

# Reducing Stormwater Pollution

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Stormwater is excess water from rainfall and snowmelts that flows over the ground and does not infiltrate the soil. Human disturbances increase the volume of stormwater generated through the addition of impervious surfaces such as parking lots, rooftops, and paved streets. For example, a typical paved driveway 15 by 50 feet can generate over 230 gallons of stormwater runoff during a half inch rainfall. This volume of stormwater is enough to fill a 60-gallon bathtub almost four times!

Stormwater is a concern not just in urban areas (Figure 1) but in suburban and agricultural locations as well. As stormwater runoff flows over the land or impervious surfaces, it picks up and transports trash and debris as well as pollutants such as pathogens, nutrients, sediments, heavy metals, and chemicals (Figure 2).

Stormwater runoff either flows directly into streams, rivers, and lakes or is directed to storm drains, often by curbs, where it enters the storm sewer system. The storm sewer system is a network of underground pipes that quickly transports stormwater to local surface waters. Due to its large volume, stormwater typically bypasses water treatment plants and is instead guided to local streams, rivers, and lakes. Pollutants that accumulate in stormwater flowing over land and impervious surfaces are introduced to these water bodies, which can adversely impact water quality (Figure 3).

**Table 1.** Common sources of pollutants in stormwater.

Pollutant	Sources
Nutrients	Fertilizers, septic system malfunction, pet waste, livestock waste, grass clippings, leaves, atmospheric deposition
Pathogens	Sewer system overflows, septic system malfunction, pet waste, livestock waste, wildlife waste, garbage
Sediments	Bare soils, construction sites, eroding stream beds and banks
Heavy metals	Automobiles (e.g. brakes and tires), manufacturing
Hydrocarbons	Oil and gas, exhaust, burning yard waste and trash
Pesticides	Over application on yards, gardens, and fields; spills and leaks

## Effects of Stormwater Pollution

Stormwater pollution can negatively affect both human and environmental health. Trash and other debris in water bodies can kill or disable water fowl, turtles, fish, and other aquatic animals. High levels of nutrients—particularly nitrogen and phosphorus—promote bacterial growth and algal blooms which in turn can deplete oxygen in surface waters. When oxygen levels become too low (hypoxia), fish and other aquatic organisms die. Because warmer waters hold less oxygen, stormwaters flowing across hot parking lots and streets can thermally pollute streams by raising water temperatures and thus decreasing oxygen levels. Stormwater runoff may also contain pathogens, heavy metals, and other chemicals that may pose a health hazard to humans who come into contact with untreated waters. Stormwater pollution increases the risk of drinking water con-

tamination and water treatment costs for downstream communities (Table 1).

Streams receiving stormwater can undergo changes in their morphology or shape. Storm sewer systems rapidly deliver stormwater to streams causing an increase in peak flow and a decrease in flow duration. Velocities can increase causing stream beds and banks to erode. Reduced infiltration rates resulting from impervious areas mean less groundwater recharge and less baseflow for streams. Flow regimes can change from perennial to intermittent as baseflow decreases or even ceases. Such a change negatively affects aquatic life as many macroinvertebrates and fish are sensitive to changes in flow regimes.

A large number of methods exist for managing stormwater pollution. This publication reviews some of these techniques and provides a list of recommended resources for additional information.



**Figure 1.** Flooding of streets is a concern in urban areas.



**Figure 2.** Stormwater runoff picks up trash and other pollutants and carries them to streams.



**Figure 3.** Unidentified blue substance flowing into storm drain located at the edge of a parking lot.

## Managing Stormwater Pollution

Stormwater pollution is managed in two main ways: source reduction and structural best management practices (BMPs). Source reduction seeks to control pollutant sources and includes practices such as implementing sediment and erosion control measures, not littering or picking up trash, using less fertilizer, and picking up pet waste. Structural BMPs also seek to decrease runoff volume by increasing infiltration and/or promoting storage. Examples of structural BMPs include practices such as rainwater harvesting, permeable pavement or pavers, infiltration trenches, rain gardens, stormwater wetlands, and riparian buffers.

### Source Reduction

Preventative practices are a simple means of reducing stormwater pollution by controlling pollutant sources. Examples of such activities include picking up trash and pet waste, properly disposing of household waste, practicing environmentally friendly landscaping, maintaining septic systems, and practicing proper sediment and erosion control techniques.

