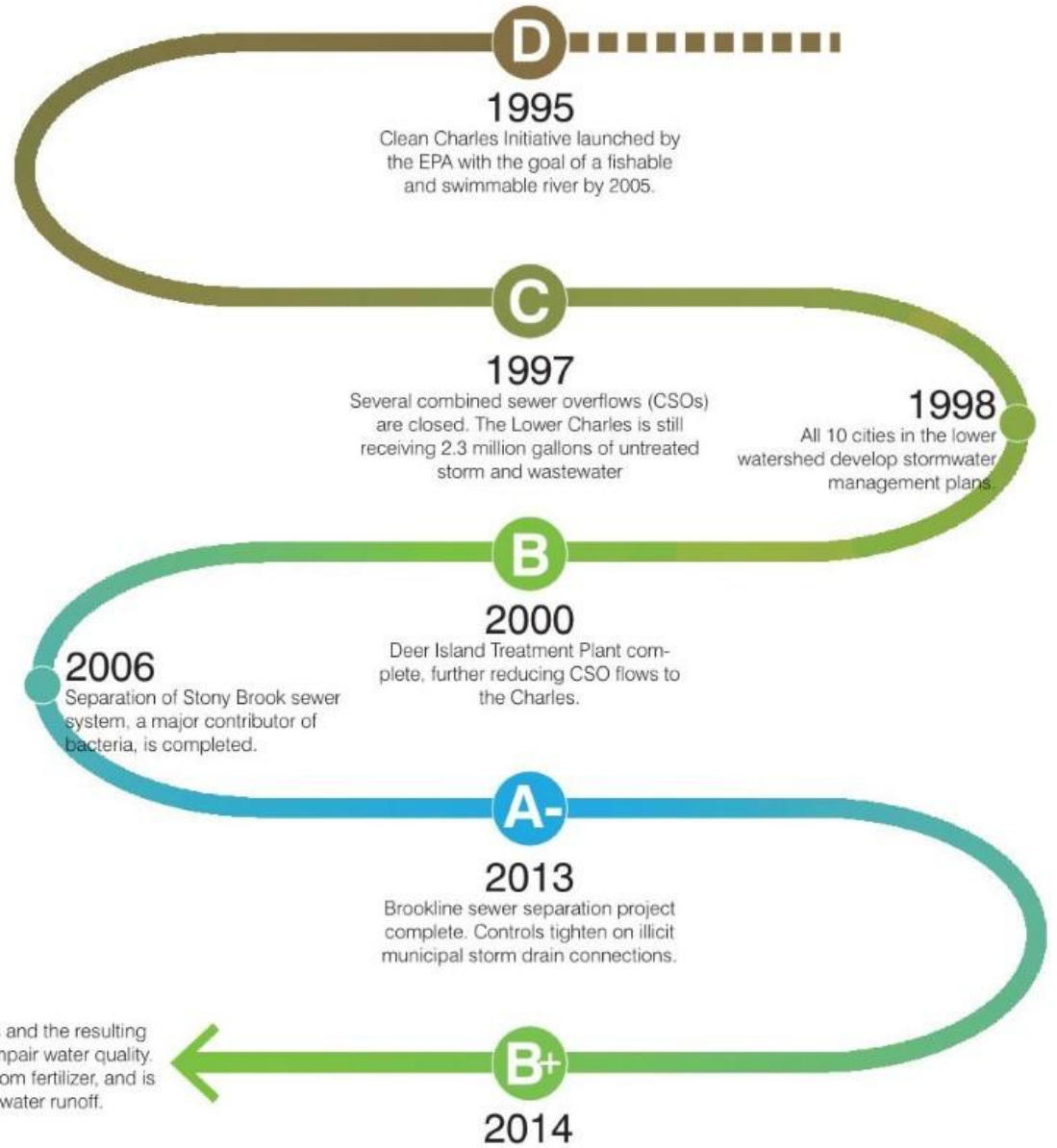
Other things we can do to help the Charles River

- Clean-up and properly dispose of pet waste;
- Disconnect runoff from your home using rain barrels, rain gardens, and other practices;
- Use phosphorus-free detergents;
- Don't wash or repair your car on the street where stormwater runoff can pick up soaps and automotive fluids;
- Use compost instead of fertilizer;
- Plant trees that can intercept rainfall;
- Help keep debris and litter out of storm drains; and
- Educate others about the impact of stormwater on the Charles River.

Charles River Water Quality

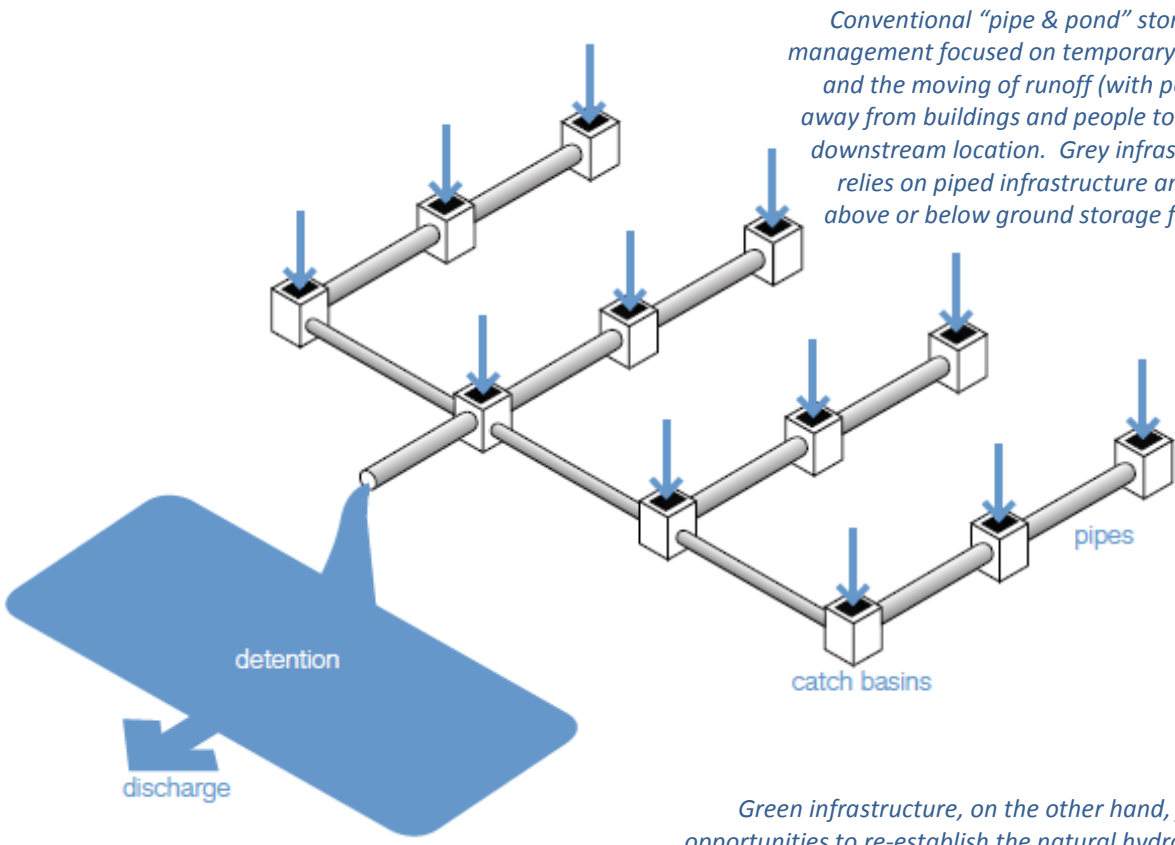
EPA Report Card Grades :: 1995 - Present

Sources: Charles River Watershed Association & US EPA

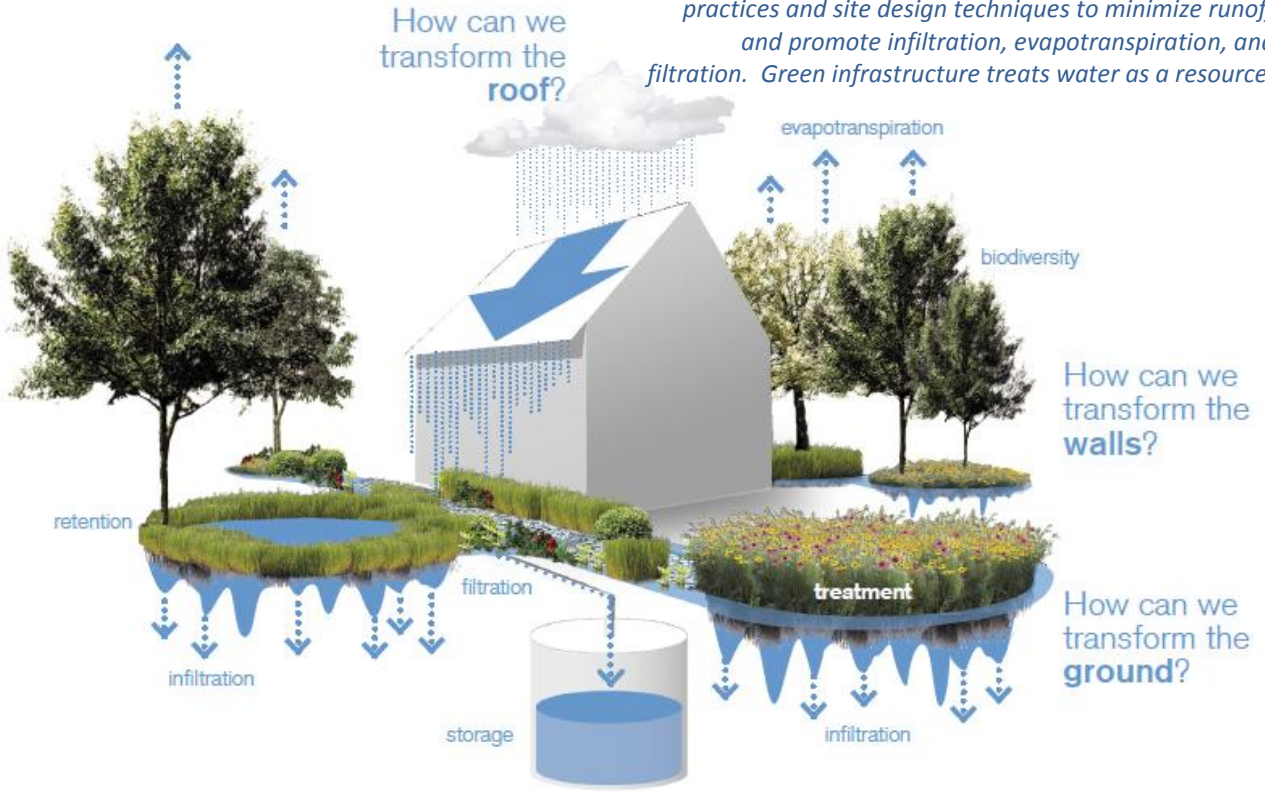


Timeline of water quality scores in the Charles River.

