Ground Water & Stormwater Management

Key Message

Contaminated stormwater is a major source of ground water and surface water degradation. Furthermore, land-development practices often create impervious surfaces that increase stormwater runoff and inhibit ground water recharge. A combination of approaches is needed to improve runoff quality and maximize quality recharge to ground water. These approaches include preventing the contamination of stormwater, minimizing impervious surfaces, segregating clean and contaminated stormwater, and applying best management practices (BMPs) that promote natural aquifer recharge and treat stormwater sufficiently before it is discharged to ground water.

***Top:** Construction of buildings, streets, and parking lots prevents rainfall from recharging soil and ground water. It also increases the rate of runoff and contributes to water pollution. This is an aerial view of San Francisco, California.*

***Left:** An unknown number of stormwater drainage wells (UIC Class V) such as this can be found throughout the country, discharging stormwater directly into ground water.*

Photo Credits. Top: Copyright © Bruce Molnia, Terra
Left: Oregon DEQ

Keeping on the Sunny Side of Stormwater Runoff

"Local governments nationwide are beginning to utilize Low Impact Development (LID) along with other storm water management approaches to deal with water quality problems associated with urban development and redevelopment. Many have revised their ordinances and building codes and incorporated these concepts into holistic growth-development plans. However, it is critical that they acknowledge and address the potential for transferring a problem from surface water to ground water. The key to protecting both surface and ground water is to make sure that we select best management practices that proactively address the generation and treatment of potential storm water contaminants before they enter the hydrologic cycle."

Mary Ambrose, P.G. | Water Policy Specialist | Texas Commission on Environmental Quality

why Stormwater matters to ground water…

While stormwater runoff is the natural result of a precipitation event, stormwater in urbanized watersheds greatly influences ground and surface water quality and quantity—not to mention the health of aquatic ecosystems. Whether it is rainwater or snowmelt, water has to go somewhere. In natural, undeveloped areas, a large percentage of relatively uncontaminated precipitation infiltrates the ground, thus recharging ground water; the remaining runoff flows to nearby water bodies or evaporates.

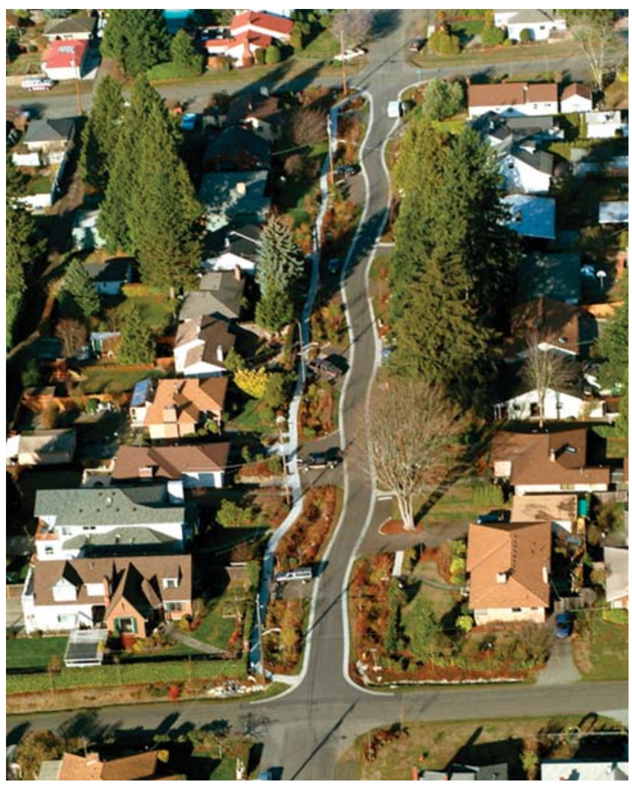


Photo: Stormwater magazine www.StormH2o.com

A redevelopment project in Seattle, Washington, includes a natural drainage system and a site-design strategy to treat and promote onsite stormwater infiltration. Such proactive approaches save communities and property owners money while reducing overall environmental impact.

Development alters natural systems as vegetation and open spaces are replaced with new areas of impervious surfaces, such as roads, parking lots, roofs, and turf, which greatly reduce infiltration and thus ground water recharge. A much larger percentage of precipitation becomes surface runoff, which moves across land areas at accelerated speeds, creating additional problems of soil erosion, flooding, and natural habitat destruction. Uncontrolled runoff also collects pollutants such as sediments, pathogens, fertilizers/ nutrients, hydrocarbons, and metals, which ultimately contaminate and degrade surface and ground water.

Photo: Michael Kedzierski

A stormy day in Salt Lake City, Utah.

Historically, stormwater hasn't received the same level of attention as other pollution sources, but it is now clear that this neglect can have serious consequences. So, taking their cue from nature, communities, planners, engineers, architects, and businesses have begun to identify practical ways to restore natural hydrology and prevent the contamination of our water resources.

Many innovative, effective, and earth-friendly stormwater management approaches are in practice already—and more are hitting the streets each day. Federal and state policies, guidance materials, and outreach efforts are turning this corner. USEPA and some states have embraced Low Impact Development (LID), which emphasizes reducing impervious areas, disconnecting impervious areas from one another, and treating stormwater so that it can infiltrate the ground near the source. The real challenge will be to make these approaches standard practice at the local level and to ensure that they are designed and maintained properly so that ground water is not degraded.