The term “floatables” refers to the trash or litter that floats on the water surface. Floatables include items such as soda bottles, plastic bags, foam containers, and cigarette butts. This litter is washed into the storm system and nearby water bodies when it rains. Once in streams, rivers, and lakes, floatables are not only visual pollution; they also harm wildlife who ingest or become entangled in the trash. Placing trash in designated receptacles (not littering) is the first step to reducing floatables. A pilot study in New York City has shown that frequent manual street sweeping (more than twice per week) in addition to mechanical sweeping greatly reduced the quantity of floatables. Once floatables enter the storm sewer system, a number of technologies are available for controlling their discharge such as screens and trash racks, netting, baffles, catch basin modifications, and containment booms.

Activities such as auto care and home improvement can be major sources of stormwater pollution. Using a car wash or washing on a permeable surface helps

ensure dirty, soapy water does not enter the storm sewer. Spilled oil and other automotive fluids should be cleaned up with an absorbent material such as a towel, clay-based kitty litter, or sand. To dispose of old, unused auto fluids contact the local government or an auto repair shop for drop-off locations. Before starting a home improvement project, make sure nearby storm drains are protected from construction debris such as sawdust, paint, and packing materials. Contact the local government to find out the recommended way to dispose of unused remodeling items such as paint, sealers, and lacquers.

Landscaping practices offer another opportunity to prevent stormwater runoff and pollution. Yard waste such as grass clippings and leaves should not be swept onto the street or into a storm drain. Doing so can cause the storm drain to clog, which can result in flooding. Also, excessive plant matter in streams can result in low dissolved oxygen levels which negatively effects aquatic life. Instead, yard wastes can be composted to provide a free source of fertilizer. Cover bare soils with mulch or seed to prevent runoff of sediment. Be careful not to over fertilize lawns and gardens or to apply chemicals or fertilizers within 24 hours of rainfall. Not only is this practice wasteful, but it also pollutes stormwater. Proper fertilization rates depend on the type of grass, time of year, and nutrient levels present in the soil. The best way to determine the appropriate fertilizer rate is to have the soil tested and consult the NRCS or local extension office.

Septic systems should be inspected annually by a qualified professional, such as a certified septic system installer, to ensure they are functioning properly. **Never inspect a septic tank alone. Never enter a septic tank.** Toxic gases are produced as part of the natural treatment processes, and these gases can kill quickly. Generally, a 1,000-gallon septic tank serving a household of four people should be pumped every three to five years. The local health department can assist in identifying qualified inspectors and licensed pumpers.

Siltation is a leading cause of impairment to Kentucky’s waterways with much of the suspended sediments originating at construction sites. Elevated levels of

suspended sediment negatively impact aquatic life by reducing visibility making it harder to find food, burying and smothering organisms, and clogging their gills. A number of BMPs are available to control erosion at construction sites. These BMPs emphasize site preparation, soil stabilization, slope protection, drainage systems, and stream and wetland protection. Commonly used BMPs include seeding, mulching, matting, silt fence, check dams, sediment basins, and bioengineering.

### Structural Stormwater BMPs

Structural stormwater BMPs are used to increase stormwater storage and/or infiltration and reduce stormwater pollutant loads. These BMPs vary in size from small applications typical of a homeowner to large-scale practices employed by developers, commercial businesses, and governments.

### Rainwater Harvesting

Rainwater harvesting is the practice of collecting and storing stormwater runoff from roofs and other impervious areas for future use in activities such as washing automobiles, watering lawns and gardens, and even flushing toilets. Rainwater harvesting can be accomplished using small aboveground containers such as rain barrels to large aboveground or underground cisterns or tanks. Remember, harvested rainwater is **not potable**, meaning it is not safe to drink.

A rain barrel is an inexpensive way to conserve and store rainwater from rooftops (Figure 4). Rain barrels help control erosion and water settling near building foundations by redirecting it to more desirable locations. Rain barrels can be easily constructed from 55-gallon plastic drums. Multiple rain barrels can be connected to store larger volumes of rainwater.

Maintenance is minimal with rain barrels. To minimize algal growth, rain barrels should be emptied every five to seven days. To maximize rainwater capture, rain barrels should be emptied before each rain event. During freezing conditions, rain barrels should be winterized by draining all water, piping, and connections and storing indoors or opening all spigots and leaving outdoors.