Graphic Credit: Offshoots, Inc.



Green infrastructure, on the other hand, focuses on opportunities to re-establish the natural hydrology of an urban area. It relies on a distributed network of smaller practices and site design techniques to minimize runoff and promote infiltration, evapotranspiration, and filtration. Green infrastructure treats water as a resource.



Glossary

Best management practice (BMP): Feature or practice used to prevent or control pollution. May include prohibiting certain activities or following maintenance procedures.

Bioretention: A vegetated depression that allows for infiltration, evapotranspiration, and cleaning of stormwater runoff using plants and an engineered soil media. Generally planted with perennials and grasses that can tolerate both wet and dry conditions. Name commonly used as a category of green infrastructure that filters runoff using plants including rain gardens, bioswales, planters, and tree filters.

Bioswale: A linear bioretention facility that cleans stormwater runoff while conveying flows from one location to another.

Catch basin: An open or grated storm drain inlet on the ground, pavement, or curb where runoff is directed into the drainage system. Typically designed with grates, sumps, and or hoods to trap trash, debris, sediment, and oils being carried by stormwater. Also referred to as drain inlets.

Catchment: small watershed area, usually at the individual site level.

Combined sewer system: A system in which residential and commercial wastewater (from sinks, bathtubs, toilets, etc.), and stormwater runoff are collected and transported in the same pipe system. During dry weather, wastewater is carried to a wastewater treatment plant. During periods of heavy rain, however, the combined sewer system can reach capacity as stormwater flows into the pipes. When the pipes in a combined sewer system become overloaded, the excess stormwater and wastewater overflows into local rivers and lakes, this is called a combined sewer overflow (CSO). Combined sewer systems were the prevalent municipal sewer system prior to the 20th century and are still operating in older cities like New York, Boston, and Cambridge. These cities have been actively separating their sewer systems or enhancing capacity, in fact much of Boston has been separated.

Cistern: Any type of barrel, tank, or other container that stores rainwater for reuse.

Curb inlet: An opening in the curb that allows runoff to enter into a stormwater practice.

Downspout: A vertical pipe that carries water from the roof of a building to the ground.

Engineered soil: A composition of soil that does not naturally occur on site, but rather is mixed and installed for a particular purpose. For example, soils for bioretention facilities are a mostly sand with a specific amount of clay, silt, and organic matter.

Evaporation: the process of liquid water ponded on a surface converting into water vapor. If done through a plant, it is considered evapotranspiration.

Green infrastructure: The use of soil, vegetation, and other materials to naturally manage stormwater runoff as a means of creating healthier urban and suburban environments. Green infrastructure can be implemented on a large scale, as in a large network of preserved or created natural areas that provide wildlife habitat, protection against floods, and improve air and water quality. On a small scale, the use of green infrastructure techniques like rain gardens, bioswales, rain barrels, permeable pavement mimics nature by capturing water and carrying it slowly through cities.

Grey infrastructure: Used to characterize conventional stormwater management that relies on pipes, large above ground (ponds), or below ground storage (tunnels and tanks) for getting runoff away from buildings and people and discharging at a single outfall location. Also used in reference to underground structures designed to expanding storage capacity of a combined sewer system to help reduce CSOs.

Impervious cover: Hard surfaces such as pavement, sidewalks, buildings, or parking lots, where water cannot flow down into the soil below.

Infiltration: The process through which water enters soils below the ground's surface.

Infiltration Practices: Group of engineered green infrastructure practices designed to put rainfall into the ground including underground chambers, infiltration trenches, dry wells, etc.

Native soil: The existing soil in a particular geographic area.

Nutrient pollution: This occurs when an excess of nutrients, namely nitrogen and phosphorus, are present in the air or flow as runoff from asphalt and other impervious surfaces into rivers and lakes, usually after heavy rains. This excess of nutrients feeds the growth of algae and potentially harmful bacteria. If a large growth of algae (an "algal bloom") occurs, it can negatively impact the habitat by blocking sunlight from reaching plants and performing photosynthesis, thus decreasing the availability of oxygen that aquatic animals need to survive.

Overflow structure: A vertical pipe or specified outlet that allows excess water from a stormwater practice to discharge back into the drainage network or receiving water.

Observation well: a small diameter, capped pipe at the surface that when opened, allows for observation of water level in an underground pipe network, such as an underdrain or infiltration practice.

Perforated: Pierced with holes that allow liquids or gases to pass through. Typically used to describe underdrain pipes.

Permeable pavement/paver: Surface such as asphalt, concrete, or paver block that is designed to allow water to pass through it.

Pervious: Allowing water to pass through it. Same as permeable and porous.

Phytoremediation: Using plants to remove pollutants from soil or water.

Plant uptake: The process of plants absorbing water and nutrients in order to grow.

Rain garden: A landscaped depression designed to collect and filter rainwater running off of driveways, rooftops, or streets. A type of bioretention facility, rain gardens are less engineered. Rain gardens can take many shapes and sizes. Plants can be neatly manicured or more “wild” and “natural” looking.

Rainwater Harvesting: Use of cisterns or other storage tank to collect rain water for temporary storage and subsequent reuse for primarily non-potable uses (e.g., irrigation, flushing toilets).

Sanitary sewer: A series of pipes that collects and transports only wastewater (sewage) and does not include stormwater.

Sedimentation: Suspended sediment particles that have eroded from the surrounding landscape settle out in water as the water sits in place.

Storm drain system: A pipe system designed to collect and move stormwater only, and direct it into a nearby lake or river. Unlike a combined sewer system, areas with separated storm drain systems have accompanying separated sanitary sewer systems to carry household and industrial wastewater.

Storm duration: The length of a storm (in hours).

Storm intensity: The rate of rainfall (in inches per hour).

Storm sewer: A series of pipes that collects and transports only stormwater.

Stormwater runoff: Rain and snowmelt flowing over the land surface. Runoff picks up pollution such as excess fertilizers, bacteria and animal waste, road salt, and excess sediment and soil. This mixture often flows into storm drains, where it eventually flows into a nearby lake or river.

Structural soil: Soil that can be compacted as needed to support a paved surface while also supporting the growth of tree and plant roots.

Surface water(body): Water that is contained by stormwater ponds, rivers, lakes, estuaries, bays, dams, wetlands, oceans.

Transpiration: The process of water being carried from the roots of a plant toward small pores on the underside of its leaves and released to the atmosphere as water vapor.

Underdrain: a perforated pipe installed at the bottom of a stormwater practice that can drain excess water if infiltration is slow.

Urbanization: land development that results in conversion of natural or rural areas to residential, commercial, and industrial uses, etc. Generally results in loss of vegetation and increased impervious cover.

Urban infrastructure: A structure or system that supports the urban environment. Examples: Roads, bridges, buildings, water distribution, sanitary and storm sewers, stormwater pond, electricity transmission lines, cable and internet.

Wastewater: Water that has been used by people for washing, flushing, manufacturing etc. Sewage is a type of wastewater.

Watershed: An area of land that drains to a specific point, such as a river, lake, ocean, storm drain inlet or outfall. Catchments, subwatersheds, and basins all refer to different watershed scales.

Directions for printing a site map of your schoolyard

You have a options for printing a site map of your schoolyard. Print your school site maps before beginning the unit, or engage students in printing them as part of the unit. Detailed steps are provided below.

1. Boston Water & Sewer Commission’s Education page is the simplest.
2. Google Earth gives you the added ability to take measurements using lines and polygons drawn on your map.
3. MassGIS Online provides aerial imagery, parcel, topography, and soils information. Streams, wetlands, watersheds, and other information may be of interest to students.