STORMWATER IN THE NATURAL ENVIRONMENT

In the natural environmental, the fate of stormwater is influenced by the timing of precipitation and/or melting, and by topography, geology, and land cover. Under natural hydrologic conditions, a large percentage of rainwater infiltrates soil or bedrock and replenishes ground water. Natural physical, chemical, and biological processes cleanse the water as it moves through vegetation and soil. Water that does not infiltrate the soil is taken up by plants (evapotranspiration), runs off into surface waters, or evaporates. Ground water, in turn, discharges to surface waters, such as rivers, streams, lakes, and wetlands. Stormwater is an integral part of the hydrologic cycle and the interplay between surface water and ground water. During periods of dry weather, ground water sustains stream baseflow and helps maintain freshwater wetlands and aquatic habitats.

Photo: Paul Jehn

STORMWATER IN THE URBAN ENVIRONMENT

In urbanized environments, the natural water cycle is drastically altered owing to a reduction in permeable

POTENTIAL STORMWATER IMPACTS TO GROUND WATER QUALITY AND QUANTITY

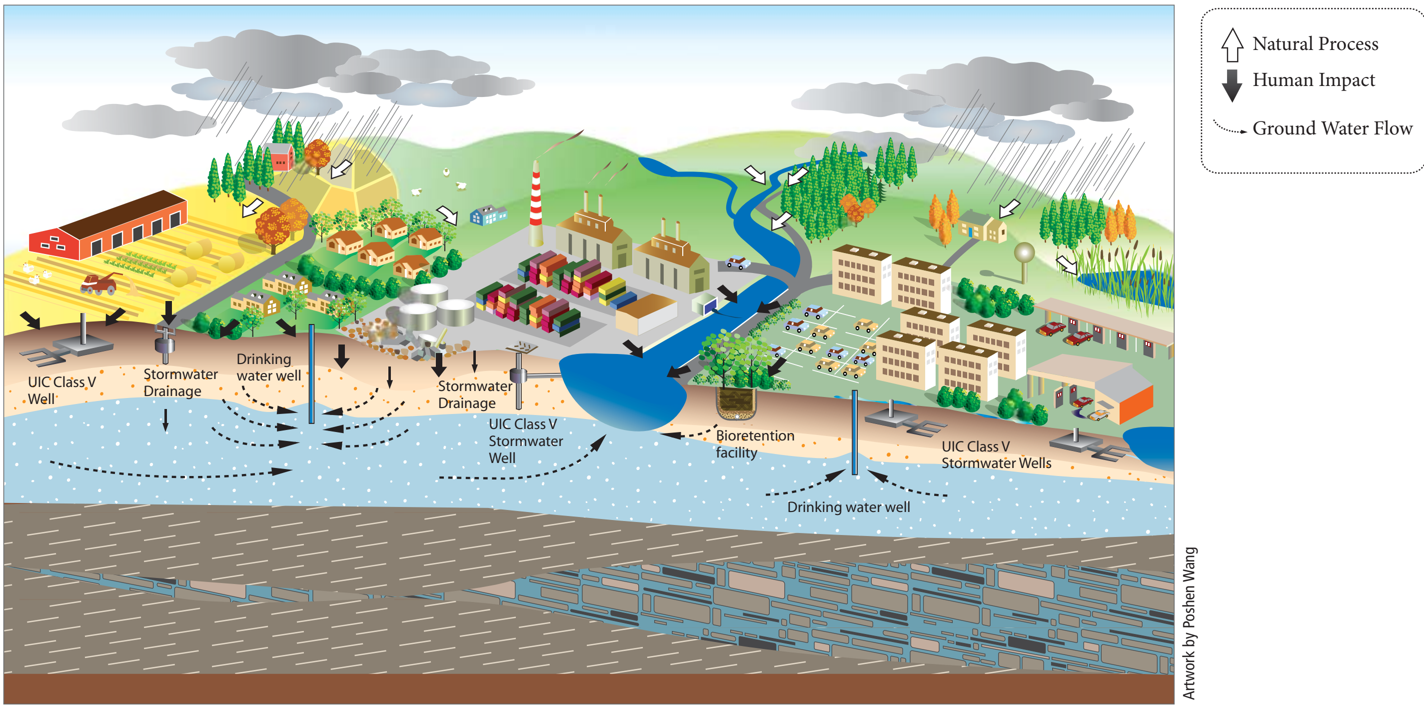


FIgure 1. *This diagram shows the many of the potential impacts on ground water from various land use types (e.g., agriculture, suburban, urban, industrial, commercial, protected areas) and the variety of paths contaminated stormwater can take to ground water (e.g., UIC Class V stormwater injection or drainage wells, bioretention facilities, land-surface runoff into rivers and streams, and land-surface infiltration into shallow aquifers). The interconnection between surface water and ground water is also shown as stormwater contaminants move between the two regimes. Showing the location of drinking water sources further demonstrates how stormwater contaminants can influence the water we drink.*

areas, such as fields and woodlands, and an increase in impervious surfaces, such as roads, rooftops, sidewalks, parking lots, concrete structures of all sorts, and compacted soils stripped of vegetation. The amount of stormwater runoff and concentrations of contaminants in stormwater runoff tend to increase with population density.

With increased impervious surfaces, less rain soaks into the ground, and less vegetation is available to soak up, store, and evaporate water. Impervious surfaces reduce ground water recharge, which leads to reduced stream baseflows. Impervious surfaces cause an increase in runoff volume and speed, which increases the frequency of high stream flow and associated flooding and erosion. Impervious surfaces also retain heat, which increases runoff temperatures and, in turn, surface water temperatures.

