United States Environmental Protection Agency

EPA Publication Number 905F13001
July 2013

Implementing Stormwater Infiltration Practices at Vacant Parcels and Brownfield Sites

U.S. Environmental Protection Agency
Office of Water
Office of Solid Waste and Emergency Response

Introduction

This document presents information to assist communities, developers, and other stakeholders in determining the appropriateness of implementing stormwater management practices that promote infiltration at vacant parcels and brownfield sites.

A brownfield is a property where redevelopment or reuse may be complicated by the presence (or likely presence) of contamination. Vacant parcels may also be brownfield sites depending upon their prior use. Redevelopment of brownfield properties is often conducted using approaches that are specifically designed to reduce or eliminate the human and ecological health risks associated with these substances. Common risks associated with brownfield sites include:

Risk To…	Resulting From…
Human health	Direct contact, inhalation, or ingestion
Groundwater	Leaching of a contaminant(s)
Nearby surface waters or ecosystems	Runoff from the site which has picked up contaminants due to leaching or erosion

Strategies for reducing or eliminating these risks can include removing contaminated soil or waste materials, treating soils on site, placing a cap or barrier over contaminated areas, bioremediation, or monitored natural attenuation.

Many urban and suburban communities are required to develop municipal stormwater management programs to control the discharge of pollutants from their separate stormwater and sewer systems. These municipal stormwater programs typically require new development and redevelopment projects to implement best management practices (BMPs) that reduce pollutant discharges and control stormwater runoff. The specific requirements for each stormwater program can vary, but many programs require or encourage development projects to address stormwater runoff through controls that either infiltrate stormwater prior to its runoff from a property or provide for the detention and treatment of the stormwater before it is discharged.

Communities seeking to implement sustainable stormwater management frequently use rain gardens, bioswales, permeable pavement and other practices, often referred to as *green infrastructure*, to manage runoff. These stormwater infiltration practices often allow accumulated runoff water to percolate into the subsoil which reduces stormwater runoff. Projects that infiltrate stormwater runoff on-site can provide multiple benefits, including decreased stormwater infrastructure costs, increased groundwater recharge, and decreased pollutant loads in stormwater runoff.

Vacant or under-utilized parcels may appear to be promising places to locate stormwater infiltration practices. However, it is important to reconcile the goal of sustainably managing stormwater with brownfield site considerations. Infiltrating stormwater at sites where there are contaminants present may mobilize the contaminants and increase the potential for groundwater contamination.

This document was developed to assist communities, developers and stakeholders in making decisions about whether to implement green infrastructure infiltration practices at brownfield sites. With careful site analysis and planning, decision-makers can plan for stormwater management practices which promote the infiltration of stormwater while minimizing the potential for mobilizing contaminants.

Stormwater Management Approaches

Stormwater management practices are typically intended to capture, convey (through ditches or sewers) and in some cases treat stormwater which runs off of roads, parking lots, rooftops, and other impervious surfaces or areas of active construction in an urban or suburban area. Stormwater practices may also include storing wet weather flows, for example in a detention basin, to help prevent localized flooding. In addition, stormwater management approaches may include green infrastructure practices to trap pollutants and reduce the amount of stormwater to be conveyed and discharged.

Installation of a subsurface stormwater storage and infiltration gallery.

Successful implementation of stormwater management and infiltration practices at brownfield sites requires careful planning; stormwater management planning and implementation should be integrated with site investigations, state approvals, the selection of clean-up approaches and techniques, and the design and engineering of site improvements. The safe implementation of stormwater infiltration needs to be considered during the early phases of planning for site redevelopment. Locating infiltration practices so that they do not mobilize contaminants requires a collaborative effort by team members responsible for delineating and defining the contamination, remedial engineering, site planning, and site design.

When is a vacant parcel or infill redevelopment site a "brownfield," where contamination issues need to be considered?

There are a number of simple approaches to determine if a property could be characterized as a brownfield site. The history of prior use is a good indicator of brownfield potential. Prior land uses and the types of activities that took place on the site are often good predictors of whether there will be contaminants and/or waste materials in the soil that could complicate the redevelopment and reuse of the site. The following graphic illustrates the general relationship between property use/site history and the associated probability of contamination.

Low Probability of a contaminated site ⟷ High Probability of a contaminated site
Park - Farm - Residential - Retail - Commercial - Service Station/Dry Cleaners - Industrial
Past and Present Property Use

Note that while the graphic shows the relative probability that there will be contamination at a site, each site needs to be considered individually. For example, some land presently used as park space may have had a different land use in the past. Farming areas may have past pesticide use or farm waste management issues. A residential lot may have an old oil tank buried in the yard or area where trash was burned.