1. Boston Water & Sewer Commission

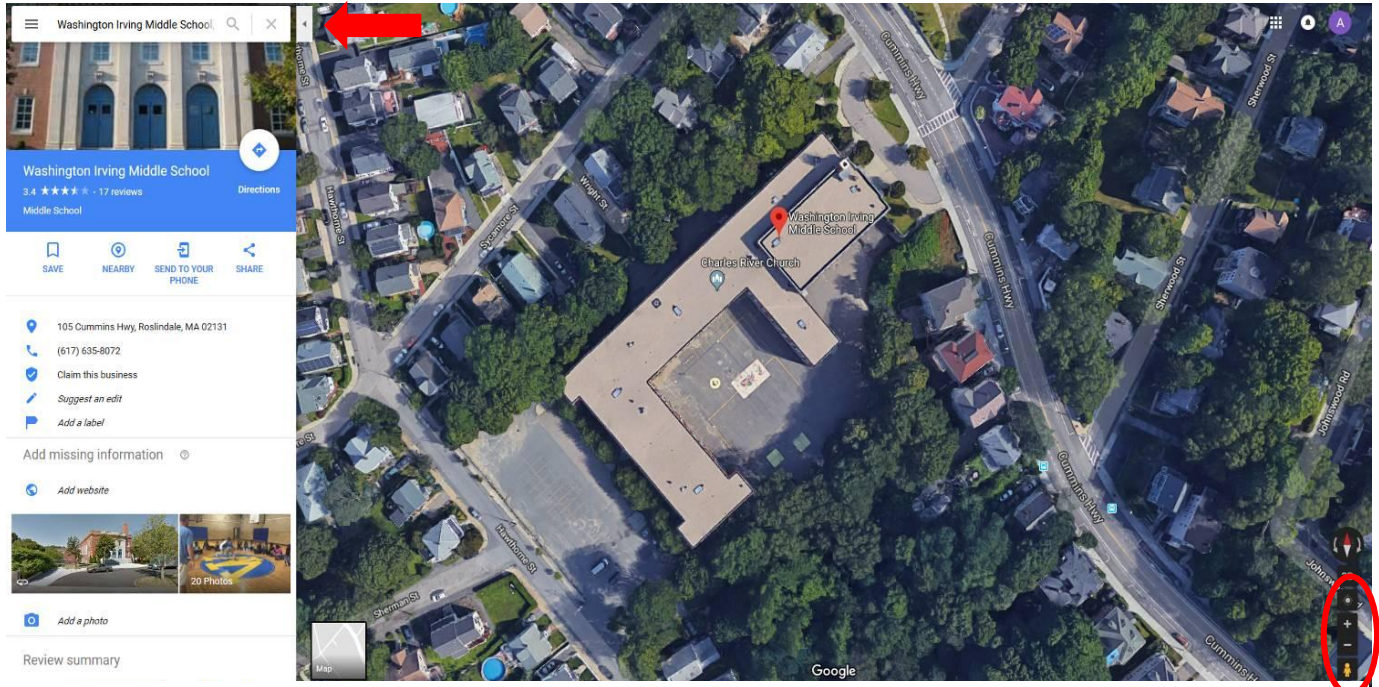
Go to BWSC stormwater website where large PDF maps of the city will be posted for your use. These maps will include aerial images, property boundaries, topography, and soils. You will need to identify the Map Tile your school is located in and then download that tile. From there you can locate/zoom to your school site, take a screen capture and print. More instructions will be available on this site http://www.bwsc.org/GI_LID.asp.

2. Google Earth

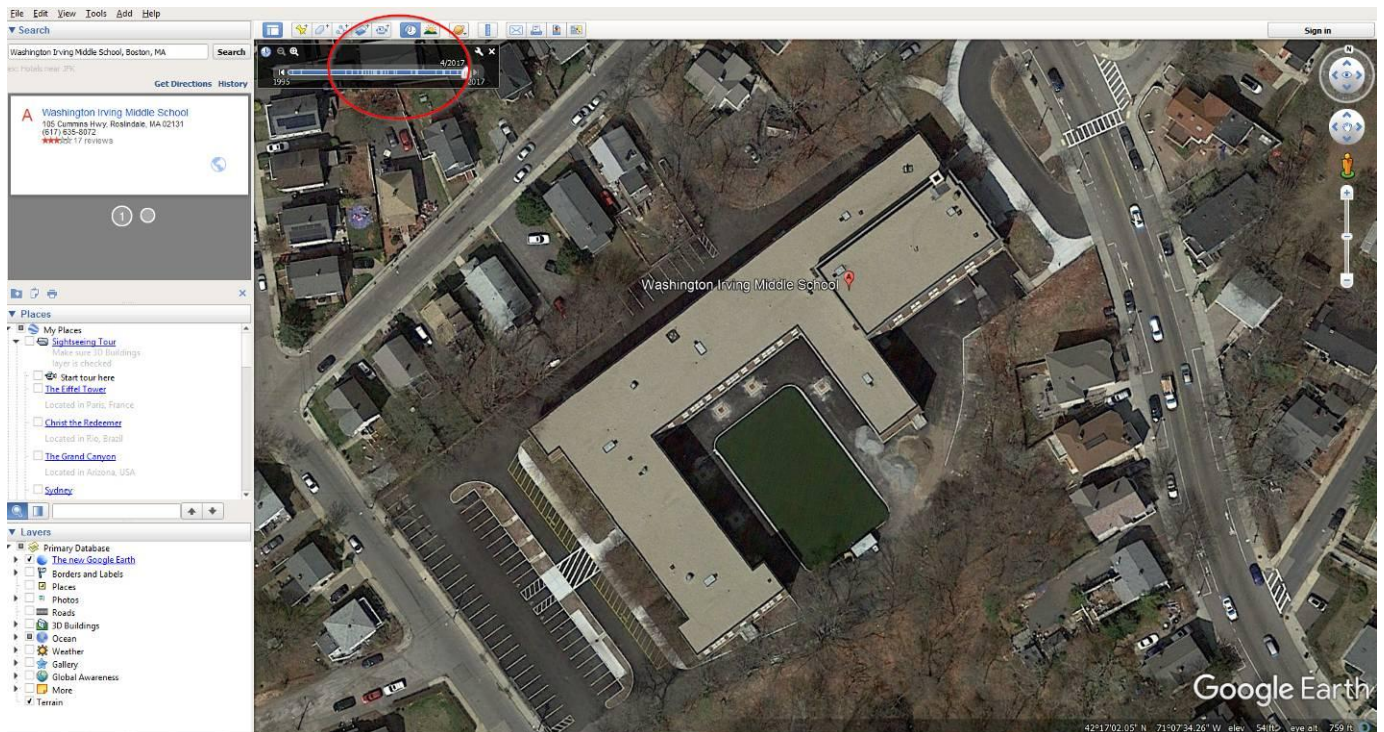
Use google maps (or google earth) to find your school. Google Earth pro version offers you the ability to take measurements of lines and polygons drawn on your map, which would be helpful in calculating the size of drainage areas and land cover types. Go to Google Maps: <https://www.google.com/maps>

Step 1. Type the name or address of your school into the search bar in the upper left-hand corner of the window. Be sure to include the city and zip code.

Step 2. Adjust the zoom level to see the entire school property using the scroll button on your mouse or the plus and minus symbols in the lower right-hand corner of the window. If necessary, use the arrow to the right of the address search bar to collapse the search panel so that the entire map is visible. Note that if you use Google Earth, you often have more aerial option years to choose from.

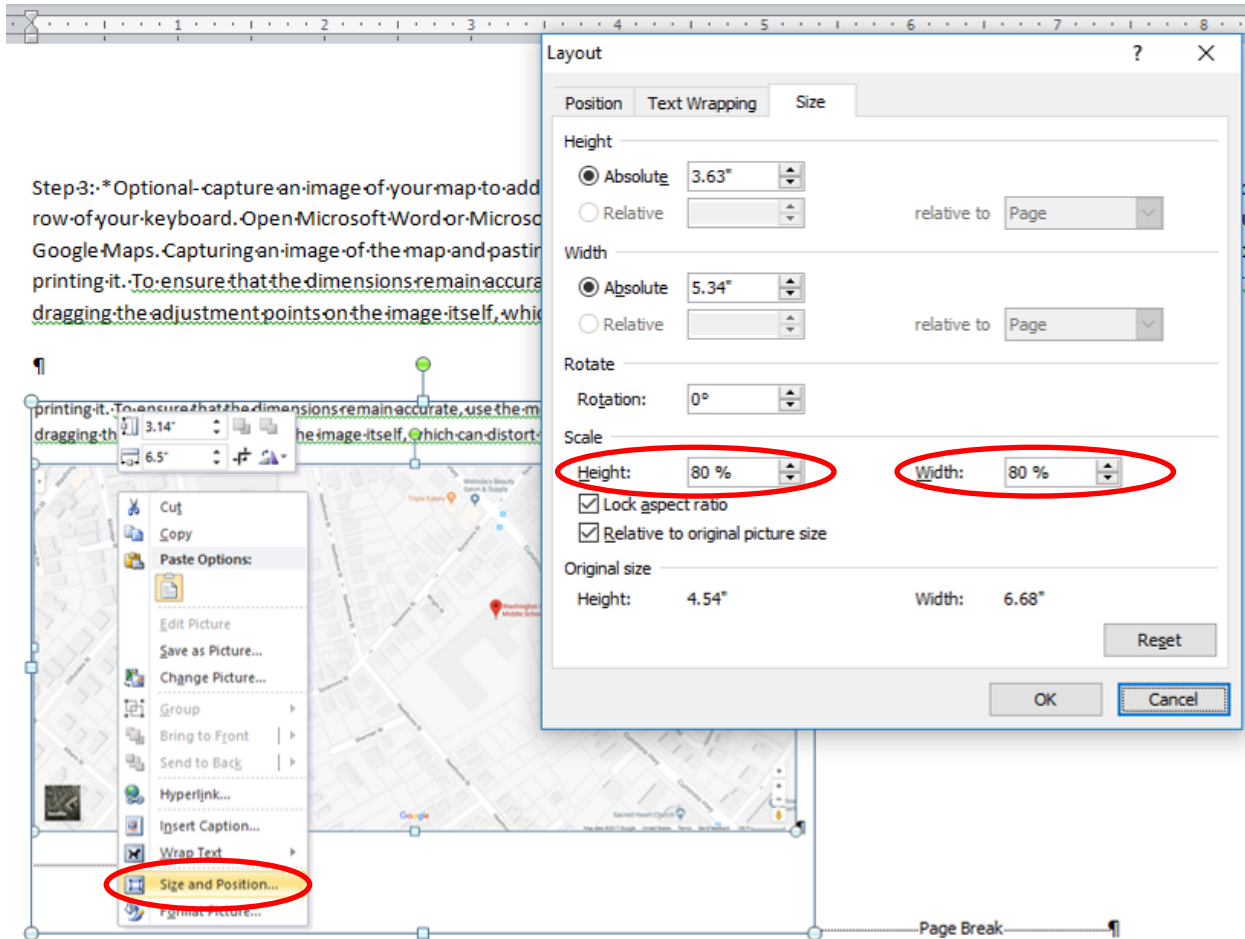


This screen shot from Google maps shows an aerial taken prior to GI construction in 2017.