**Figure 4.** Rain barrels are an easy way to conserve stormwater.

Cisterns function in a similar manner to rain barrels except they have a much larger storage capacity. Often, cisterns are placed underground, but aboveground systems are also available. Selection of the cistern size depends largely on the expected amount of rainfall for an area, level of demand for the rainwater, and size of the collection area. Pretreatment (e.g. filtration and first-flush), distribution piping, and pumping systems are also important.

With cisterns, regular but simple maintenance is required. Tanks should be inspected for debris and cleaned annually to remove any debris. Gutters, downspouts, and pretreatment systems should also be inspected every few storms to ensure they are not blocked by debris and are functioning properly.

### Permeable Pavement/ Permeable Pavers

Permeable pavement and permeable pavers promote groundwater recharge by allowing stormwater runoff to percolate through the materials and infiltrate into the underlying soil. Temporary storage is provided by void spaces in the material. Some nutrient and pathogen pollutant loads in stormwater runoff may also be reduced as permeable pavements can act as a biofilter—a biologically active barrier where microorganisms break down contaminants thereby improving water quality (Table 2).

Permeable pavement looks similar to standard asphalt or concrete except void spaces are created by omitting fine materials such as sand (Figure 5). Compacted gravel is not considered permeable



**Figure 5.** Permeable pavement, a good option for walking paths and trails, was used on part of the Legacy Trail in Lexington, Kentucky.

pavement. Permeable pavers consist of permeable interlocking concrete pavements (PICP), concrete grid pavers (CGP), or plastic turf reinforcing grids (PTRG) (Figure 6). Use of permeable pavement and permeable pavers is limited to pedestrian and light to medium vehicle use and should not be installed in high-traffic areas or where heavy vehicles are operated. Ideal locations for permeable paving materials include greenways, driveways, and overflow parking lots.

The main design considerations for the use of permeable pavement and permeable pavers include slope and soil permeability. Slope should ideally be less than 0.5 percent to allow stormwater to

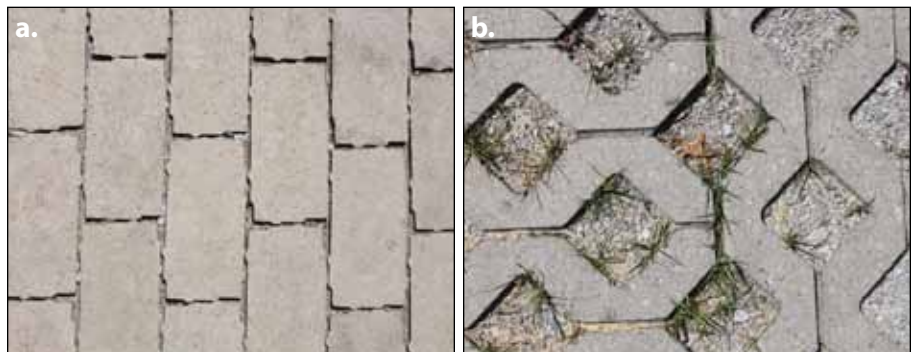
effectively infiltrate the permeable paving material as opposed to flowing over it. Soil permeability should be at least 0.5 inches per hour to allow for adequate infiltration. If underlying soils do not meet the permeability requirement, modification using sand and/or gravel is required. Also, a 2-foot minimum depth is required between the bottom of permeable paving materials and bedrock or the water table, although 4 feet is desired.

One important design consideration for permeable pavements, specifically pervious concrete, is the density of the concrete mixture. Fine particles (sand) are typically omitted from the mixture, but excess amounts of cement can increase the mixture density and reduce the porosity of the concrete structure. While increasing cement content can improve the concrete strength, infiltration rates through the pervious concrete layer will decrease as concrete porosity decreases.

To prevent clogging from eroding soils, permeable paving materials should be installed after the contributing drainage area has been stabilized. A vegetative filter strip—an area of close-growing plants designed to treat sheet flow—is recommended around the perimeter of the permeable surface to pretreat stormwater runoff by removing sediments and

**Table 2.** Types of permeable pavers.

Type	Description
Permeable interlocking concrete pavement (PICP)	Concrete blocks; voids created at corners
Concrete grid pavers (CGP)	Porous concrete blocks (finer particles eliminated from concrete); additional voids created between blocks
Plastic turf reinforcing grids (PTRG)	Grass is intertwined with plastic mesh to stabilize grass and soil



**Figure 6.** A variety of permeable pavers are available including (a) permeable interlocking concrete pavements (PICP), (b) concrete grid pavers (CGP), and plastic turf reinforcing grids (PTRG) (not shown).