Prior uses of a property can and should be identified from a review of records such as current and past zoning requirements, title search results, and deed records. Environmental records related to a specific location (address or area) can be obtained from the interactive EnviroMapper web site (http://www.epa.gov/emefdata/em4ef.home) maintained by the U.S. EPA. The EnviroMapper web site provides access to several U.S. EPA databases to provide information about environmental activities that may affect air, water, and land anywhere in the United States. Maps depicting the locations of environmental events, contamination, or other concerns also can be generated. Many states also have environmental records databases that can provide information regarding potential contamination at particular properties.

A vent for an underground storage tank is an indication that the tank is still present.

A visit to the property can provide information regarding past use and the potential for the property to be impacted by environmental contamination. Certain features at a property may be indicators of potential contamination including the presence of:

- Underground storage tank vents or fill ports.
- Monitoring wells.
- Soil piles covered with plastic sheeting or tarps.
- Staining of soils and/or dead vegetation.
- Excavations that are not backfilled with clean material.

The identification of the location and size of the area where compound concentrations represent an unacceptable risk is crucial to the planning of stormwater management practices.

At some properties, contaminated debris may remain from previously demolished buildings. In such cases, it is important to obtain records from the demolition to determine if environmental hazards, such as fuel oil tanks or lead based paint, were removed prior to the building demolition.

The site factors discussed above are typically considered as part of a site investigation (Phase I and II Environmental Site Assessments) carried out to confirm if the property is impacted from a prior use(s) or otherwise potentially contaminated.

Importance of Site Characterization

Prior to the initiation of any brownfield site reuse or redevelopment, a site investigation will normally be conducted to obtain information regarding the property's potential contamination. Knowledge regarding any potential contamination is needed to plan for any potential remediation, to make the property safe for occupation, and to address environmental and possible ecological concerns in a safe and cost-effective manner. Lenders, insurers and State and federal environmental regulations often require an environmental investigation of a commercial property at the time of property transfer to identify potential contamination and the potential environmental and health impacts from any contamination. Environmental investigations are normally conducted in the following stages:

Phase I Environmental Site Assessment
Commonly includes the identification of environmental concerns through a visual examination of the property, acquisition and review of historic environmental records and property use information, property ownership and lien records, historic aerial photographs, and other records related to the prior use and ownership of the property.

Phase II Environmental Site Assessment
Conducted to determine if the information and potential conditions identified in Phase I are evidence of contamination and if such conditions create an environmental impact. This phase can include soil borings or test pits to collect samples of surface and subsurface soils for laboratory analysis. Monitoring wells can be installed to collect groundwater samples for laboratory analysis. Environmental impacts are characterized by size and depth through sampling of subsurface materials and groundwater.

Supplemental Site Assessment
If contaminant concentrations identified during Phase II represent an unacceptable risk, a supplemental site assessment is needed to identify the horizontal and vertical extent of contamination. Once identified, risks can be further evaluated along with remedial approaches for site construction to reduce risks to an acceptable level.

Environmental conditions at brownfield properties need to be well-understood to ensure any necessary cleanup meets environmental regulatory requirements and to effectively design remedial efforts (if needed). The identification of the location and size of the area where contaminant concentrations represent an unacceptable risk is crucial to the planning of stormwater BMPs. Project stakeholders, regulators and designers need to have access to and evaluate this information in order to plan which stormwater management practices can be placed at a site.

Is Infiltration Appropriate?

Stormwater management approaches that include infiltration need to be carefully evaluated when being considered for a brownfield site, or potentially contaminated property. The following questions can be used to help determine if infiltration or other stormwater management approaches are appropriate for a specific brownfield property. To summarize key steps in the decision-making process, a decision tree is presented near the end of this document. A detailed environmental site investigation, as described above, should be completed to identify the location, limits and contaminants in soil and groundwater so the questions below can be answered and the decision tree can be used effectively.