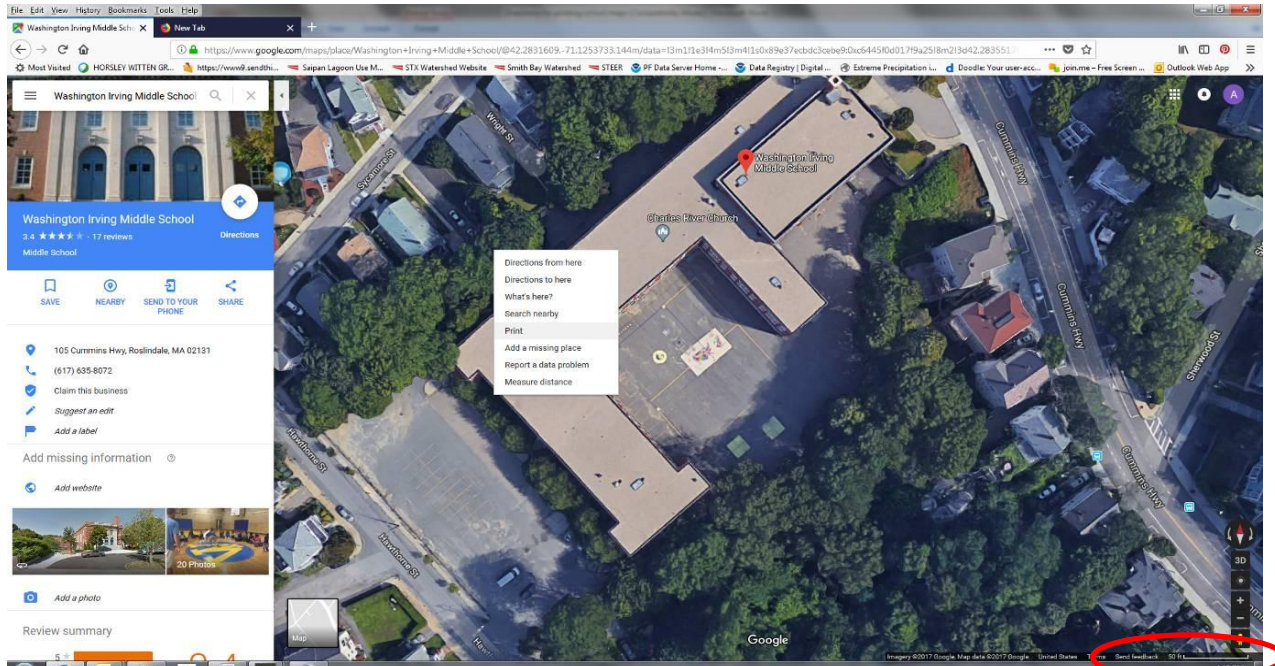


This screen shot from Google Earth shows the most recent aerial imagery that was taken after GI construction in 2017. You can select the "history" button and select past aerials as well (red circle).

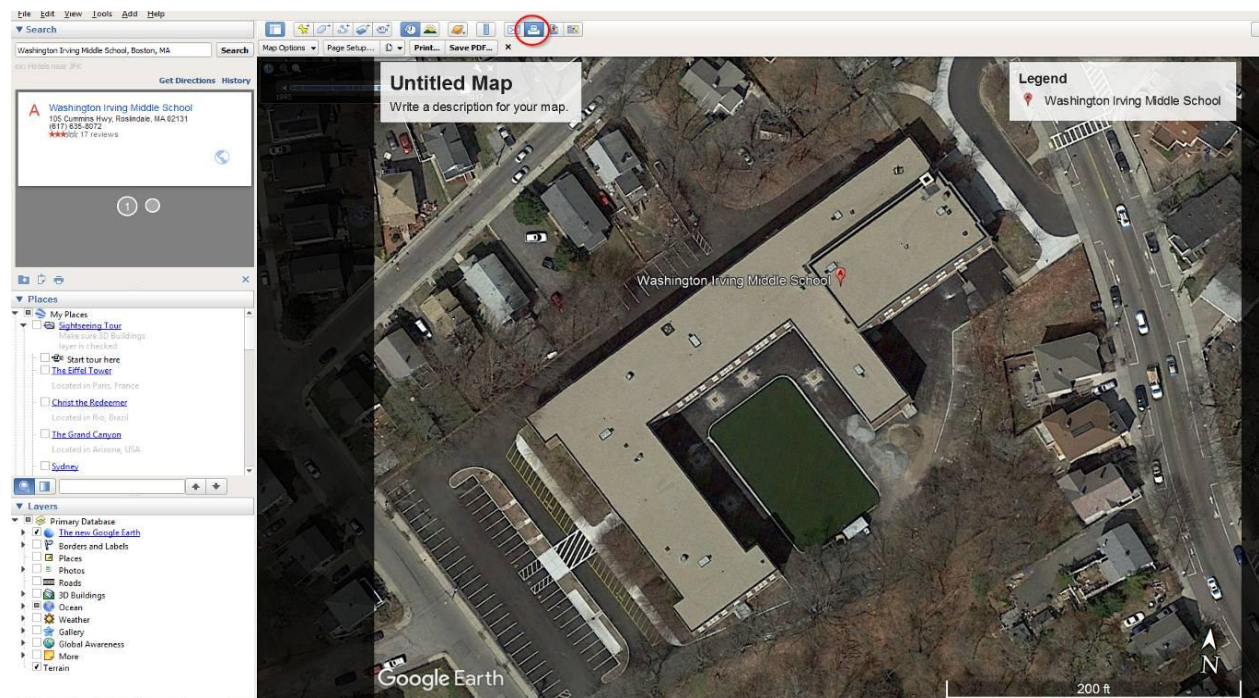
Step 3. Optional- capture an image of your map to add to a worksheet or Powerpoint presentation by pressing the Print Screen key on the top row of your keyboard. Open Microsoft Word or Microsoft Powerpoint and use the “Paste” function to insert the screen capture you just made in Google Maps. Be sure to include the scale. Capturing an image of the map and pasting it in a Word document or a PowerPoint slide allows you to crop the image using the “Format” menu in the toolbar before printing it. To ensure that the dimensions remain accurate, use the menu that appears when you right-click on the image to resize it rather than dragging the adjustment points on the image itself, which can distort the dimensions of the features on the map.



Step 4: Print the map for students to use from Google Maps by selecting, “Print” from the menu that appears when you right-click on the map. Your students will be able to use the scale bar in the bottom right corner of the image to measure lengths and distances on the map.

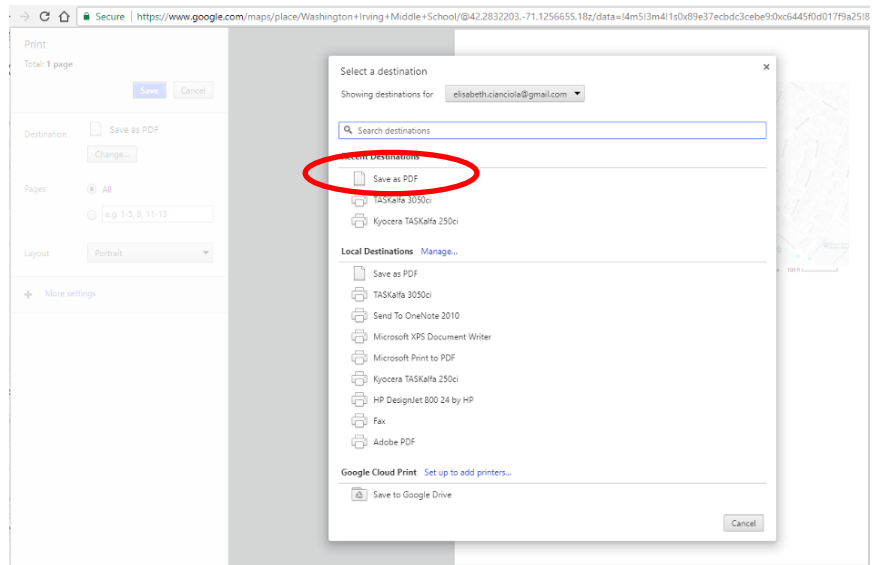


Printing from Google Earth, be sure to print the scale.