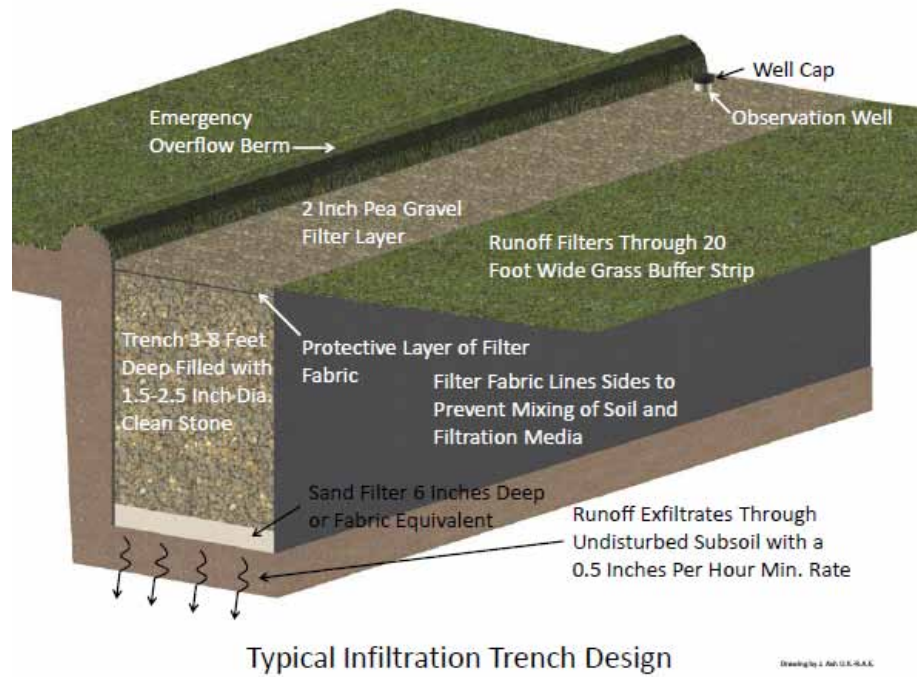
other solids. Regular maintenance in the form of annual vacuum sweeping or high-pressure washing is required. Avoid using salt, sand, or other de-icing chemicals, which can cause clogging.

### Infiltration Trenches

Infiltration trenches are long, narrow, shallow excavations designed to store stormwater runoff and to allow it to seep into the ground through the bottom and sides of the trench. These systems are generally designed for small, frequent storm events. Infiltration trenches are designed to handle sheet flow from small drainage areas (e.g. 2 acres or less) such as parking lots. Infiltration trenches should not be used if the stormwater runoff contains significant concentrations of soluble pollutants as these pollutants could contaminate the groundwater.

Typically 3 to 8 feet deep, these trenches are lined with a filter fabric to prevent soil particles from mixing with the clean stone that fills the trenches (Figure 7). As with permeable paving materials, soil permeability should be at least 0.5 inches per hour. The bottom of the trench should be 3 to 5 feet above the seasonal high water table. A bypass system should be included to convey high flows around the trench.

As with permeable paving materials, infiltration trenches should be installed after the contributing drainage area has been stabilized. To prevent clogging, a pretreatment BMP such as a vegetated filter strip should be used in conjunction with an infiltration trench. Regular inspection is required to check for signs of clogging. Clogging most often occurs in the surface layer. Once clogged, the first layer of stone and filter fabric must be removed and replaced. If water is visible in the observation well 24 hours to a few days after a storm event, the bottom of the trench is likely clogged. To correct the problem, all of the stone, fabric and accumulated sediment must be removed, and the bottom of the trench must be scarified or tilled. The trench must be refilled with new stone and fabric.



**Figure 7.** Infiltration trenches are useful for managing parking lot runoff, but they do require pretreatment to prevent clogging. Adapted from Schueler (1987).