1. Is a LNAPL, DNAPL, biodegradable waste, or leachable contaminant source present at the site?

A light non-aqueous phase liquid (LNAPL) is a liquid that has a density less than water, allowing it to float on groundwater (e.g., diesel fuel). A dense non-aqueous phase liquid (DNAPL) is denser than water, allowing it to sink or move downward through the groundwater table (e.g., tetrachloroethylene). LNAPLs and DNAPLs are considered substances that tend to flow though subsurface soils and are often the source of soil or groundwater impacts at a brownfield site. Because LNAPLs and DNAPLs are independently mobile and can produce multiple hazards, the use of infiltration or stormwater management practices in close proximity to LNAPLs or DNAPL contaminated areas should generally not be considered. Areas of the site that do not contain LNAPL or DNAPL can be considered for infiltration only if the proposed infiltration will not move or spread the LNAPL or DNAPL. More information concerning LNAPLs can be found at: http://www.epa.gov/wastes/hazard/correctiveaction/curriculum/download/lnapl.pdf.

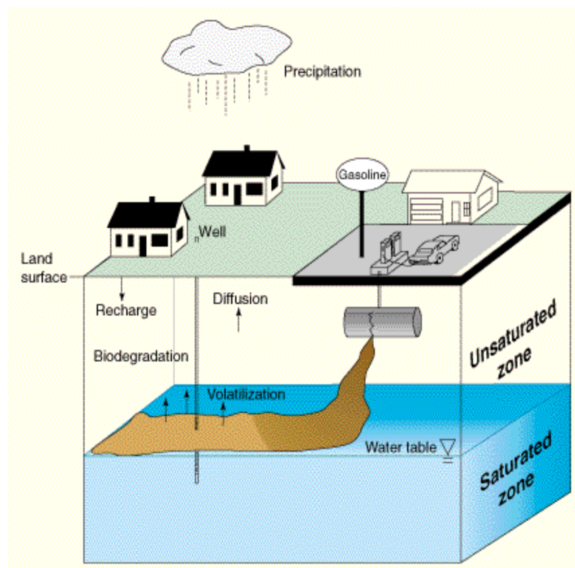


Illustration of a release from a gasoline storage tank with LNAPL floating on the groundwater table.

U.S. EPA has developed a Synthetic Precipitation Leaching Procedure (SPLP) (USEPA Method 1312) to simulate the leaching of compounds from contaminated soil and certain wastes as a result of precipitation infiltrating the ground surface. The SPLP test can be conducted on samples of soil or other materials from a brownfield site (e.g., debris). A defined amount of the material is mixed with laboratory grade water in a rotary agitator for a period of 18 hours. At the end of mixing, the water portion of the mixture is extracted for laboratory analysis to identify the resulting concentration in the leachate. These leachate concentrations or SPLP results are then compared to groundwater quality, surface water quality or to applicable site specific clean-up standards (compound concentrations that represent acceptable risk). If the SPLP result identifies compound concentrations in the leachate that are less than the clean-up standard, stormwater most likely can be infiltrated through the material as long as there were sufficient SPLP tests to properly characterize the material from a leachability standpoint.

Contaminants that are leachable or water soluble generally present relatively greater risks as compared with some other categories of contaminants, because the contaminants can be mobilized relatively easily through the soil from infiltrating stormwater and impact groundwater. Other contaminants, such as many metals, can bind to the soil and may be less likely to be mobilized by infiltrating stormwater. In considering whether infiltration practices are appropriate at a particular site, the nature of the contaminants present should be evaluated to assess if the contaminants are likely to be mobilized by the water moving through the soil. If there are leachable or water soluble contaminants present on a site, it is usually not advisable to locate infiltration practices over or near the contaminated areas. Volatile organic compounds, phenols, and herbicides are classes of compounds that are often highly water soluble.

Biodegradable waste materials (e.g., garbage) often produce gases and leachates that impact soil and groundwater. The rate in which leachates and gases are produced from biodegradable materials often is increased by the application of water. Therefore, stormwater management practices that promote infiltration are generally not advisable at sites where there are biodegradable materials in the ground.

Remedial measures are often planned at brownfield sites to prevent leachable or water soluble contaminants from spreading and impacting groundwater and/or surface waters. A common approach is to apply an impervious cap over the contaminated area. Other approaches include using the building footprint or impervious areas such as parking lots to prevent infiltration. Also, vertical barriers can be installed to prevent lateral groundwater flow and spreading leachable or water soluble compounds. If these or other remedial measures are planned, infiltration practices should only be considered if they do not negatively impact the operation of remedial measures proposed for the site (see question 5, below).

2. Is groundwater beneath the property impacted or could it become impacted?

Decisions regarding the appropriateness of implementing infiltration practices at a brownfield site must take into account if there are contaminants present on the site (question 1) and whether the groundwater beneath the site is contaminated. In some cases, groundwater under a site can be contaminated, even if those contaminants are not present on the site. This can happen for example when activities or site conditions at an upgradient property caused the groundwater to become contaminated.