In the developed environment, stormwater also plays an active role in transporting contaminants. As stormwater flows over the land surface, it picks up materials such as debris, chemicals, oil and grease, dirt, road salt, sediment, fertilizers, bacteria, and animal wastes—which then enter water courses or infiltrate to ground water. The longer pollutants remain in the environment, shifting through different phases of the hydrologic cycle and building up in ponds and wetlands and, in some cases, basins designed to control stormwater, the greater the possibility that they will infiltrate and accumulate in ground water over time. Besides increasing pollutant loads in surface and ground water, contaminated stormwater can have adverse effects on people, plants, animals, fish, and the aquatic ecosystem as a whole.

STRATEGIES FOR REDUCING STORMWATER IMPACTS

Traditional stormwater management techniques use devices such as gutters, drains, and pipes to collect runoff from impervious surfaces and convey it to various discharge points, often by way of detention basins or other treatment structures. As a result, large

MICHIGAN GROUND WATER STEWARDSHIP PROGRAM SPREADING THE WORD ON ECO-FRIENDLY LAWN CARE

Half of Michigan's residents rely on ground water for their drinking water. That's why the Michigan Ground Water Stewardship Program (MGSP), within the Michigan Department of Agriculture's Environmental Stewardship Division, has been created as a cooperative effort designed to reduce the risks of ground water contamination associated with the use of pesticides and nitrogen fertilizers. The program is funded through fees that are assessed on sales of pesticides and nitrogen fertilizers. More than $3 million annually is distributed through a competitive grants process to local stewardship teams that set local ground water protection priorities based on local needs.

The MGSP, which is voluntary, locally driven, and designed to address the concerns of individuals, offers community outreach and education throughout the state to address a number of ground water-related issues, including environmentally friendly lawn care. With the goal of educating everyone, not just farmers, MGSP seeks to enlighten residents that what they do on their property can have an impact far beyond it.

Lawn care practices are a major source of stormwater runoff and ground and surface water pollution. Residents learn that fertilizers and pesticides applied on their on land can move off site and eventually get into the waters that make up their watershed. Rather than just putting an ordinance in place, MGSP helps homeowners evaluate their lawn management in light of its impact on water resources. They learn about relatively simple things they can do to help the environment—starting with their own lawns and yards. MGSP's tips include:

- Use native plants to create "rain gardens" near storm drains in their yards and natural buffer strips along shorelines and drainage ditches to filter out pollutants before they reach the watershed.
- Before purchasing fertilizer, have a soil test done to determine soil needs.
- Maintain septic systems properly and locate compost piles far from waterways,
- Cut grass high, at about 3 to 4 inches. (Studies performed at Michigan State University's Hancock Turfgrass Research Center show that with a higher cut, lawn quality is improved and nutrients and other contaminants are kept on the property, rather than running off. A higher cut also reduces weed competition, improves drought tolerance and promotes beneficial insects.)
- Mulch fallen leaves into the lawn and return clippings to the turf to recycle the nutrients.

For more information, go to:
http://www.kbs.msu.edu/mgsp/

volumes of untreated or minimally treated stormwater rapidly discharge into ground and surface waters.

There are better ways to manage stormwater that aim to replicate the predevelopment hydrology of a site. These approaches also seek to mimic nature's processes for treating stormwater. In this scenario, stormwater management becomes an integral part of site and building design, rather than an afterthought.

This new stormwater management paradigm can be found under the umbrella of Low Impact Development (LID), pioneered in Prince George's County, Maryland. LID is a hydrology-based approach to land development that is designed to reduce impacts on watersheds and other aquatic resources through the

A rain garden in the Marcy Holmes Neighborhood of Minneapolis, Minnesota. Rain gardens are designed to slow down, capture, and absorb water using elements similar to those in nature—plants, rocks, shallow swales and depressions—that hold water temporarily rather than let it quickly drain or run off. Rain gardens reduce drainage and flooding problems, keep pollutants out of the nearby streams, rivers, and lakes, and bring beauty and wildlife to the landscape.

Photo: Dawn Easterday

use of a variety of best management practices (BMPs). It is based on the premise that natural systems can accomplish a great deal if they are not overwhelmed with large volumes of stormwater or inordinate pollutant loadings.

A key aspect of LID is reducing the amount of impervious surface on development sites, thus reducing the amount of runoff that must be managed. This approach relies on thoughtful site design, decentralized stormwater management, native vegetation, landscaping, and small-scale hydrologic controls designed to minimize, capture, treat, and infiltrate stormwater.

LID stormwater BMPs can involve one or a combination of strategies. For example:

- Reducing impervious surfaces to decrease surface runoff and promote stormwater infiltration into the ground. This often involves protecting and encouraging trees and open space, minimizing pavement, and using permeable surfaces (e.g., permeable pavement, turf block, gravel).
- Disconnecting impervious areas by directing runoff elsewhere (e.g., directing residential downspouts to landscaped areas or rain barrels, and eliminating roadside curbs, where appropriate, to allow water to run off over the shoulder).
- Intercepting stormwater by capturing rainwater before it comes into contact with an impervious surface (e.g., trees, ecoroofs, roof gardens).
- Detaining and infiltrating stormwater in small vegetated areas, allowing it to soak into the ground or move more slowly into the storm system (e.g., planter boxes, infiltration basins, swales, soakage trenches, drywells, rain gardens).