### Rain Gardens

Rain gardens are bioretention areas that use a conditioned planting bed and landscaping in a shallow depression to filter stormwater runoff from impervious surfaces (Figure 8). Rain gardens are typically designed to hold runoff from a 1-inch storm event and detain stormwater for only one to two days. Like permeable paving materials and infiltration trenches, soil permeability is important. For non-sandy soils, soil modifications are required. A mixture consisting of at least 50 to 60 percent washed sand and 5 to 10 percent organic matter is recommended. If faster infiltration rates are needed, increase the percentage of sand. Be sure to maintain a balance between having enough fines to uptake pollutants and promote plant growth while ensuring an adequate infiltration rate (minimum of 0.5 inches per hour). Maintaining a high cation exchange capacity (CEC) will promote the removal of pollutants. CEC refers to the ability of the soil to retain nutrients and metals. It is increased through the inclusion of fines and organic matter.

To ensure adequate infiltration, dig to a minimum depth of 4 feet. An optional sand filter layer (generally 1 foot) can be placed at the bottom of the rain garden. A pea gravel curtain drain should be



**Figure 8.** Rain gardens are an aesthetically pleasing way to treat stormwater runoff.

installed along the down-gradient edge of the rain garden, but up-gradient of the berm, to allow for overflow. The pea gravel curtain should extend the entire depth of the rain garden. Depending on site needs, an underdrain system can be constructed to connect to the storm sewer system, or water can be allowed to simply infiltrate into the subsoil.

Research indicates that plant selection can also impact nitrogen and phosphorus removal. Select native plant species that combine the traits of deep rooting depths, large root mass, and fast growth rates to maximize nutrient removal. A number of plant species have been studied for

phytoremediation—the use of plants to clean up soil and water pollution. Refer to the Resources section for a list of studied plant species or contact your local extension or NRCS offices. After planting, place a 2- to 3-inch layer of hardwood mulch on the surface to prevent erosion and retain moisture for plants.

## Stormwater Wetlands

Stormwater wetlands or constructed wetlands consist of shallow permanent pools, generally 1 to 1.5 feet deep, and wetland plants. The specific design largely depends on drainage area and land availability. Generally, stormwater wetlands consist of a sediment forebay (small pool) at the inlet and a second small pool or micropool at the outlet. The sediment forebay is designed to settle incoming solids while the micropool allows dewatering below the water surface where floatables may be present. To accommodate maintenance and revegetation, design the wetland so that it can be dewatered, if needed.

Stormwater wetlands are similar to natural wetlands, but they are specifically designed to treat stormwater runoff and provide water quality improvements and runoff storage, and as such are usually less biodiverse. Stormwater wetlands achieve pollutant removal via settling, plant uptake, and microbial transformations. Flow paths are maximized to increase stormwater retention times. Since these systems are largely used in urban settings, aesthetics are a major design component (Figure 9).

Stormwater wetlands can be constructed on dry or wetland lands regardless of whether or not a wetland was previously located at the site, although consideration should be given to drainage area, topography, soils, geology, “hotspots,” and available land area. Unless stormwater wetlands receive baseflow from groundwater to support a permanent pool, they should be located to receive runoff from a sufficiently large drainage area. The size of the contributing area will depend on local rainfall. Stormwater wetlands are generally located on shallow slopes; however, sufficient slope must be maintained from the inlet to the outlet to allow gravity conveyance of water. The type of soil



**Figure 9.** Stormwater wetland at McConnell Springs in Lexington, Ky.

present must also be considered. Fine-textured soils are preferred as these will hold water. Permeable layers of sand or gravel will cause a wetland to drain. In karst geology, check for the presence of sink holes and the potential for sink hole development. In such cases, an aquatic safe pond liner should be considered. If stormwater runoff comes from hotspots, or areas producing high concentrations of metals and hydrocarbons, a liner is required. The amount of land available for stormwater wetlands will guide the design. Typically, wetlands are sized so that the surface area is 1 to 2 percent of the contributing drainage area.

Nursery stock and seeding are the most common methods of establishing wetland vegetation. Establishment of vegetation through volunteer means is not recommended because of the potential for invasive species colonization. A variety of vegetation should be selected to account for the wide range of water depths present in the wetland. Consideration should also be given to the phytoremediation potential of the vegetation for incoming pollutants. Try to match plants with phytoremediation potential to the pollutants the wetland will be receiving.