Generally speaking, if the groundwater beneath a site is known to be contaminated, it is not a good idea to implement infiltration practices at the site. The movement of contaminants in groundwater can be accelerated by an infiltration practice potentially resulting in environmental impacts to neighboring properties. However, there could be situations where infiltration practices can be implemented, depending upon the specific circumstances, including the compounds and concentrations present in a groundwater plume. An example might be a situation where natural attenuation has been selected as the appropriate strategy for dealing with a groundwater plume with a low concentration of contaminants where there is little potential for off-site migration. Relatively clean rain water infiltrating down to the groundwater may have the effect of speeding up the natural attenuation process.

Following is a specific example when it could be a good idea to implement stormwater infiltration practices even though there is identified groundwater contamination in the area:

> *Stakeholders from a watershed partnership met with agency and city staff for an update on the cleanup of the Superfund sites, an area-wide groundwater problem that covers many square miles in the watershed. In response to questions about the impacts stormwater infiltration could have on the ongoing Superfund cleanup, Superfund and city staff pointed out that in some areas of the watershed stormwater infiltration and the resulting acceleration of pollutant mobilization would be beneficial for the groundwater cleanup if the pollutants are mobilized within the zone of influence of extraction wells used for groundwater remediation.*

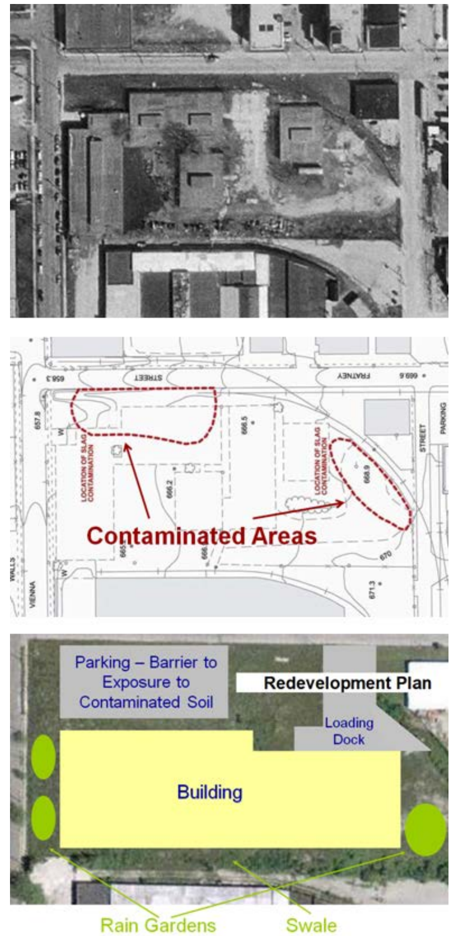
Close coordination between those considering infiltration projects and those managing the groundwater remediation is necessary to determine if/when an infiltration project may be beneficial. Situations where infiltration could aid in the remediation of certain contaminants in some environments should be discussed with EPA and/or the state remediation program.

When evaluating a site to determine if stormwater infiltration practices may be appropriate, it is important to consider whether or not groundwater is contaminated on an adjacent property and whether that property is located upgradient from the parcel where green infrastructure is being considered. Contamination from an upgradient property may eventually travel to the parcel. Decisions about whether to infiltrate stormwater when there is known groundwater contamination in the area should be made carefully on a case-by-case basis, taking into account the type of contaminants and whether infiltrating stormwater will affect environmental or human health risks.

Other appropriate stormwater practices can be designed that provide filtration (treatment) benefits and promote evapotranspiration, but not allow for infiltration. This topic is further discussed in the section below titled, “Stormwater Management without Infiltration.”

3. Are areas or parts of the property not impacted?

Often the entire brownfield property is not impacted or problematic material can be relocated to create an area that is not impacted by contamination. In planning to implement stormwater management at a brownfield site, the volume, location and thickness of contaminated areas should be reviewed. If an area of the site is not impacted or can be remediated to remove the contaminants, it may be appropriate to plan infiltration practices in such areas (see example at right). At this case study site, impervious surfaces -- barriers to exposure and to limit downward movement of contaminants in the soil as a result of rainfall and infiltration -- are placed over the areas with contamination and green infrastructure practices are located in other uncontaminated areas of the site.



Example redevelopment plan using green infrastructure while placing barriers over contaminated soils.