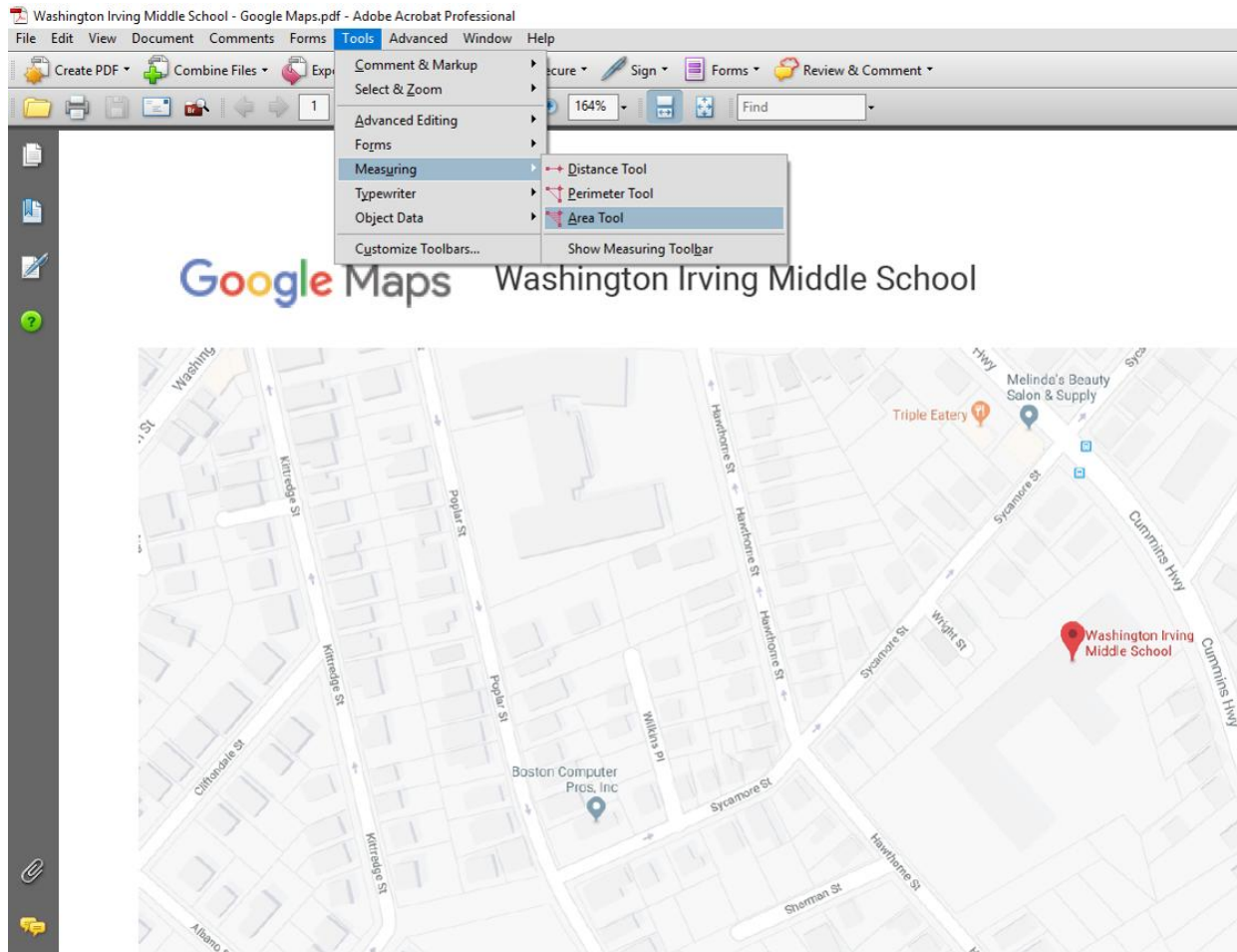


Print from Google Earth by clicking on the printer icon in menu bar.

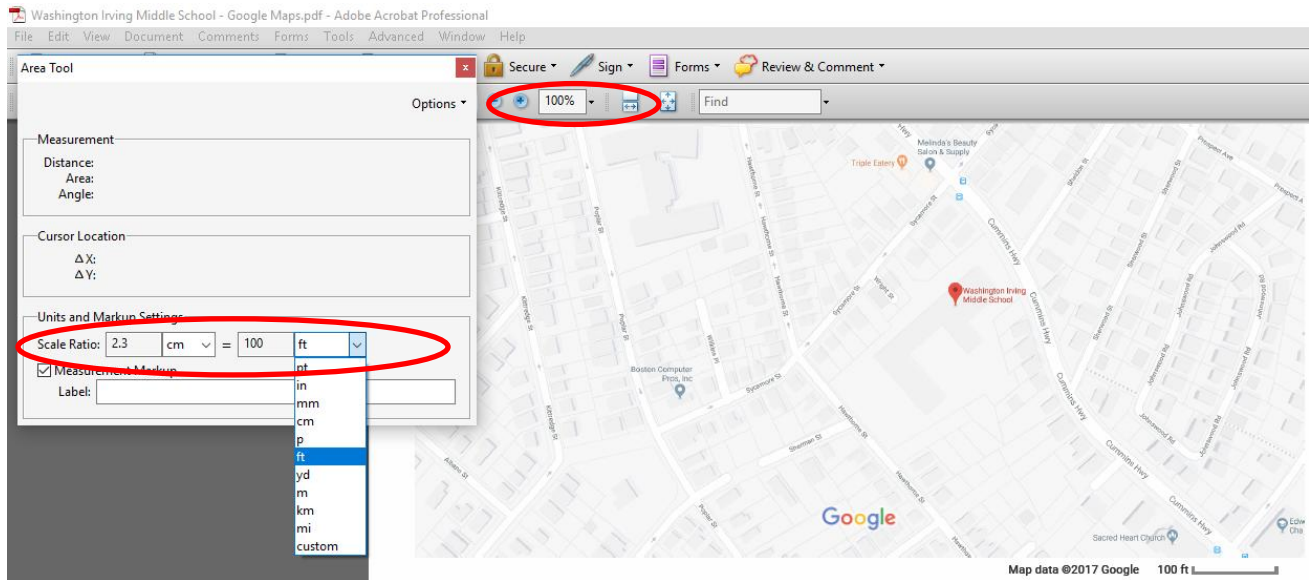
Step 5. Save your map as a PDF file. To do this from Google Maps, right-click on the map and select “Print” from the menu that appears and click the “Print” button in the upper right-hand corner of the window, as you did in Step 4. Instead of using your printer, choose “Save as PDF” in the subsequent menu. You will then be able to choose the location where you would like to save the map and change the map title.



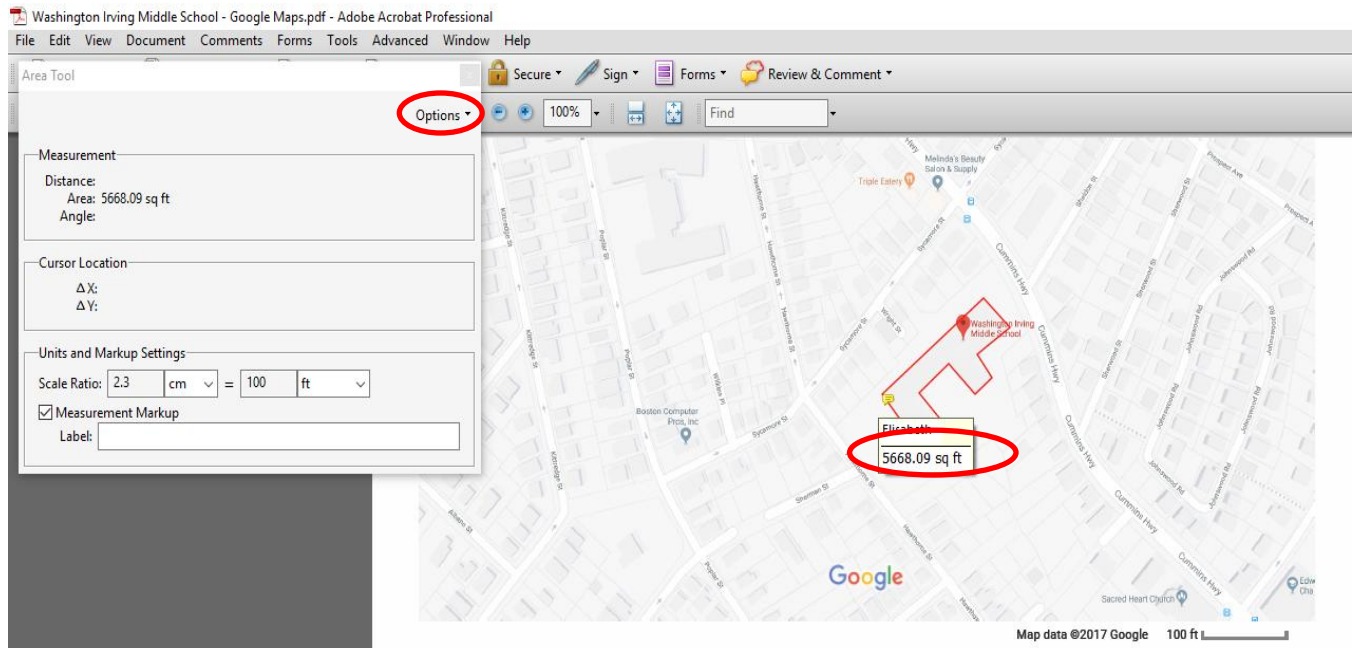
Step 6. To have your students use Adobe software to measure areas, have them navigate to the file location of your map and open it using Adobe Acrobat Professional. In the toolbar, open the “Tools” menu and select “Measuring,” then “Area Tool.”



