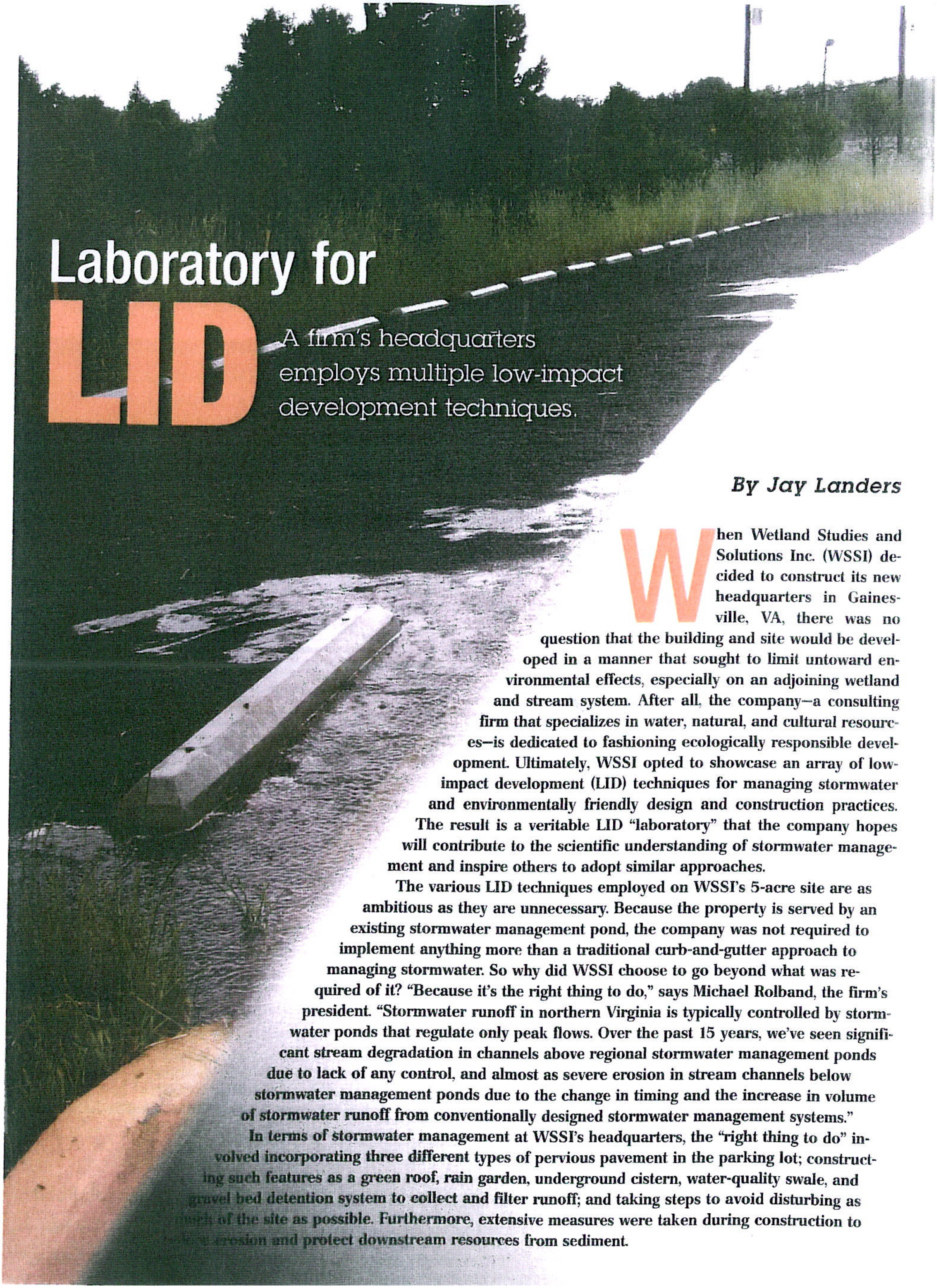


# Laboratory for LID

## A firm's headquarters employs multiple low-impact development techniques.

### By Jay Landers

When Wetland Studies and Solutions Inc. (WSSI) decided to construct its new headquarters in Gainesville, VA, there was no question that the building and site would be developed in a manner that sought to limit untoward environmental effects, especially on an adjoining wetland and stream system. After all, the company—a consulting firm that specializes in water, natural, and cultural resources—is dedicated to fashioning ecologically responsible development. Ultimately, WSSI opted to showcase an array of low-impact development (LID) techniques for managing stormwater and environmentally friendly design and construction practices. The result is a veritable LID "laboratory" that the company hopes will contribute to the scientific understanding of stormwater management and inspire others to adopt similar approaches.

