Intro to Green Stormwater Infrastructure

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Water always wins. That's a simple truth regarding flooding. Green Stormwater Infrastructure (GSI) is designed to help balance the odds by using systems that recreate natural processes to reduce stormwater runoff. GSI is based on the fact that nature is the best way to "control" water. However, it takes a lot of undeveloped space to replicate natural systems (such as marshes), something by definition that urban areas do not have. Therefore, science must step in to develop substitutes. And law must make it happen.

Green Stormwater Infrastructure, Generally

Green stormwater infrastructure is said to do three things to runoff from rainstorms: slow it down, spread it out, and clean it up. Think of the difference of how water travels down a paved driveway versus how it moves across the grass-covered yard next to the driveway. By slowing the speed of the water as it goes downhill, GSI makes it less likely the water causes flooding or erosion. It also offers the chance for the water to be absorbed into the earth, rather than shunted downstream. The absorption helps clean the water before it enters a stream, river, or lake.

The fact that GSI reduces water pollution gives it an advantage over impervious stormwater infrastructure made of concrete, sometimes called gray infrastructure. The term impervious is used to describe surfaces such as concrete and asphalt that do not absorb water. Typical forms of gray infrastructure used to address stormwater runoff include concrete detention/retention facilities designed to hold water. Frequently, these detention/retention structures are built below the surface. Concrete culverts are another form of gray infrastructure.

Green infrastructure mimics the natural environment, and therefore, GSI can be an attractive element to any development. However, GSI can have higher construction costs than gray infrastructure, and the costs for long-term maintenance of the facilities tend to shift from the developer to the municipality. These are two major reasons GSI is not used more often. Another reason may be that municipalities are unaware of minor changes to ordinances that can make a measurable impact on stormwater runoff. This article gives examples of low-cost changes to implement GSI.

Why Stormwater Management Is Important

While both green and gray infrastructure can reduce water quantity from runoff, only green infrastructure effortlessly improves water quality, a step that helps cities comply with federal law. Cities are required by the federal Clean Water Act (CWA) to reduce pollutants from stormwater that enters waterbodies.[1] Stormwater is a problem because as it runs across roofs, through parking lots, and down streets, it picks up oil, pesticides, and other chemicals which are then washed into waterways.

Application of the CWA rule was divided into two stages. Phase I, in 1990, required cities to get permits if they had municipal separate storm sewer systems (MS4) serving 100,000 people or more. An MS4 is a facility that processes wastewater from homes and businesses, but not stormwater. The permitting rule does not apply to so-call "combined systems" in which stormwater and home and business wastewater are treated. Phase I also requires permits for construction activities that disturb five acres or more, as well as for certain industries. Regulations issued in 1999, known as the Phase II rules, applied the permit requirement to MS4s in smaller cities identified as "urbanized areas."[2] The Phase II rules also extended the permit requirement to construction activities to sites of one acre or more. Thus, for small towns and those with combined water treatment systems, stormwater ordinances are primarily aimed at the construction phase of projects.

Stormwater Ordinances

Requirements for managing stormwater conditions at construction sites are found in city ordinances. A typical provision for a stormwater ordinance for new construction will have language similar to that found in these two examples:

> Plans and supporting documentation shall be certified by a registered professional engineer licensed by the state that … the post-development runoff rate does not exceed the pre-development runoff rate. (Mobile (AL) Municipal Ordinances § 17-7(c).)
>
> The stormwater management facility will be designed so that, except in unusual circumstances, the rate of runoff of surface water from the site … will not exceed the rate of

> runoff from the site in its undeveloped or natural condition as generated by the 2-, 10-, 25-, and 100-year storm events (Oxford (MS) Municipal Ordinances § 98-118(b).)