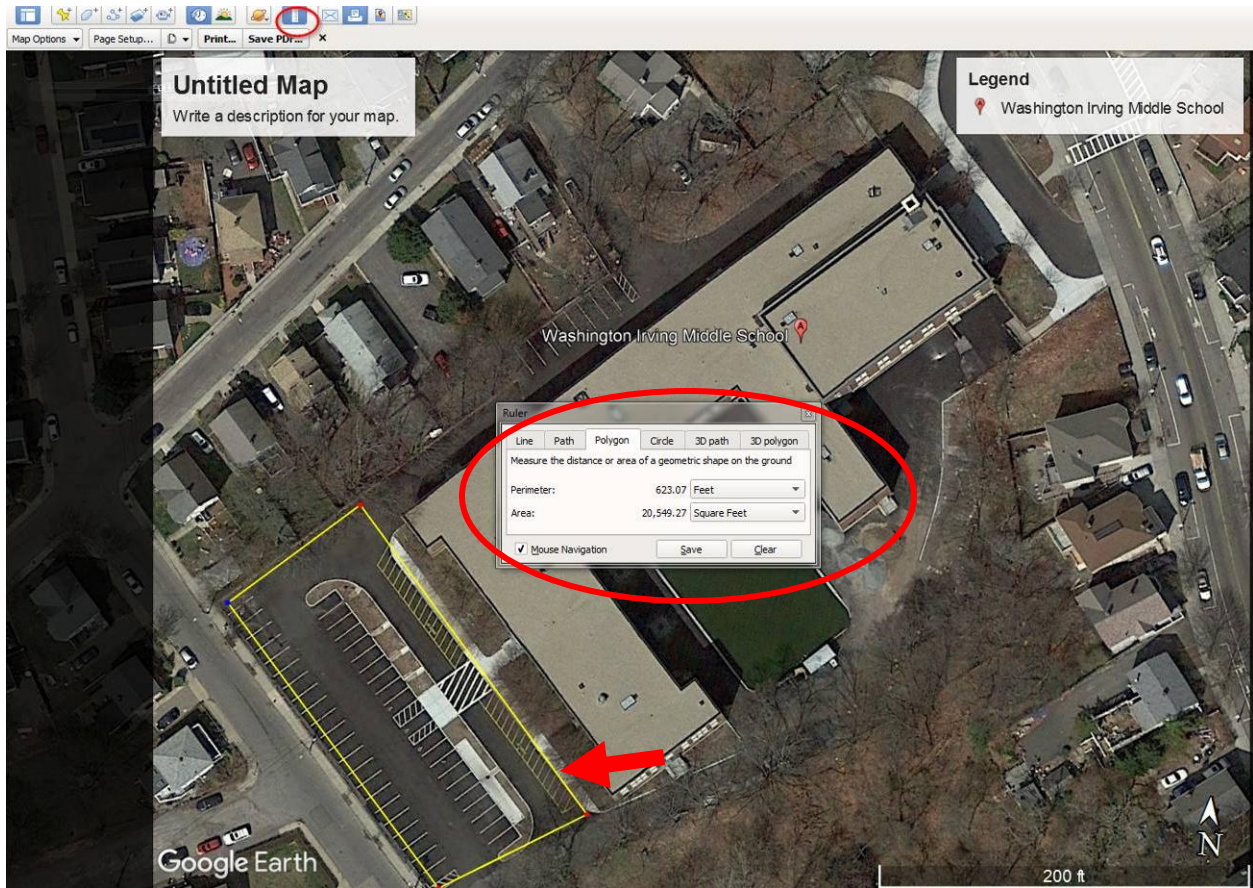
Step 7. When the Area Tool window appears, have students measure the length of the scale bar on the map (at 100% zoom) and enter the measurements in the Scale Ratio.



Step 8. Use the plus sign cursor that appears to trace around a straight-edged feature on the map, such as a school building or parking lot. You will need to click once in order to trace around each corner and click twice in order to close the polygon. Adobe will then create an annotation that calculates the area of the polygon. You can export the annotations to Microsoft Excel using the Options menu in the Area Tool window for ease of summing areas of various shapes.



Note: If you are using Google Earth, you can draw polygons and make measurements without saving as a PDF. Click on the measuring tool in the toolbar, select line or polygon in the ruler menu, and use the cursor to draw your area to be measured. You can change the unit of measurement in the ruler menu.

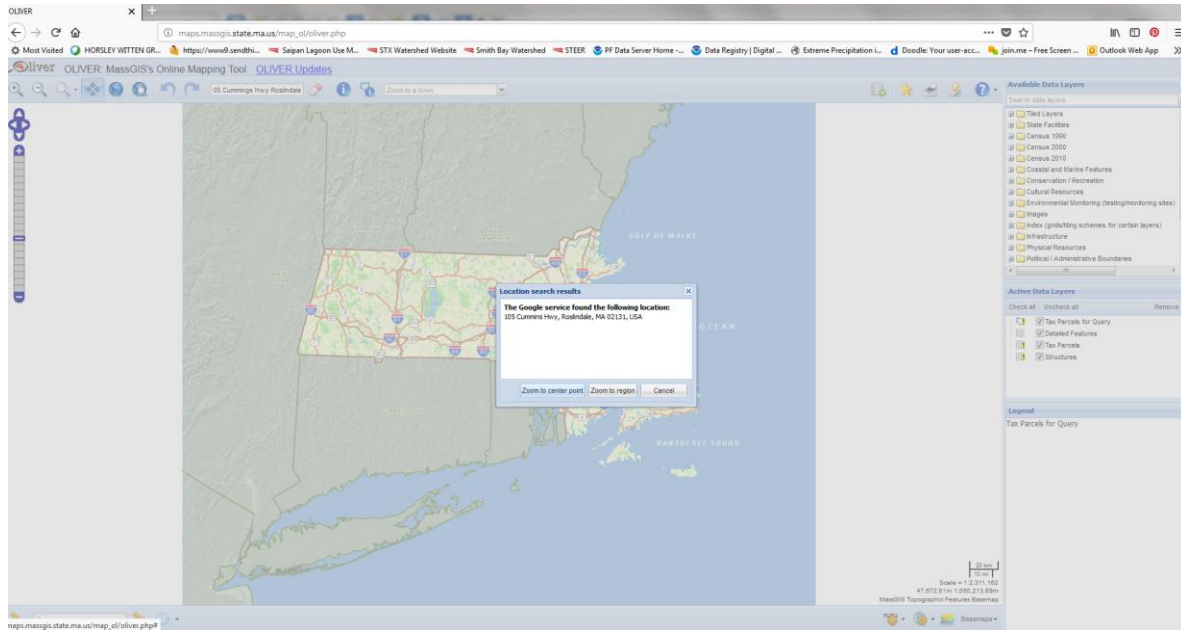


3. MassGIS Online

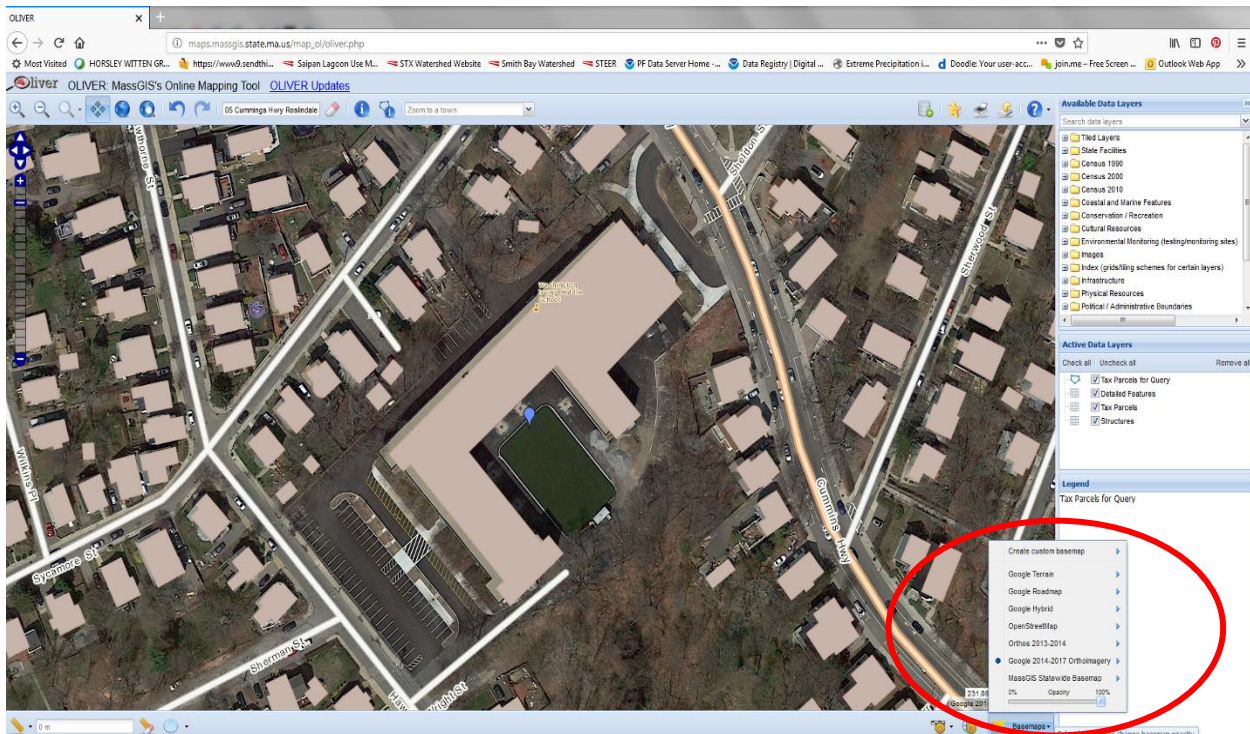
You can go to MassGIS Online, which provides access to many different types of mapping information that can be further explored by students. At a minimum, you will want to use the aerial imagery, parcel, topography, and soils information. Streams, wetlands, watersheds, and other information may be of interest depending on where your school is located.

Step 1. Go to <https://www.mass.gov/get-a-map>, click on the Open OLIVER interactive tool (or just go to http://maps.massgis.state.ma.us/map_ol/oliver.php).