LID seeks to design the developed environment so that it remains a functioning part of the hydrologic system. It provides technological tools to plan and develop most types of urban sites to maintain or restore a watershed's hydrologic and ecological functions. It is an important means for maintaining stream baseflows, minimizing loss of recharge to aquifers, maintaining stream and wetland buffers, addressing flood concerns, and reducing stormwater pollutant loads from developed areas.

Photo: http://commons.wikimedia.org/wiki/Image:North-Bend-Uplands-Runoff-pond-3942.jpg

A system of stormwater infiltration ponds in the Uplands neighborhood of North Bend, Washington.

It is important to note, however, that while many LID techniques effectively manage stormwater, they are not always applied from the perspective of potential impacts to the three-dimensional watershed, which includes ground water. Without considering ground water, even LID techniques can allow polluted stormwater to impact ground water.

RECHARGE WITH CARE

While the LID approach has both strong environmental benefits and great possibilities to enhance the developed landscape, it can pose a threat to ground water if we are not careful. As discussed earlier, stormwater, particularly from urban areas, contains high concentrations of contaminants that may not be adequately removed or attenuated when stormwater is infiltrated into the ground. As techniques that capture, treat, and infiltrate stormwater onsite continue to be developed, improved, and widely used, federal and state regulators and local communities must keep in mind these potential impacts by considering aquifer sensitivity, the quality of stormwater, and the potential impact of stormwater on ground water.

Infiltration drainage systems typically allow stormwater from impervious surfaces to be temporarily stored and then released into ground water over a period of time. However, a New Jersey study found that "infiltration of storm water through detention and retention basins may increase the risk of ground water contamination, especially in areas where the soil is sandy and the water table shallow, and contaminants may not have a chance to degrade or adsorb onto soil particles before reaching the saturated zone" (Fischer et al., 2003).

An 18-month study monitoring swales and detention pond systems receiving stormwater runoff from interstate highway, residential, and commercial land-use areas in Florida found that most stormwater can likely be infiltrated with minimal impacts (Harper, 1988). The study indicated that removal processes in soils are likely to reduce most infiltrated pollutants; however, some pollutants are more likely to cause problems than others, and these must be more carefully considered in infiltration projects. The author cautions that critical pollutant source areas should be avoided and that pretreatment before infiltration to remove particulate forms of the pollutants should be considered.

Photo: Dawn Easterday

This development project in Minnesota uses several methods of managing stormwater to mitigate negative impacts to water quality. The grassy swale area provides filtration before stormwater recharges the underlying aquifer.

Concerns associated with stormwater infiltration involve the design life of the systems and the potential to contaminate ground water if they are not applied appropriately and monitored and maintained so they function as intended. Earlier generations of infiltration BMPs (e.g., infiltration trenches, retention ponds) tended to clog with silt, largely because they were not properly sited, designed, installed, or maintained. Once clogged, such systems do not work and may even degrade surface water quality by allowing resuspended sediment to run off into receiving waters. (NHDES, 2001)

A big issue is that while there is more and more interest in using infiltration BMPs, we have relatively little information on the transport of pollutants around and through infiltration systems. What is the risk to ground water resources from recharging polluted stormwater? There are situations where infiltration is simply not suitable because the potential to contaminate ground water is too great (e.g., stormwater from industrial sites, petroleum storage facilities).

Photo: Cassie D'Alessandro

Photo: whizchickenonabun

A study by Robert Pitt and colleagues (1994) found that some pollutants in stormwater may have an impact on ground water in certain circumstances. These pollutants include nutrients (e.g., nitrates), pesticides (e.g., lindane and chlordane), other organics (e.g., 1,3-dichlorobenzene, pyrene, fluoranthene, VOCs), pathogens, heavy metals (e.g., nickel and zinc), salts (e.g., chloride, road salts). (See Table 1.)

Pollutant threats vary with land uses and human activities. For example, as detailed in the study, pesticides tend to be found in urban runoff from residen-

Rain in Fisherville, Kentucky, and a strip mall in Lexington, Kentucky. Ground water quality in Kentucky is generally good; water quality is directly related to land use, geology, ground water sensitivity, and well construction. Nonpoint-source impacts on ground water quality from anthropogenic sources occur primarily from nutrients and pesticides associated with agricultural activities. In addition, urban sprawl and stormwater runoff impact karst aquifers and improper stormwater injection in karst areas also impacts local karst ground water quality.