The "storm events" referred to in the second example are common data points in stormwater ordinances. Rainfall rates for storms are based on an area's historical rainfall and defined in terms of frequency and intensity. For example, a stormwater code may require a project to be built so that rain from a 100-year storm will not amount to excessive runoff. A 100-year storm is one that has a 1 percent chance of occurring in a year. It does not mean that after a big storm it will be 99 years until the next big storm. In fact, with the climate's changing patterns, some municipalities have had 1,000-year storms twice in 5 years, despite the odds of one such storm occurring in a year being 0.1 percent.[3]

Specific information for storm events is found in a database called Atlas 14[4] produced by the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce. For example, the Atlas 14 database shows that for Gulfport, Mississippi, a 2-year 24-hour storm yields an average rainfall of 5.85 inches, versus a 25-year 24-hour storm, which produces 11 inches of rain. In Tuscaloosa, Alabama, a 2-yr storm brings 4.09 inches of rain, and a 25-year 24-hour storm, 7.19 inches. Sometimes the rainfall amounts are specified within the ordinances, as done by Oxford, Mississippi:

> The 24-hour duration precipitation frequency values to be used … are 4.25 inches for the two-year storm, 5.21 inches for the ten-year storm, 7.01 inches for the 25-year storm, and 8.75 inches for the 100-year storm. (§ 98-118(b).)

Ordinances require developers to accommodate specific rainfalls to avoid causing flooding when they add impervious surfaces, as shown by these provisions from the northern Gulf Coast:

> All stormwater detention structures must attenuate the post-development peak flow rates from the 2-year, 5-year, 10-year, 25-year, 50-year and 100-year, 24-hour design storms to release a graduated discharge at or below predevelopment peak flow rates. (Daphne (AL) Municipal Ordinances §18-4(B)(2).)
>
> Projects shall be designed so that post-development peak discharge for the 10-, 25- and 100-year frequency storm events will not exceed the pre-development peak discharge rates … to the maximum extent practical…. (D'Iberville (MS) Municipal Ordinances § 13-86(a).)

Or they might apply to particular design features, rather than to the development as a whole. Take, for example, this language from the ordinances of Orange Beach, Alabama:

> Swales shall be designed to percolate 80 percent of the runoff from a 3-year, 1-hour design storm within 72 hours after a storm event, assuming average antecedent conditions. (§ 42-312(L)(12).)

Zoning and GSI

Zoning codes dictate the appearance of areas, such as by capping the amount of impervious surface at a site. For example, a residentially-zoned area usually will require more green space than will the business center of a town. Such requirements can influence stormwater runoff.

Common examples of where zoning ordinances influence GSI are in landscaping and parking lot requirements where natural areas may be required for aesthetic reasons. Those aesthetic goals will also have a green benefit. In fact some municipalities, such as Biloxi, Mississippi, state in their ordinances that a purpose of landscaping is to "reduc[e] stormwater runoff and the costs associated therewith." (Biloxi (MS) Zoning Ordinances 23-6-3(B).)

As an example of how zoning can establish GSI, consider this parking requirement from the zoning ordinances of Cape Coral, Florida:

> Clearly identified, unpaved parking that is graded and covered with sod to provide a surface that is durable and stable, and which will assist in managing stormwater, dust, and erosion may be permitted for up to 50% of the off-street parking requirements for the following uses: 1. Agriculture or farming uses; 2. Cemeteries; 3. Funeral homes, mortuaries, and crematoria; 4. Places of worship; 5. Religious facilities; or 6. Parks and recreation facilities owned by the government. (§ 6.8.1(E))

In this way, the city offers a way to help address parking needs while reducing the amount of impervious pavement. It is a low-tech form of GSI.

A zoning requirement to have landscaped islands in parking lots will succeed in reducing runoff provided there are not large, uninterrupted expanses of impervious surfaces, i.e. a lot of concrete with nowhere for the water to be absorbed. If water drains across a large impervious area, it will move faster, making it more likely to scour or erode a natural area once it gets there. Landscape islands in parking lots are a way to interrupt large impervious areas. But if curbs surround those islands, much of the green benefit will be lost as the water will flow around the islands rather than be absorbed within them.