Maintenance largely consists of routinely dredging the forebay, inspecting vegetation during growing and dormant seasons, removing invasive species, inspecting outlet structures, and removing trash. If desired, wetland vegetation can



**Figure 10.** Riparian buffers provide a number of stormwater benefits and ecosystem services. This photo shows an example of a NRCS established riparian buffer along a stream draining agricultural lands in Fayette County, Ky.

be harvested to remove nutrients from the system and minimize their release during vegetation dieback in the autumn.

## Riparian Buffers




Riparian buffers are vegetation zones located alongside streams, wetlands, lakes and ponds (Figure 10). These areas link terrestrial and aquatic environments. Riparian buffers provide a number of benefits such as filtering pollutants, stabilizing streambanks, regulating water temperature, and providing food and shelter to wildlife. Typically, riparian buffers consist of three zones: a zone of trees adjacent to the water followed by a zone of shrubs and then a zone of grasses. As each zone provides benefits at differing levels of effectiveness, stormwater pollution needs should be considered when selecting vegetation (Table 3).

Riparian buffers are effective at treating overland flow as this runoff passes through the buffer en route to the stream; however, pipes from stormwater systems often directly discharge into streams bypassing riparian buffers.

Riparian buffers generally require minimal maintenance. Buffers should be inspected annually to check for tree survival and invasive species colonization. In urban environments, one of the greatest challenges to riparian buffer development and tree survival is lawn mowers. No-mow perimeters should be clearly marked, and if needed, fencing should be installed.

**Table 3.** Vegetation effectiveness for select riparian buffer benefits.

Benefit	Vegetation Type		
	Trees	Shrubs	Grasses
Streambank stabilization	High	Moderate	Low
Filtering sediment	Low	Moderate	High
Filtering nutrients, pesticides, pathogens	Moderate	Low	Moderate
Improving aquatic habitat	High	Moderate	Low
Improving forest habitat	High	Moderate	Low
Improving field (pasture) habitat	Low	Moderate	High
Flood protection	High	Moderate	Low
Visual diversity	High	Moderate	Low

Low  Moderate  High 

## Summary

Stormwater runoff and water pollution are problems worldwide, and the situation will continue to expand along with our demand for water as the human population grows. As outlined in this publication, there are many methods for reducing the impacts of stormwater pollution on our environment. Awareness of the problem is the first step toward a solution, and through proper management techniques, communities are progressing toward a secure and sustainable future for water.

## Resources

### Stormwater pollution prevention

- Lexington-Fayette County Division of Water Quality: <http://www.lexingtonky.gov/index.aspx?page=665>
- Sanitation District #1 (Northern Kentucky): <http://www.sd1.org/default.aspx>
- Louisville Metropolitan Sewer District: <http://www.msdlouky.org/>

### Source reduction and structural BMPs

- Your local extension office
- National Resource Conservation Services (NRCS) office: <http://www.nrcs.usda.gov/>
- Your local government's division of engineering office

### Household waste disposal

- Your local environmental, health or solid waste agency
- U.S. Environmental Protection Agency, Household Hazardous Waste: <http://www.epa.gov/osw/conservation/materials/hhw.htm>

- Lexington, Kentucky, Division of Waste Management: <http://www.lexingtonky.gov/index.aspx?page=666>
- Northern Kentucky Household Hazardous Waste Action Coalition: <http://www.nkyhww.org/DisposalMethods.aspx>
- Louisville, Kentucky, Household Hazardous Materials: <http://www.louisvilleky.gov/SolidWaste/Household+Hazardous+Materials.htm>

### Sediment and erosion control practices for construction sites

- Kentucky Transportation Center at the University of Kentucky: <http://www.ktc.uky.edu/>

### Septic system inspector

- Your local health department
- Kentucky Environmental Management Branch: <http://chfs.ky.gov/dph/info/phps/enviromgmt.htm>

### Selecting plant species that have been studied for their phytoremediation properties

- Your local extension office
- National Resource Conservation Services (NRCS) office: <http://www.nrcs.usda.gov/>
- Hinman, C. 2005. Appendix A: Sampling of plant species studied for phytoremediation. In: Low Impact Development Technical Guidance Manual for Puget Sound. Puget Sound Action Team and Washington State University Pierce County Extension. Available at: <http://www.superorg.net/archive/proposal/plant%20species%20phyto.pdf>

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