POTENTIAL OF STORMWATER POLLUTANTS TO CONTAMINATE GROUND WATER

					Contamination Potential		
Pollutants	*Compounds*	*Mobility (sandy/low organic soils)*	*Abundance in Stormwater*	*Fraction Filterable*	*Surface Infiltration and No Pretreatment*	*Surface Infiltration with Sedimentation*	*Subsurface Injection with Minimal Treatment*
Nutrients	nitrates	mobile	low/moderate	high	low/moderate	low/moderate	low/moderate
Pesticides	2,4-D	mobile	low	likely low	low	low	low
	γ-BHC (lindane)	intermediate	moderate	likely low	moderate	low	moderate
	malathion	mobile	low	likely low	low	low	low
	atrazine	mobile	low	likely low	low	low	low
	Chlordane	intermediate	moderate	very low	moderate	low	moderate
	diazinon	mobile	low	likely low	low	low	low
Other Organics	VOCs	mobile	low	very high	low	low	low
	1,3-dicloro-benzene	low	high	high	low	low	high
	anthracene	intermediate	low	moderate	low	low	low
	benzo(a) anthracene	intermediate	moderate	very low	moderate	low	moderate
	bis(2-ethylhexyl) phthalate	intermediate	moderate	likely low	moderate	low	moderate
	butyl benzyl phthalate	low	low/moderate	moderate	low	low	low/moderate
	fluoranthene	intermediate	high	high	moderate	moderate	high
	fluorene	intermediate	low	likely low	low	low	low
	naphthalene	low/inter.	low	moderate	low	low	low
	pentachlorophenol	intermediate	moderate	likely low	moderate	low	moderate
	phenanthrene	intermediate	moderate	very low	moderate	low	moderate
	pyrene	intermediate	high	high	moderate	moderate	high
Pathogens	enteroviruses	mobile	likely present	high	high	high	high
	Shigella	low/ inter.	likely present	moderate	low/moderate	low/moderate	high
	Pseudomonas aeruginosa	low/ inter.	very high	moderate	low/moderate	low/moderate	high
	protozoa	low/ inter.	likely present	moderate	low/moderate	low/moderate	high
Heavy Metals	nickel	low	high	low	low	low	high
	cadmium	low	low	moderate	low	low	low
	chromium	inter/very low	moderate	very low	low/moderate	low	moderate
	lead	very low	moderate	very low	low	low	moderate
	zinc	low/very low	high	high	low	low	high
Salts	chloride	mobile	seasonally high	high	high	high	high

Table 1. *A summary of the pollutants found in stormwater that may cause ground water contamination problems for various reasons. Source: Robert Pitt et al., 1994.*

tial areas, especially in dry weather flows associated with landscaping irrigation runoff. Volatile organics are mostly found in industrial areas. Zinc is often found in roof runoff and areas where galvanized metal comes into contact with rainwater. Road salts are at their greatest concentrations in snowmelt and early spring runoff in northern areas.

The Pitt study emphasizes that control of these compounds requires various approaches, including source-area controls, end-of-pipe controls, and pollution prevention. However, "with a reasonable degree of site-specific design considerations to compensate for soil characteristics, infiltration may be very effective in controlling both urban runoff quality and quantity problems." In keeping with the LID approach to stormwater management, the study encourages use of the natural filtering and sorption capacity of soils to remove pollutants, but cautions that the potential for some types of urban runoff to contaminate ground water through infiltration requires some restrictions, including adequate pretreatment or diversion of polluted waters away from infiltration devices.

Stormwater infiltration is of greater concern now because federal stormwater requirements under the National Pollutant Discharge Elimination System (NPDES) encourage infiltration of stormwater as a means of avoiding an NPDES permit for a discharge to surface water, and because more states are recognizing the potential for reducing hydrologic impacts of urbanization by recharging a prescribed amount of stormwater.

LEMON GROVE, CALIFORNIA'S, STANDARD URBAN STORMWATER MITIGATION PLAN (SUSMP) INCLUDES RESTRICTIONS ON INFILTRATION

The City of Lemon Grove, California, has adopted a local ordinance that includes the guidance contained in USEPA's *Potential Ground Water Contamination from Intentional and Non-Intentional Stormwater Infiltration* (EPA/600/R-94/051). Step 10 of the ordinance addresses restrictions on the use of infiltration BMPs. This provision states that three factors significantly influence the potential for urban runoff to contaminate ground water: pollutant mobility, pollutant abundance in urban runoff, and the soluble fraction of the pollutant. The risk of ground water contamination may be reduced by pretreating urban runoff. At a minimum, stormwater infiltration BMPs must meet the following conditions:

- Urban runoff from commercial developments must undergo pretreatment to remove both physical and chemical contaminants prior to infiltration.
- All dry weather flows must be diverted from infiltration devices.
- Pollution prevention and source control BMPs must be implemented at a level appropriate to protect ground water quality at sites.
- The vertical distance from the base of any infiltration structural treatment BMP to the seasonal high ground water mark must be at least 10 feet.
- The soil through which infiltration occurs must have physical and chemical characteristics that are adequate for proper infiltration durations and treatment of urban runoff for the protection of ground water beneficial uses.
- Structural infiltration treatment BMPs may not be used for areas where there is industrial or light industrial activity and other areas where there is a high threat to water quality land uses and activities.
- The horizontal distance between the base of any infiltration structural BMP and any water supply wells must be 100 feet.

Where infiltration BMPs are authorized, their performance must be evaluated for impacts on ground water quality. In those instances where the City has determined that implementation of proposed infiltration BMPs has the potential to impact ground water quality in another jurisdiction, the City may require that a notification be placed upon those proposing such use in addition to the required protection measures.

Source: www.ci.lemon-grove.a.us/documentview.asp?DID=97

THE UNIVERSITY OF NEW HAMPSHIRE STORMWATER CENTER

DEDICATED TO PROTECTING WATER RESOURCES THROUGH EFFECTIVE STORMWATER MANAGEMENT

The UNH Stormwater Center, funded by the National Oceanic and Atmospheric Administration (NOAA) through a grant from the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET), studies stormwater-related water quality and quantity issues. The center's mission is to:

- Test stormwater control measures.
- Disseminate test results and evaluations.
- Demonstrate innovative stormwater management technologies.