To see how curb requirements in a zoning code can influence stormwater reduction, consider Biloxi's ordinance:

> All planting areas shall be protected from vehicle damage by the installation of curbing, wheel stops, or other comparable methods. This standard shall not prohibit the use of planting areas as on-site stormwater management devices. (§ 23-6-3(D)(2)(c).)

This could be read as requiring continuous strips of curbs, installed without regard to water flow. In comparison, consider this language from Orange Beach's zoning code directing curbing to be designed in consideration of stormwater:

> Protective curbing around landscaped area will leave openings for the flow of water onto unpaved areas. (§ 8.010407.)

The language in the Orange Beach provision protects the plants from being run over while still allowing landscaping to absorb stormwater runoff.

Raingardens and Other Green Retention Structures

Many municipalities have ordinances requiring natural detention or retention facilities, however, they may be required only within certain types of zoning. For example, Gulfport, Mississippi includes this GSI practice within its zoning code for areas zoned "Natural or Rural":

> Any required stormwater detention areas shall be naturalistically shaped and disposed, and shall be planted with native wetland species. (§ 3.5.2 (d)-(e).)

Applying this good idea to more zoning classifications would increase a city's ability to manage stormwater runoff.

A highly effective type of a GSI retention facility is a raingarden. A raingarden retains water by being built in a depression lower than the surrounding area: picture a bowl-shaped flowerbed. It has several feet of gravel and rocks below the depressed surface for water to percolate into. And it has plants chosen for the raingarden to tolerate the sometimes lingering water (in gardening terms, having wet feet). The idea is that stormwater runoff will channel into the depressed area where it will slowly percolate into the ground.

A study of stormwater requirements in six southern cities of the United States, including Biloxi and Orange Beach, found that raingardens substantially reduced stormwater runoff.[5] However, raingardens require some technical knowledge for design and placement, and require continued maintenance. A simpler alternative to a raingarden is to establish required infiltration rates for all landscaped areas. For example, an ordinance could require landscaped parking islands to have an infiltration rate of X inches per hour for a 2-year 24-hour storm. This could still allow turf, which is relatively easy to maintain. The turf would be the top layer over soil and a soil barrier; at the bottom, a thick layer of gravel to improve water infiltration. This is akin to a "dry well," a hole filled with rocks below the planting layer. Alternatively, ordinances could require the use of plants that absorb more water than turf does.[6] This meets the goal of improving water retention without changing the percentage of landscaped areas or requiring more technically challenging structures. And it would reduce the times parking spaces are unusable due to flooding.

Conclusion

The most efficient solution to reducing stormwater runoff may be the one that improves water quality as well. But green stormwater infrastructure requires a blending of science, law, and economics. Cities could look to their zoning codes as a place to implement GSI practices without adding a regulatory burden to development.

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Endnotes

1. 33 U.S.C. § 1342. The permit is known as a National Pollutant Discharge Elimination System (NPDES) permit.
2. "Urbanized area" is defined by the U.S. Census Bureau as any densely populated area of 50,000 people or more. U.S. Census Bureau, *Classification and Urban Area Criteria*.
3. *See* Tom DiLiberto, *Torrential Rains Bring Epic Flash Floods in Maryland in Late May 2018*, NOAA Climate (May 31, 2018) (describing two 1,000-year or greater storms that flooded Ellicott City, MD in 2016 and 2018).
4. NOAA, *Atlas 14 Point Precipitation Frequency Estimates*.
5. L. Abera, et al., *Evaluating the Effect of City Ordinances on the Implementation and Performance of Green Stormwater Infrastructure (GSI)*, Environmental Challenges 4 (2021), p. 6.
6. *See, e.g.* Ethan M. Dropkin, et al., *Woody Shrubs for Stormwater Retention Practices*, Cornell University.