4. Are there State standards I can refer to as a guide in making decisions about infiltration practices?

Many states have developed soil concentration standards for various compounds for the soil to groundwater leaching pathway. See for example Tables1 and 2 below. Standards are continuously being updated and vary from state to state. Where soil standards/criteria have been established, such standards can be helpful in evaluating whether infiltration practices may be suitable at a particular site. However, it should be noted that in most cases the standards were developed based on typical rainfall amounts entering the soil profile. The standards as established generally do not take into account the relatively larger amounts of water that would move through the soil if infiltration practices are installed.

Table I: Generic Leach-Based Soil Values for Organic Chemicals
Ohio EPA Derived Leach-Based Soil Values

Chemical (Organics)	**Soil Type I** (mg/kg)	**Soil Type II** (mg/kg)	**Soil Type III** (mg/kg)
Benzene	0.017	0.0090	0.015
Toluene	6.8	4.1	7.7
Ethylbenzene	12	7.9	16
Total Xylenes	156	96	191
Styrene	0.46	0.37	0.62
Naphthalene	0.27	0.28	0.36
n-Hexane	121	111	104

Methyl Ethyl Ketone	1.8	1.8	1.8
Phenol	1.1	1.1	1.2
Carbon Tetrachloride	0.25	0.25	0.28
1,2-Dichloroethane	0.0030	0.0020	0.0030
1,1,1-Trichloroethane	1.2	0.74	1.3
Vinyl Chloride	0.0090	0.0050	0.012
1,1-Dichloroethene	0.28	0.10	0.24
cis-1,2-Dichloroethene	0.12	0.070	0.12
trans-1,2-Dichloroethene	0.41	0.23	0.40
Trichloroethene	0.036	0.023	0.048
Tetrachloroethene	0.15	0.11	0.27

Table 2: Generic Leach-Based Soil Values for Inorganic Chemicals
Ohio EPA Derived Leach-Based Soil Values

Chemical (Inorganics)	**Leach-based Value** for sources ≥ ½ acre (mg/kg)	**Leach-based Value** for sources< ½ acre (mg/kg)
Antimony	3.6	7.2
Arsenic	3	6
Barium	56,000	110,000
Beryllium	57	114
Cadmium	21	42
Chromium	56	113
Lead	89	178
Mercury	12	23
Nickel	182	363
Selenium	2.15	4.3
Silver	3120	6240
Thallium	1.5	3.0
Vanadium	130	65
Zinc	44,000	88,000

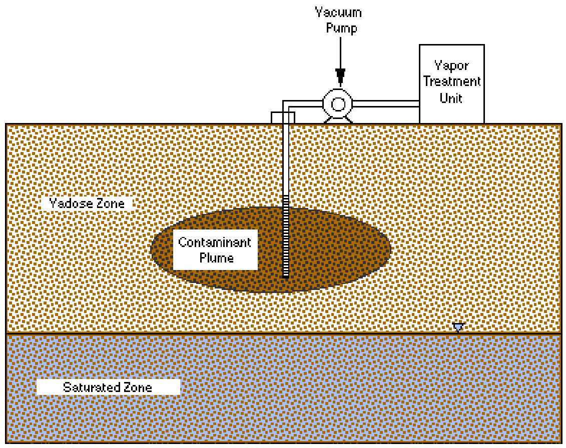
Notes on Tables 1 and 2:

1. Source: http://www.epa.ohio.gov/portals/30/vap/docs/sec-g-att.pdf
2. mg/kg – milligram of compound per kilogram of soil (by dry weight). Soil Type I is clean sand and gravel. Soil Type II is silty sand. Soil Type III is till/clay.
3. Values provided are examples only. Check the applicable requirements and criteria in your State. To learn more about practices in other states, the following website provides links to State brownfield programs: http://www.epa.gov/brownfields/state_tribal/state_map.htm.
4. Risk-based models/calculations can be used in some situations to provide information for decision-making about clean-up and re-use of brownfield sites. See for example http://www.deq.state.ok.us/factsheets/land/SiteCleanUp.pdf and/or http://www.nj.gov/dep/srp/guidance/rs/igw_intro.htm. Appropriate soil concentrations are calculated using standardized equations or models taking into account site-specific information. In certain situations allowable soil concentrations are calculated using computer models designed for modeling vadose zone contaminant migration based on relatively more extensive site-specific information on soil types, site conditions, and local climate. One of the factors normally considered in a risk-based model/analysis is the likelihood that groundwater could become contaminated. A model/analysis will oftentimes use regional rainfall data and site and soil characteristics to evaluate if it is likely contaminants will leach and groundwater could be at risk. It may be possible to adapt these methods to evaluate if implementation of infiltration practices at a brownfield site will pose a significant risk to groundwater resources. In adapting a model/method for this purpose, it will be important to take into account the fact that more stormwater would be draining through the soil if there are engineered infiltration practices, vs. what amounts would be draining through the soil just from precipitation falling on the site.