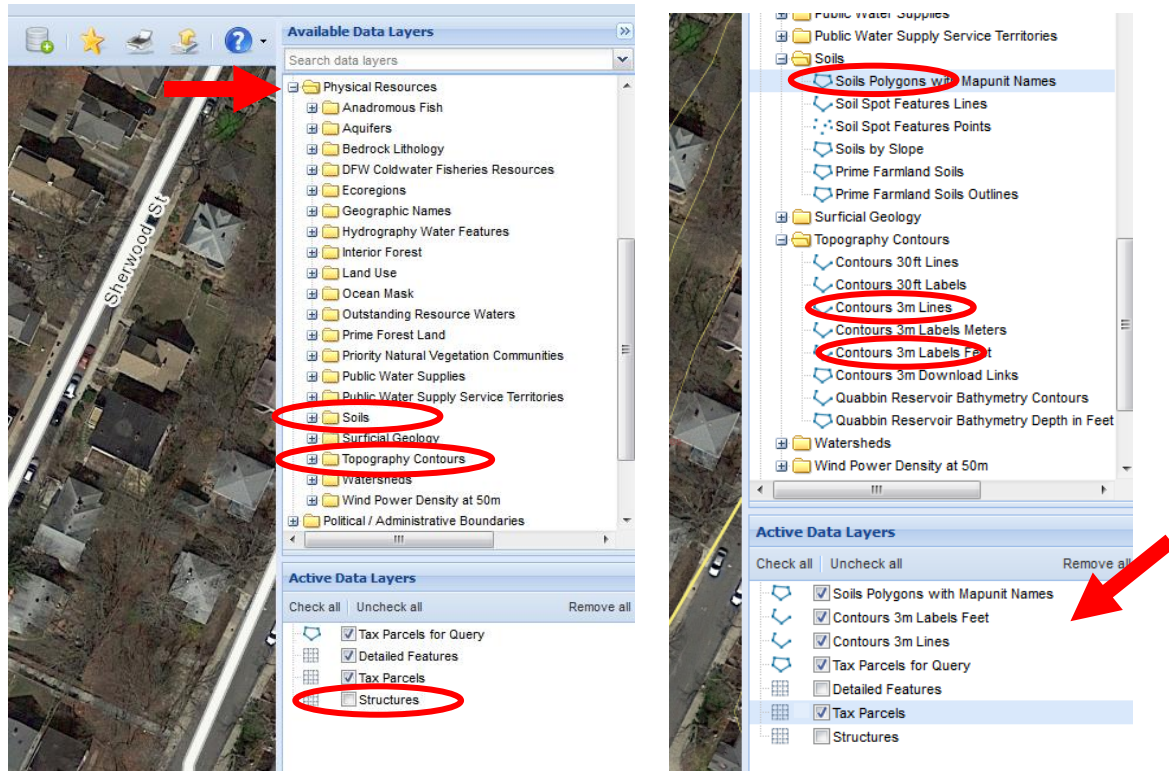
Step 2. Enter the address and town of the school. And zoom to that location



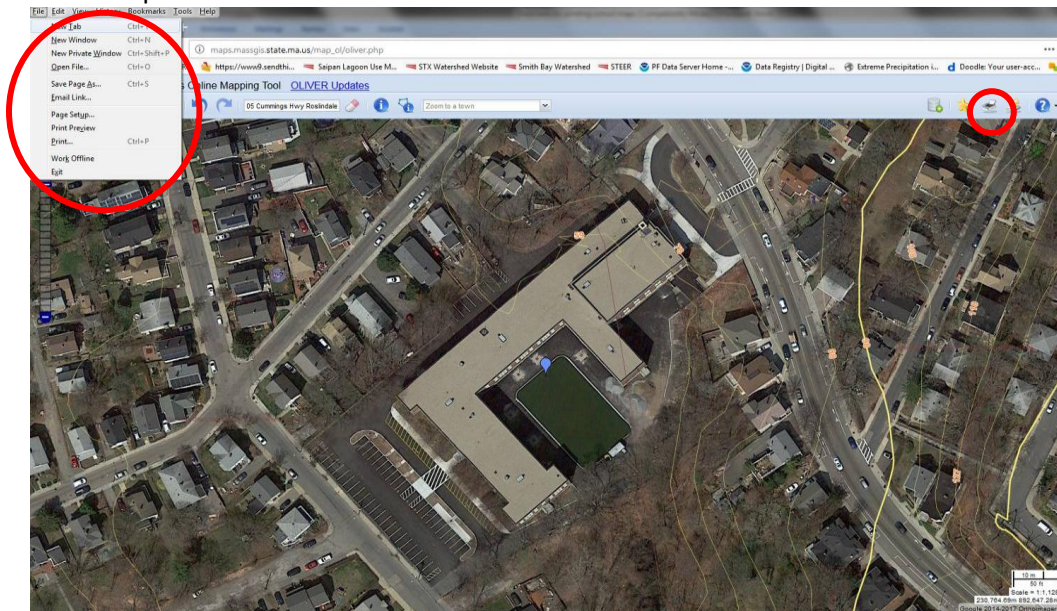
Step 3. Go to bottom right and select basemaps. Choose the image you want, most likely the most recent date.



Step 4. In the column on the right, turn off “structures” layer by unchecking the box in the Active Data Layers menu. Search through the Available Data Layers menu for the Physical Resources folder. Open that folder and find the soils and topography folders. Click on soil polygons and 3m contour lines and labels. These layers will be moved into the Active Data Layers for your map.



Step 5. You can print or save your map your map using the print button or File menu in the top left. Or you can just do a screen capture (make sure to get the scale). You cannot take measurements in the Mass Online map.



Guide to Outdoor Teaching and Learning

Tips for Outdoor Teaching

If you haven't taken your class outdoors before, consider these tips:

1. Choose a special gathering place outside where you begin and end each lesson. Begin by reiterating (or eliciting from students) the instructions you gave indoors, and debrief before going back in.
2. Decide ahead of time what routines you will use for getting in and out of the building. You may want to practice these routines once or twice before beginning these investigations.
3. Consider using a different door than students use at recess.
4. Every student should have a notebook or clipboard and pen or pencil, and/or the supplies they need for the investigation.
5. Carrying supplies may help students take themselves and the task more seriously.
6. Assemble a bucket of tools that you take out each time, which students can elect to use on their own to answer questions that arise (sidewalk chalk, tape measures, string).
7. Consider building in an initial lesson in which students are largely getting oriented to the outdoor environment—perhaps conducting a scavenger hunt or mapping activity—and learning outdoor routines. Their task may be simple, and the time outdoors, brief. In your mind this may be a “practice” lesson, but don't identify it as such.
8. Working as field scientists requires dressing for the weather. Alert them a day ahead of time that you will be going outdoors, and discuss appropriate clothing. Going out in the rain is one of the best ways to learn about stormwater runoff. Rain jackets and boots will be useful of course, but not all students will have them. Some teachers keep a few extra ponchos on hand.
9. Engage students in figuring out how to conduct research in the rain. They are scientists studying rain, what strategies can they come up with? Someone (you or several students with an umbrella and cell phone) could take video of water flow; some things can be observed out the window, some might require getting wet.

See Online Support for Outdoor Teaching at BPS Science Department

Suggested Field Experiences

- Visit the river closest to you (Charles, Neponset or Mystic) to give students firsthand experience of a river ecosystem (to kayak, muck about, or collect data in the field).
- Visit examples of green infrastructure around town.
- Follow water downhill from your school until you reach a body of water. Invite students to determine the water body closest to the school.
- Visit the [Waterworks Museum](#) and Chestnut Hill Reservoir
- Visit the Boston Water and Sewer Commission

Drainage Detectives: Tips for Creating a Schoolyard Watershed Map

As Drainage Detectives students create a watershed map of their schoolyard identifying smaller watersheds (aka catchments, or drainage areas) within it.

Use the tips below to help students plan and develop an investigation of the path stormwater runoff takes on their schoolyard. Each school will be different, but these basic tips should help with most sites. Remember it's ideal to observe water flow when it's raining. Engage students in figuring out how that could be done.

Key to their investigation: surface runoff flows downhill. A watershed is the total upland area that drains to a given low point.

1. Orient students to the aerial site map of the schoolyard.

Your map may have topographic contours showing elevations, but that is not necessary. Being outside, you can see how the topography changes.

Identify the boundaries the students are restricted to for this activity (i.e., the property line, parking lot, or back of school). Depending on number of students, size of area to cover, etc., assign groups to different parts of the schoolyard. They will report back on their section to create a schoolyard watershed map.