One unique feature is its field research facility used to evaluate and verify the performance of stormwater management devices and technologies.

This facility serves as a site for both testing stormwater treatment processes and performing technology demonstrations. The testing results and technology demonstrations serve a vital role for municipalities, town engineers, and others charged with developing and implementing stormwater management plans. The purpose of the stormwater management plans is to reduce nonpoint-source pollution, the nation's single largest water quality problem.

The research facility houses three categories of stormwater treatment processes: conventional structural devices, low-impact development designs, and manufactured devices. In addition to its main field facility, center researchers are planning two other field projects: a porous pavement parking lot (already built and being tested) and a street-vacuuming study. Both of these projects represent measures to treat and/or minimize stormwater at the source, rather than after it is collected.

The center's research program has three main objectives: (1) to provide rigorous independent evaluations of stormwater treatment technologies, (2) to aid municipalities and others charged with developing and implementing stormwater management plans in compliance with Phase II of the Clean Water Act, and (3) to address concerns that have surfaced as the result of research.

Visit the UNH Stormwater website at: *www.unh.edu/ erg/cstev/*

An assortment of stormwater treatment technologies.

Photos: University of New Hampshire Stormwater Center

FEDERAL STORMWATER REGULATION

In 1987, Congress amended the Clean Water Act to create, in two phases, a comprehensive national program for addressing stormwater discharges. Phase I extended the National Pollutant Discharge Elimination System (NPDES) to require permits for stormwater discharge from a large number of priority sources, including medium and large municipal separate storm sewer systems (MS4s) that serve urbanized areas and several categories of industrial activity, including construction activity.

The Stormwater Phase II Final Rule (December 1999) expands the Phase I program by requiring operators of smaller systems and small construction sites to implement programs and practices to control stormwater runoff. Under Phase II, hundreds of urbanized communities, as well as institutions (e.g., public universities, state highway facilities, prisons) that have separate storm sewer systems are regulated. To comply, they must develop comprehensive stormwater management programs that include:

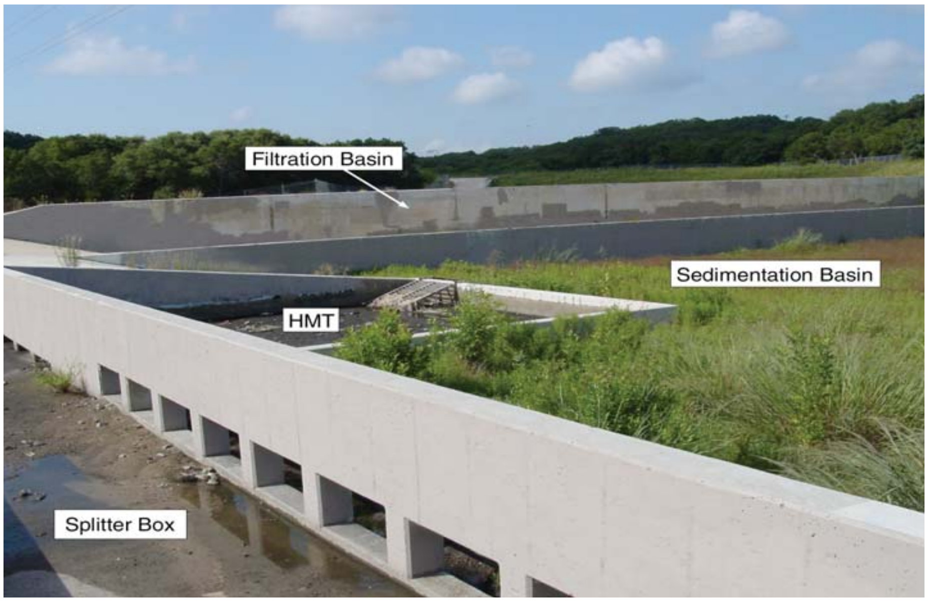
- Educating and involving the public.
- Finding and removing illicit discharge connections such as sanitary sewage being routed into storm sewers.
- Controlling runoff from construction sites during and after construction.
- Preventing stormwater pollution at municipal facilities.

WHO REGULATES STORMWATER RECHARGE?

States can and do play an important role in controlling and overseeing stormwater discharges to ground water. In a 2005 Ground Water Protection Council (GWPC) survey of state regulatory personnel, more than half of the states that responded indicated that they encourage stormwater infiltration, where feasible, over surface discharge.

The majority of responders indicated that some type of authorization is needed for installing units designed to direct stormwater into the subsurface, both infiltration systems and direct discharge systems. The type of authorization required ranges widely, from UIC rule authorization to different permitting mechanisms, such as sensitive area permits, stormwater general permits, or individual permits. Several states have enhanced protection/restrictions for introducing stormwater into the subsurface (more protective or otherwise segregated) in or near source water protection areas, wellhead protection areas, vulnerable aquifers, or other sensitive ground water areas.

Site-specific case studies have documented ground water contamination from stormwater drainage wells. States need this information in order to regulate stormwater discharges to ground water in a way that maintains ground water availability while preventing contamination. USEPA's current stormwater guidance, *Potential Ground Water Contamination*



Storm water structures along roadways can capture hazardous materials from catastrophic spills (either intentional or unintentional). This photo shows how a hazardous materials trap (HMT) can be sited within the footprint of the storm water control structure (a sand filter in this case) to both treat stormwater and collect hazardous material. Note that the invert of the openings from the splitter box to the HMT is set slightly lower than that of the openings into the sedimentation basin, allowing any hazardous spills as well as the first flush of runoff to be captured by the HMT. Once the HMT is full, the backwater level rises and allows the remaining runoff to enter the sedimentation basin directly. HMTs must be drained after a rain event (either manually or by use of an automatic siphon device).