5. Will infiltration interfere with required remediation?

Decision-making about infiltration practices at a brownfield property should take into account any remedial actions planned for the site. For example, vertical barriers planned to keep contamination from moving laterally could be negatively impacted by installing infiltration practices nearby and increasing the pressure differential on the side where infiltration is increased. Increased hydraulic pressure on a vertical barrier could increase leakage through the barrier and reduce the effectiveness of the barrier over time.

Stormwater infiltration practices could in some situations also interfere with a soil vapor extraction system (SVE, see http://www.epa.gov/oust/cat/sve1.htm or http://www.frtr.gov/matrix2/section4/4-7.html). Such systems are commonly installed to reduce the vapor pressure beneath buildings to evacuate any vapor risk that may be caused by contaminants beneath the building. Increased infiltration can increase the moisture content of the vadose zone, raise the groundwater table, and reduce the size of the vadose zone. These changes can prevent the SVE system from operating properly and may result in high volumes of condensate from the vapor collected, which is commonly contaminated and requires proper handling, treatment and disposal.



Soil vapor extraction system schematic.

The planning and design of infiltration and stormwater management practices needs to be integrated with the overall site design and remediation planning at a brownfield property.

6. How does the site interact with other sites or land uses nearby?

Some brownfield sites are located near sensitive areas such as wellhead (public water supply) protection zones, rivers, lakes, fens, or wetlands. Where a site is near an area that is relatively more sensitive in terms of potential health risks or ecological risk, the need to protect these areas should be considered in making determinations about implementation of infiltration practices. For example, at a site immediately upgradient of a wetland or fen that is dependent on shallow groundwater inputs, an extra margin of safety may be appropriate in deciding whether to implement infiltration practices.

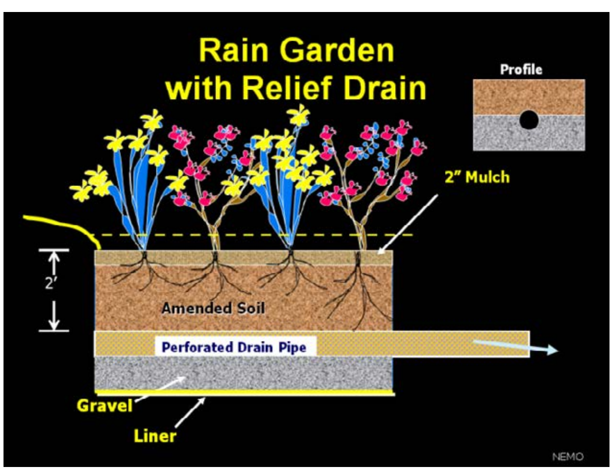

Too much stormwater routed into a forested wetland can harm the trees. Implementing infiltration practices upstream of the wetland may help protect it. (photo credit: Center for Watershed Protection)

Land use and site activities in or near areas where stormwater will drain to infiltration practices also should be evaluated. Some post-redevelopment land uses or site activities may present relatively greater risks than others. For example, if stormwater will be running off from a nearby gas station or industrial loading area and potentially draining to an infiltration practice, implementing the infiltration practice in this situation could present relatively greater risks to groundwater. Runoff from potentially contaminated areas should be routed to appropriate stormwater facilities which may include oil and water separators and other treatment facilities which do not encourage infiltration. Implementing an infiltration practice where the run-on may include dissolved contaminants is not advisable.

Understanding how the site will be redeveloped or reused in the future may affect decision-making regarding when infiltration may be appropriate or where practices should be located. For example, if the site will be used for above-ground petroleum storage tanks and dispensing fuel, this future use of the site should be taken into account in the evaluation of the appropriateness of implementing infiltration practices. For situations where there are above-ground tanks a spill prevention, countermeasure and control (SPCC) plan may be needed. SPCC plans provide for secondary containment and/or operational procedures and precautions to ensure that a spill is prevented and controlled in the event of a release. Installing infiltration practices in areas that could be impacted by a potential release, as identified in a SPCC plan, is generally not recommended.