The various LID techniques employed on WSSI's 5-acre site are as ambitious as they are unnecessary. Because the property is served by an existing stormwater management pond, the company was not required to implement anything more than a traditional curb-and-gutter approach to managing stormwater. So why did WSSI choose to go beyond what was required of it? "Because it's the right thing to do," says Michael Rolband, the firm's president. "Stormwater runoff in northern Virginia is typically controlled by stormwater ponds that regulate only peak flows. Over the past 15 years, we've seen significant stream degradation in channels above regional stormwater management ponds due to lack of any control, and almost as severe erosion in stream channels below stormwater management ponds due to the change in timing and the increase in volume of stormwater runoff from conventionally designed stormwater management systems."

In terms of stormwater management at WSSI's headquarters, the "right thing to do" involved incorporating three different types of pervious pavement in the parking lot; constructing such features as a green roof, rain garden, underground cistern, water-quality swale, and gravel bed detention system to collect and filter runoff; and taking steps to avoid disturbing as much of the site as possible. Furthermore, extensive measures were taken during construction to [illegible] erosion and protect downstream resources from sediment.

## Understanding LID

Often touted as a holistic strategy for managing stormwater, LID includes several basic tenets, among them conserving and protecting a site's natural features, minimizing impervious areas, directing runoff to natural areas that slow it down and enable evaporation or infiltration, and using many small-scale controls to reproduce the functions of natural areas. Such functions typically include infiltration, detention, retention, evaporation, and groundwater recharge. During site preparation and construction, LID calls for the use of measures to limit erosion and prevent soil compaction.

All photos: Wetland Studies and Solutions Inc.

**An aerial view of WSSI's headquarters in Gainesville, VA**

The upshot of such efforts is to mimic a site's predevelopment hydrology. Indeed, this was a major goal of WSSI as it set out to design and construct its new headquarters, which includes office and warehouse space. By using the various LID techniques, the firm aimed to reduce the site's post-development curve number to its predevelopment curve number. And by increasing the site's storage capacity and its time of concentration, WSSI sought to minimize the effects that runoff would have on downstream water bodies.

Finally, the company aimed to prove that it could comply with Virginia's requirements for reducing pollutants in stormwater solely by using LID approaches. However, stormwater management was not WSSI's only goal. As part of an effort to certify its headquarters a "green building," the firm also incorporated numerous strategies to make the building environmentally friendly.

## Retaining Runoff

Among the site's many LID approaches, the gravel bed detention system—also known as the underground detention system—is

perhaps the most critical. Runoff from the building's roof, the rain garden, impervious asphalt parking areas, and pervious parking areas enters the detention system via infiltration or a system of underdrains. Encompassing an area of approximately 7,890 square feet, the underground detention system has an average depth of 3.5 feet and contains about 40% void space, for a total storage volume of 10,513 cubic feet.

Designed to detain runoff from the one-year storm, the gravel bed detention system is connected to a manhole by an underdrain. Under normal, non-flooding conditions, all water exits the manhole via an orifice that has a diameter of 1.625 inches. This orifice is designed to release the volume of water associated with a one-year storm in 24 hours. Upon discharge from the detention system, water enters a wetland and stream system at the back of the site. To minimize streambank erosion, the water enters at a low velocity and at an acute angle to the stream's flowpath.

An 8,000-gallon cistern is sized to capture and store the first 0.5 inch of roof runoff for use in irrigating the site's native landscaping. Although WSSI evaluated the possibility of employing this so-called gray water in such nonpotable uses as toilets, the firm determined that the cost associated with regulatory barriers was too high.

The irrigation system includes a level sensor in the underground cistern to ascertain whether water is available. A 2-horsepower pump removes water from the cistern and sends it through a drip-irrigation system consisting of a network of flexible perforated pipe. If the cistern lacks a sufficient amount of water when irrigation is needed, a 1.5-horsepower booster pump is available to draw water from the site's public water supply.

The cistern employs a floating filter and intake valve to draw water from below scum that accumulates on the water surface and above any sediment that might collect on the bottom. Although runoff from the roof is not expected to contain significant amounts of sediment, the system includes a self-cleaning filter to remove sediment before the water enters the irrigation system. WSSI intends to monitor sediment levels in the cistern during the next few years to see if this assumption holds true, says Jennifer Brophy-Price, a civil engineer with the firm.

Flows to the cistern in excess of 8,000 gallons are conveyed via a pipe to the rain garden. In extreme circumstances, a separate pipe within the cistern conveys additional flows to the gravel bed detention system. "The emergency overflow is only going to be used in very large storms," Brophy-Price says.