Photo: USGS

Infiltration basins can be a very effective technique for controlling urban runoff quality and quantity problems. However, because of the potential for some types of urban runoff to contaminate ground water through infiltration, some restrictions are needed, including site-specific designs that consider soil characteristics.

from Intentional and Nonintentional Stormwater Infiltration (Pitt et al., 1994), developed under the NPDES stormwater program, is probably not sufficiently protective of ground water. For example, the guidance promotes the use of Class V stormwater drainage wells as BMPs to prevent the release of pollutants to surface waters. However, the placement of diverted stormwater underground via such wells may endanger underground sources of drinking water.

States need state-of-the-art technical and best management practices guidance to protect ground water from stormwater discharges. At a minimum, a complete compilation and synthesis of case studies on ground water contamination from stormwater discharges is needed. It is inefficient for the states to individually research this subject whenever they are revising their stormwater rules and/or guidance, when much of the same research could be applied nationally.

Another federal and state regulatory issue related to ground water impacts from stormwater is the definition of Underground Injection Control (UIC) Class V wells. Based on the definition published in the 1999 Class V Rule, stormwater Class V wells include stormwater drainage structures that are wider than they are deep, such as improved sinkholes and subsurface fluid distribution systems.

Yet there are still some categories of stormwater drainage structures that fall into a gray area as to whether they are considered Class V wells. Thus, they may present risks to underground sources of drinking water similar to those posed by Class V stormwater drainage wells. Federal and state UIC Class V Programs and NPDES Stormwater Programs must work together to clarify such issues and educate communities on how to best manage and regulate stormwater to protect all water resources effectively.

Photo: David Gleason - http://www.flickr.com/photos/mindfrieze/217930914/ Photo: Susanne Jespersen

Two green roofs in Chicago, Illinois. In addition to their ecological, aesthetic, and temperature-moderation values, green roofs dramatically reduce the volume of stormwater runoff and the peak flow rate. Rapid runoff from roof surfaces can result in flooding, increased erosion, and the discharge of contaminants directly into surface and ground water. A green roof can absorb stormwater and release it slowly over a period of several hours. The bottom photo shows a prairie twelve stories up on the roof of Chicago's City Hall.

THE STORMWATER UTILITY ALTERNATIVE

An alternative to private ownership with public oversight of stormwater BMPs is for the municipality to take ownership and maintenance responsibility for all stormwater BMPs, assessing an annual fee to cover all costs (e.g., maintenance, repair). A growing number of communities nationwide have established stormwater utilities so they can assess fees to fund their stormwater systems and annual maintenance costs and provide a wide range of services. The utility approach may, in fact, be one of the most effective ways to ensure BMP maintenance and consequently intended performance.

Washburn, Wisconsin's, Storm Water Management Utility

Until the heavy rainfalls of 2000 and 2001, which caused considerable public and private property damage, the City of Washburn, Wisconsin, was able to ignore stormwater management issues. With each passing storm, however, it became more apparent that existing stormwater conveyance systems could not handle regularly occurring runoff and that long-range plans and the use of appropriate BMPs were needed to minimize future problems.

Washburn needed a stormwater management system that would retain water on the properties that generate storm water, wouldn't overload conveyance and handling systems, and would eliminate flooding and minimize environmental degradation, thereby improving living conditions in the city. Regardless of their location in the watershed, the city recognized that all properties have an impact on stormwater drainage and that stormwater needed to be viewed from a total management perspective. Much research and deliberation made it clear that a stormwater utility would allow for such an approach.

The City of Washburn's Storm Water Management Utility went into operation in 2006. It is self-supporting, just like the city's water and wastewater utilities. Revenue collected from utility services is dedicated solely to stormwater management. The monthly utility fees pay for the operation, maintenance, and capital improvements of the system. The charge also provides an incentive for the largest generators of storm water—commercial, industrial, and institutional properties—to incorporate BMPs within their properties.

Source: http://www.cityofwashburn.org/storm.htm

One factor that may have a bearing on how states approach stormwater infiltration is a determination as to whether infiltration is considered to be an "aquifer recharge system" or a "stormwater disposal system." The GWPC survey indicates that the majority of states view stormwater infiltration as disposal, suggesting that recharge is not addressed with the same level of concern for ground water as it would if it were treated as a drinking water source. State drinking water, UIC, and stormwater regulatory programs need to coordinate the manner in which they control stormwater discharges to ground water. They also need stormwater monitoring (surface or ground water) requirements for units that infiltrate or directly discharge stormwater to ground water.

LOCAL REGULATION IS THE KEY TO STORMWATER MANAGEMENT

The day-to-day work of managing stormwater rests, for the most part, with local governments. In fact, communities may have several stormwater requirements that they must meet. For example, the federal NPDES Stormwater Phase II requirements require many urban communities to develop comprehensive stormwater management programs. States may also have comprehensive stormwater management policies or requirements that communities must meet. However, both must have a ground water component to be fully effective.