Stormwater Management without Infiltration

When contaminants are present but at concentrations sufficiently low that they do not adversely affect site re-uses or cause risks to public health, stormwater management approaches that filter or treat stormwater, or which store and reuse stormwater, may be more appropriate vs. infiltration practices. In situations where infiltration would not be advisable, site planning and alternative BMP designs often can be used to achieve stormwater management goals.



Rain Garden with liner and underdrain. Designs such as this allow for filtration and evapotranspiration, but prevent infiltration into subsoils.

There are many methods to incorporate stormwater management at a brownfield site without directly infiltrating stormwater into the underlying soils. Typically a green infrastructure practice with plants, e.g., a rain garden, is used as a bioretention or *bioinfiltration* practice. The stormwater is treated or filtered by the soil and the plants, some water goes back into the air through evapotranspiration, and most of the water infiltrates into the soil. An alternative design that can be used when there is contamination present in subsoils is a rain garden with an impermeable liner and an underdrain or overflow pipe to convey excess water to a nearby storm sewer or point of discharge. This type of practice can be thought of as *biofiltration*. The plants and soil perform filtration and treatment functions, some evapotranspiration will occur, and the water that is conveyed to the sewer system or receiving water is cleaned. However, the water will not infiltrate through the contaminated soil toward the groundwater.

Green roofs and cisterns for rainwater harvesting can also be used at sites where there are contaminants of concern in the soil. These stormwater management practices help reduce the amount of runoff soaking into the ground or running off site, and can provide corollary benefits. For example, green roofs can help reduce urban heat island effects, and because they serve as an insulation layer can help reduce energy costs for a building. Using a cistern can provide water conservation benefits; stormwater that is collected during rain events can be used during dry weather periods to irrigate lawns and gardens, thereby helping to conserve potable water.