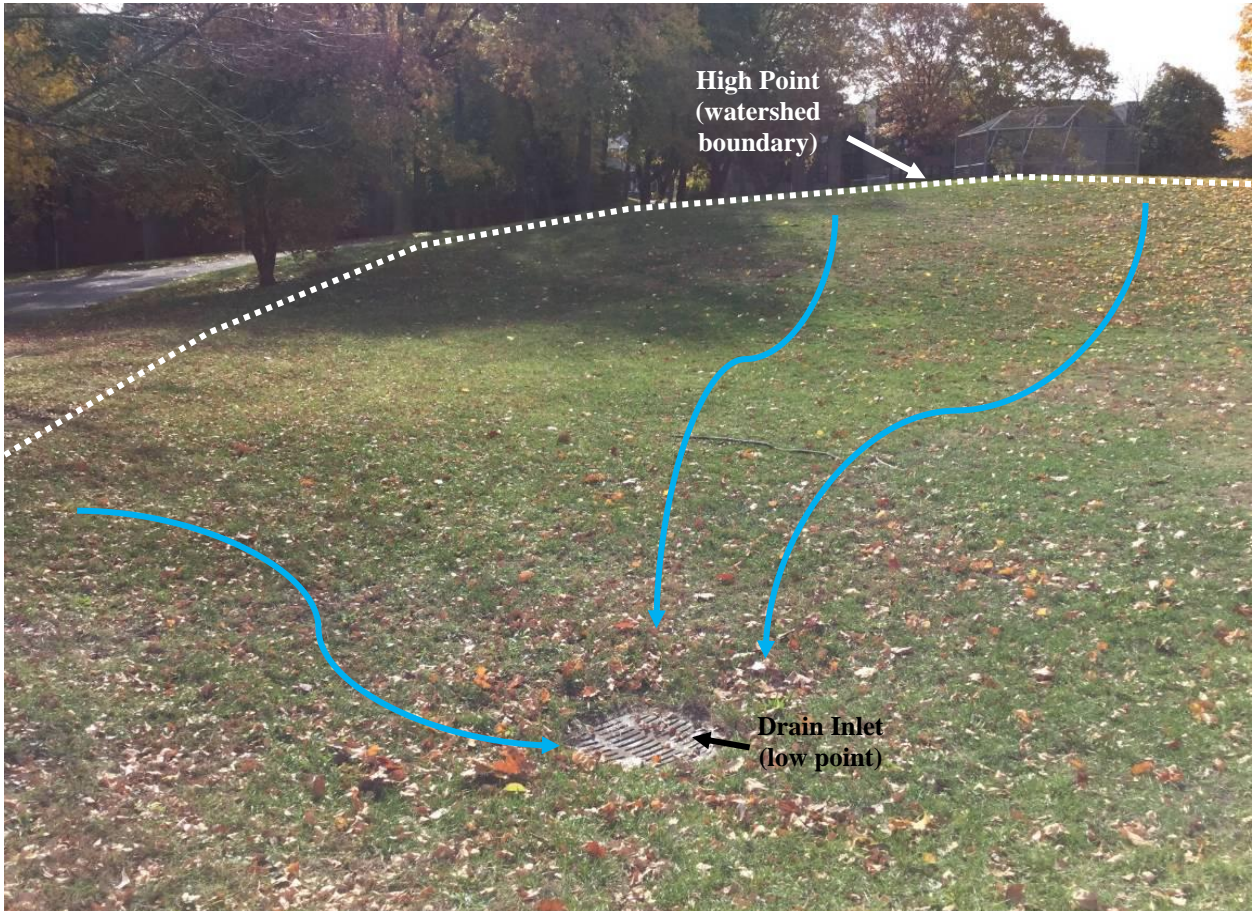
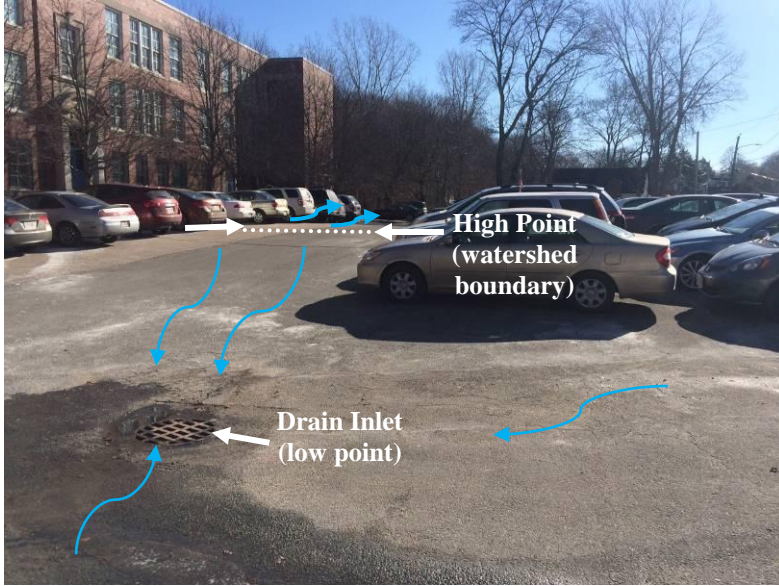
2. Look only at surface flows.

Just look at surface flows and assume that stormwater going into an inlet structure goes directly to the City's drainage system (unless there is an obvious connection to GI). If you want to take it up a notch, see more sophisticated drainage detectives below.

3. Identify the obvious low points.

Encourage students to find and map visible drain inlets/catch basins. These could include:

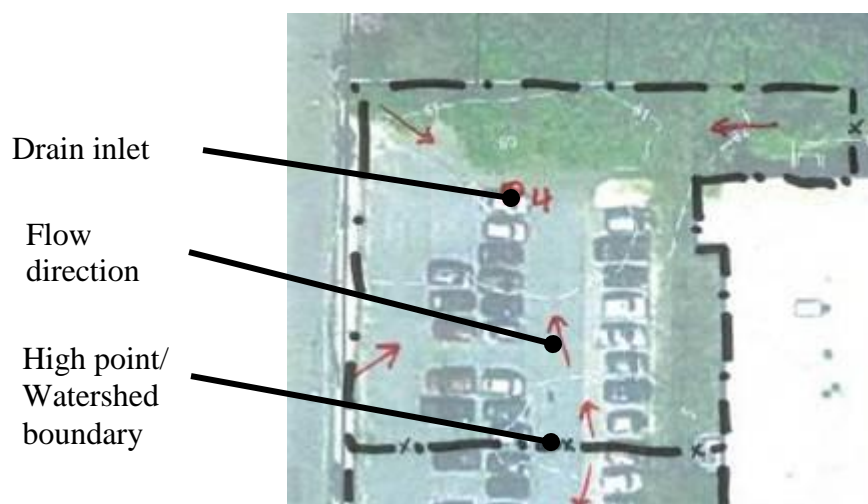
- a. flat, open grates in the pavement or in the yard (solid manhole covers are not inlets unless they accept surface runoff);
- b. curb inlets that direct where rain goes; or
- c. swales, curbing, curb cuts, or other features that direct surface flows to low points such as the street or grassed areas. Not all sites have a formalized drainage infrastructure (i.e., no catch basins).



Being outside is really the best way to identify individual drainage areas/watersheds at your school. Look for low points and high points, starting with drain inlets.

4. Delineate watersheds for each inlet/catchbasin.

- a. Stand on top of the inlet and look around. Inlets are located at a lower elevation than their immediate surroundings—at the bottom of the “watershed bowl.” Each inlet collects runoff from its individual watershed. Parking lots are good places to see this since most are visibly pitched to improve drainage. This might be hard to see if parking lot is full of cars during the school day, unless the inlets are in the middle of the drive aisle.
- b. Imagine it was raining. What is the furthest distance from the inlet that rain falls and comes your way? Students could find and map the “rim of the bowl” around each inlet by walking outward in all four directions. They should be looking for high points in elevation, or the watershed divide where runoff drains to the inlet on one side of the divide and towards a different direction on the other side.
- c. If your site is relatively flat, eyeballing high points and flow paths can be challenging. Students could look for staining that might indicate flow lines. Or use a tennis ball, or level, or hook up a garden hose to help determine which way the ground slopes.
- d. Mark the high points around each inlet on the map with a dot. Connect the dots; this is the watershed boundary for each inlet. Draw flow arrows indicating the flow path runoff takes from the top of the watershed to the inlet at the bottom.
- e. Look for roof downspouts. If you don’t see any, then the roof probably has internal drains and ties into the drainage system underground. If you do see downspouts, be sure to account for their discharge when considering the watershed boundary. Depending on the quality of your aerial map, you may have to make some assumptions about the shape and size of rooftop areas.
- f. Repeat for all inlets.



Use aerial maps to mark low points and high points. From here, you can draw flow directions and drainage boundaries.

5. Identify other low points and their watersheds.

- a. Not all low points are drain inlets. Some low points are locations where water ponds, vehicle entrances where runoff flows out onto street, or cuts in curbing where runoff goes into landscaping, grass, or an obvious stormwater management practice—i.e. GI.
- b. Look at your map. Where do areas outside of the previously delineated inlet watersheds drain?
- c. If your school is by a surface stream, maybe there is an outfall pipe that discharges directly to the stream.



Sometimes, surface drainage doesn't go to a drain inlet, rather it flows directly to street or off-site through driveways or through curb cuts into landscaping or stormwater practices.

6. Take it up a notch.

You may be able to map the underground drain pipe network, which is cool. This will require getting your hands on school site plans and/or opening up inlet and manhole covers to look for pipe connections. The lowest pipe in a structure is the one that drains out. Some manhole covers indicate junctions between stormwater drainage pipes (connections between drain inlets), but some are sanitary sewer. You can't always trust what is written on the lid, but you can generally tell by the smell and dry weather flow.

In general, pipes are straight (connect directly from one structure to another) with manholes located at junctions and turns. It is fun to open these to show kids the amazingly complex underground piped network. However, only do this with the school's facility managers and test it out in advance. If due for cleaning, inlets and manholes can be full of water/clogged and you won't be able to see anything. You'll need a crowbar or pick axe to open. Be sure traffic won't be a problem.



Popping manholes can be a fun exploration for older kids as it provides insight into runoff volumes and flow directions during or after rain events, and helps students to better understand the engineering of an underground pipe network.

Professional Development Recommendations

Professional development will be important for this unit. Teachers recommended a one day session prior to the start of school held at one of the 5 BPS GI Pilot schools with green infrastructure on site. Ideally it would include the following.

1. Review and discuss

- a. Lesson content
- b. Opportunities for authentic argumentation
- c. How to maximize community engagement opportunities

2. Background Knowledge

- a. The Charles River: its polluted past, landmark clean-up efforts, and current water quality challenge: algal blooms due to excess phosphorus.
- b. Phosphorus; a natural element, essential for plant growth; but the natural phosphorus cycle altered by humans leads to phosphorus overloading severely damaging aquatic ecosystems in urban waterways.
- c. Stormwater runoff: a result of urbanization and changes in land cover leading to stormwater runoff-- the biggest water pollution problem today and the primary cause of phosphorus/nutrient overloading.
- d. Green infrastructure: engineering solutions that replace traditional gray infrastructure (pipes) with features that use the natural hydrological cycle and properties of plants to manage and clean stormwater runoff.

3. Schoolyard Data Collection

Conduct data collection on the PD site replicating the steps students go through to analyze their schoolyard. Identify how these activities will be different at GI and non-GI sites. Map the schoolyard watershed; calculate the area of one catchment area and use it to determine stormwater runoff, and phosphorus load generated by that area. Prioritize site needs; and score the ability of different GI practices to meet these needs.

4. Outdoor Teaching and Learning

Activities should model successful strategies for taking learning outdoors, and give teachers a chance to develop outdoor protocols to use with their students.

5. Opportunities for authentic argumentation about stormwater and/or GI

Teachers should use evidence collected on-site to persuade their colleagues to agree with their position and arrive at a conclusion as a group. (see Argumentation Chart)

6. Leave with the following in-hand

- Downloaded aerial photo of your schoolyard and “schoolyard site map”
- The area of your schoolyard you will use for student investigations or a plan to involve students in the decision.
- Decide whether to use your own schoolyard or the Case Study for the final performance-based assessment.
- Locations for: the nearest water body; nearby GI installations; and your school’s location in the Charles River (or other) watershed.