But when it comes right down to it, communities need to develop their own comprehensive stormwater management programs. Local governments are making the land-use decisions that will either make or break the health and well-being of their water resources. Local governments need to recognize that they have this responsibility and develop storm sewer management programs that address the following issues:

- How to assess existing stormwater patterns.
- How to mitigate existing runoff threats to source water areas.
- How to ensure that future development will not exacerbate stormwater impacts in the water supply watershed.
- How to take into account the cumulative impacts of runoff on the water supply region or watershed.
- How to change public and political attitudes toward the value of and need for an effective stormwater management program.
- How to fund an effective stormwater management program.

Abacoa, Florida's, stormwater runoff is managed within a greenway system that provides filtration and allows recharge locally. The higher density homes allow the developers to preserve more open space.

Source: http://www.epa.gov/smartgrowth/case/abacoa_p2.htm

Recommended Actions

To USEPA:

- **Establish better coordination among federal stormwater management, ground water protection, underground injection control (UIC), and water-quality monitoring programs so that programmatic overlaps and opportunities for collaboration in protecting surface and ground waters can be identified and initiated.**

- **Accord the protection and recharge of ground water and protection of surface water equal importance when regulating and providing guidance to state stormwater programs. For example:**
  - Develop and field-test BMPs specifically designed to manage stormwater in a manner protective of ground water in different hydrogeological settings (e.g., karst, sand and gravel).
  - Ensure that states may utilize §319 funds to conduct research and demonstration projects, and to develop and field-test BMPs specifically designed to manage stormwater in a manner that is protective of ground water.

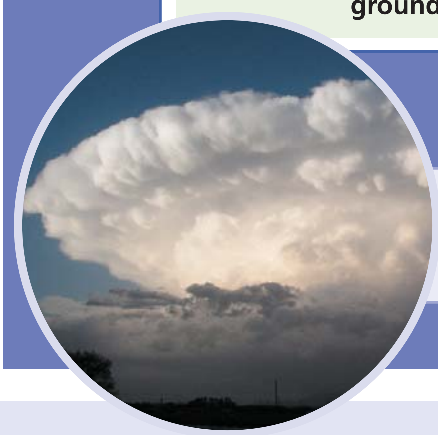
To State Agencies:

- **Establish better coordination among stormwater management, ground water protection, underground injection control (UIC), and water quality monitoring programs so that programmatic overlaps and opportunities for collaboration in protecting surface and ground waters can be identified and initiated.**

- **Review stormwater management plans and total maximum daily load (TMDL) determinations from a ground water program perspective to ensure protection and conservation of the resource.**

To Local Governments:

- **Protect all water resources through local stormwater management activities, and require the use of stormwater BMPs (including ongoing maintenance and monitoring), stormwater utilities, and stormwater management plans that are designed to conserve and protect both surface water and ground water and promote natural ground water recharge.**



A thunderstorm over Chaparral, New Mexico.

Photo: Greg Lundeen

Source: http://www.srh.noaa.gov/elp/swww/v8n1/Chaparral%20Supercell%202.JPG

Section 6 References: Ground Water and Stormwater Management

Fischer, David, E. G. Charles, A. L. Baehr. May 2003. "Effects of Stormwater Infiltration on Quality of Ground water Beneath Retention and Detention Basins" *Journal of Environmental Engineering* 129, no. 5.

GWPC. 2005. *State Regulation and Research on Storm Water Impacts to Ground Water.*

Harper, H. H. 1988. *Effects of Stormwater Management Systems on Groundwater Quality.* Final Report to the Florida Department of Environmental Regulation. Available at: *http://stormwaterauthority.org/assets/115PGroundwater.pdf* (accessed July 2007).

NHDES. 2001. *Managing Stormwater as a Valuable Resource* . Available at: *www.des.state.nh.us/dwspp/stormwater.pdf* (accessed July 2007).

Pitt, Robert, S. Clark, K. Parmer. 1994. *Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration.* USEPA. EPA/600/SR-94/051 Available at: *http://www.p2pays.org/ref/07/06744.pdf*

Stormwater-Related Websites:

USEPA Stormwater website: ht*tp://cfpub.epa.gov/npdes/home.cfm?program_id=6*

National Stormwater BMP Database: *www.bmpdatabase.org*

Bioretention and Stormwater ResearchPublications: *http://www.ence.umd.edu/~apdavis/LID-Publications.htm*

Low Impact Development Center: *http://www.lowimpactdevelopment.org/*

Stormwater journal: *http://www.forester.net/sw.html*

Stormwater Authority: *http://www.stormwaterauthority.org/*

Suggested Reading

Low-Impact Development Design Strategies An Integrated Design Approach. EPA 841-B-00-003.

Low-Impact Development Hydrologic Analysis. EPA 841-B-00-002.

Using Smart Growth Techniques as Stormwater Best Management Practices. EPA 231-B-05-002.

Photo: Daniel Rehn

Ground water is a crucial resource for Hawaii. It provides over 90% of the fresh drinking water for island residents and is used for commercial, agricultural, recreational, industrial, and thermo-electric power activities. Precipitation, the source of Hawaii's fresh ground water, is naturally filtered as it infiltrates through the soil. Favorable geologic factors (i.e., the content, structure and extent of Hawaii's volcanic rock) and hydrologic factors (i.e., reliable rainfall, recharge capacity, recharge rates) contribute to the high quality of ground water. The state also manages stormwater quality through its nonpoint-source pollution control program, protecting ground water by controlling surface water pollution, recognizing the interconnection between surface and ground water.