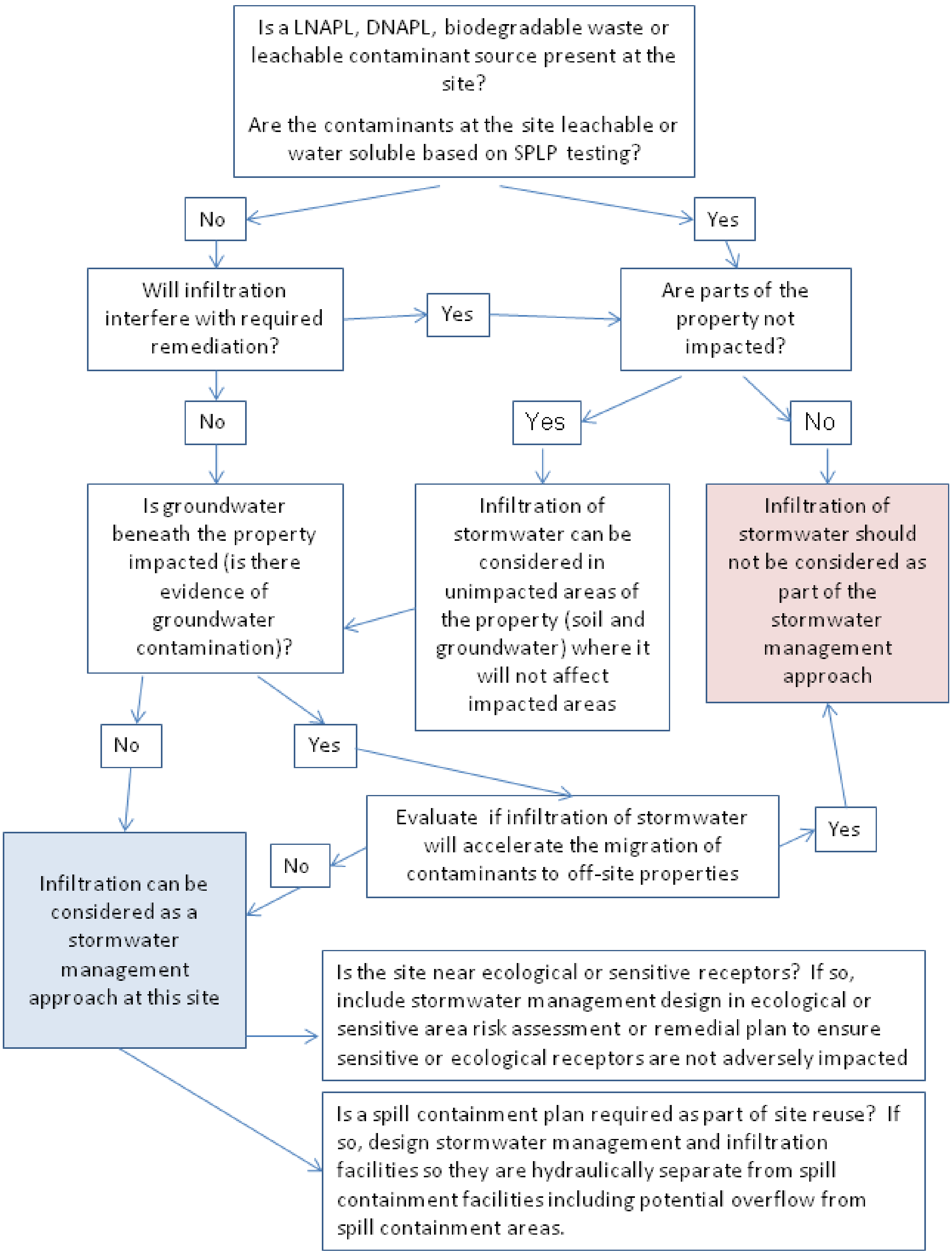
Summary

Stormwater infiltration practices can provide important benefits where implementation of such practices is feasible and environmentally protective. Benefits can include decreased stormwater infrastructure costs, increased groundwater recharge, and decreased stormwater runoff. Infiltration can be considered at infill redevelopment sites, vacant parcels, and brownfield sites, but care must be taken to evaluate the potential for stormwater infiltration to mobilize contaminants and contaminate groundwater. The decision tree presented on the following page is a graphical representation of the process for evaluating the potential to implement infiltration practices at a vacant parcel or brownfield site.

The identification of the location and size of the area where contaminant concentrations represent an unacceptable risk is crucial to the application of stormwater BMPs. The prior uses of a site and other information gathered through site assessments can provide valuable information for making decisions about the site suitability for infiltration practices. Where contaminants were or are present, soil testing can provide another layer of information valuable for decision-making.

Successful implementation of stormwater management and infiltration practices at brownfield sites requires careful planning. Stormwater management planning and implementation should be integrated with site investigation, State approvals, the selection of clean-up approaches and techniques, and the design and engineering of site improvements. Locating infiltration practices so that they do not mobilize contaminants requires a collaborative effort by team members responsible for delineating and defining the contamination, remedial engineering, site planning, and site design. At sites where infiltration practices are not advisable, it may be possible to use green infrastructure practices such as green roofs and biofiltration designs to manage stormwater and also protect groundwater.

Decision Flowchart for the Use of Stormwater Infiltration at Brownfield Sites



Resources

National Resources Conservation Service (NRCS), *"Soil Quality Indicators: Infiltration,"* USDA Natural Resources Conservation Service. January 1998.

Natural Resources Conservation Service (NRCS), *"Soil Quality Indicators,"* USDA Natural Resources Conservation Service. June 2008.

Southeast Michigan Council of Governments and Michigan Department of Environmental Quality, *"Low Impact Development Manual for Michigan – A Design Guide for Implementers and Reviewers*" (see "Implementing LID in Special Areas"), SEMCOG 2008.

U.S. EPA, Design *Principles for Stormwater Management on Compacted, Contaminated Soils in Dense Urban Areas.* http://www.epa.gov/swerosps/bf/tools/swdp0408.pdf

U.S. EPA, *Case Studies for Stormwater Management on Compacted,Contaminated Soils in Dense Urban Areas.* http://www.epa.gov/swerosps/bf/tools/swcs0408.pdf

U.S. EPA, *When are Stormwater Discharges Regulated as Class V Wells?* http://www.epa.gov/ogwdw/uic/class5/pdf/fs_uic-class5_classvstudy_fs_storm.pdf

U.S. EPA, *Brownfields and Urban Agriculture: Interim Guidelines for Safe Gardening Practices*. http://epa.gov/brownfields/urbanag/pdf/bf_urban_ag.pdf

University of Louisville, Sustainable Water Management on Brownfields Sites. http://louisville.edu/cepm/publications/practice-guides-1/PG32%20-%20Green%20Infrastructure%20on%20Brownfields.pdf/view

EPA Publication Number 905F13001

This document was developed by U.S. EPA staff and Tetra Tech, Inc. working under a contract with U.S. EPA.

Cover Image: Rendering of possible green infrastructure implementation at a vacant land parcel in Milwaukee. *Rendering courtesy of City of Milwaukee and Conservation Design Forum.*