## Keeping It Green

Separate from the building's main roof, the 3,625-square-foot green roof sits above a single-story building extension and can be entered from the second floor's training and meeting room. For protection, the underlying corrugated metal roof deck was covered with several layers of insulation and membranes. The initial layer is 5-inch-thick R30 foam insulation, followed by 0.5-inch-thick gypsum protection board. Next, a 75-mil ethylene propylene diene monomer membrane was used, on which was placed a

A growing medium was lifted to the green roof by crane.

0.5-inch-thick foam protection board, a 40-mil high-density polyethylene root barrier, and protective fabric. A drainage layer was placed to a thickness of 1 inch and covered with filter fabric.

A lightweight growing medium was lifted to the roof by crane and graded by hand according to a grading plan based on 1-inch contours. In this way, planting areas with depths ranging from 3 to 9 inches were installed depending on the types of vegetation that were to inhabit them. This method enabled the use of a hybrid approach that incorporates both shallow and deep zones, respectively known as extensive and intensive planting areas. Extensive green roofs typically employ shallow-rooted plants such as sedums in soils that are less than 4 inches deep. Intensive green roofs, on the other hand, use a soil base deeper than 4 inches to house larger perennials and shrubs.

"We decided on a maximum weight limit for the roof based on our budget and the cost of added structural support," Brophy-Price says. The grading plan then was devised to provide a diversity of planting areas while keeping within the limit. Designed to support 62 pounds per square foot, the green roof includes non-native sedums in the shallower extensive areas and more than 30 species of native plants that require deeper soils in the intensive areas. In keeping with WSSI's professional focus, the green roof also includes two small wetland areas.

Approximately 2,020 square feet of the green roof is extensive, and roughly 1,085 square feet is intensive. "We used both approaches so that the roof could be used as a demonstration of the range of options available to the building community," Brophy-Price says. The remaining area comprises stone walkways, walls, and seating areas. The green roof includes several drains that discharge to the cistern.

The green roof receives no runoff from other areas of the building. "All of the water on the green roof falls directly on the roof," Brophy-Price says. However, the wetland areas are equipped with irrigation systems that use potable water from the building when moisture sensors indicate that the areas are too dry. In the event of extreme drought, the green roof's other plants also can be irrigated as necessary.

The 1,536-square-foot rain garden is designed to treat the first 0.5 inch of runoff from 34,660 square feet of impervious roof and parking lot areas. Surrounded by an 11,700-square-foot sod buffer that filters pollutants and debris from incoming runoff, the rain garden includes, from the top down, a layer of hardwood mulch, a sandy loam soil to filter the water, and a gravel layer. Filter fabric was used to separate the soil and the gravel layer.

To ensure that the rain garden could achieve the desired infiltration rate, its soil was mixed onsite and comprises 70% sand, 15% topsoil, and 15% leaf mulch. Water that filters to the gravel beneath the rain garden flows to the underground detention system via an underdrain. During large storms, the rain garden, which has a ponding depth of 6 inches, is designed to overtop into the underground detention system.

The rain garden was planted with 10 species of native perennials, shrubs, and trees that were specifically selected for their ability to thrive in the rain garden's particular soil conditions. "Because the rain garden will be flooded with water in storms but will drain relatively quickly due to the porous soil," Brophy-Price explains, "we chose vegetation that could withstand temporary inundation but could also thrive in sandy conditions." Such species include black gum (*Nyssa sylvatica*), winterberry holly (*Ilex verticillata*), witch hazel (*Hamamelis virginiana*), sea oats (*Chasmanthium latifolium*), and New York ironweed (*Veronia novaboracensis*). Along with its aesthetic benefits, the vegetation enhances the rain garden's ability to remove nutrients and provides wildlife habitat.

## Promoting Permeability

In the parking lot, asphalt was employed only in heavily used areas. Most runoff from the asphalt parking areas, which amount to approximately 55,900 square feet, is directed to the gravel paving sections, the rain garden, and the underground detention area. The remainder is directed to the water-quality swale.

Elsewhere in the parking lot, three types of pervious pavement were used to infiltrate stormwater and reduce runoff: pervious concrete pavers; gravel; and GravelPave2, a proprietary system made by Invisible Structures Inc. of Golden, CO, that holds gravel in a grid of plastic rings fused to a filter-fabric

Planting areas with 3- to 9-inch depths were installed on the green roof depending on intended type of vegetation.

backing. As with the different planting styles on the green roof, WSSI opted to employ a variety of pervious pavements to demonstrate their use to designers and builders.

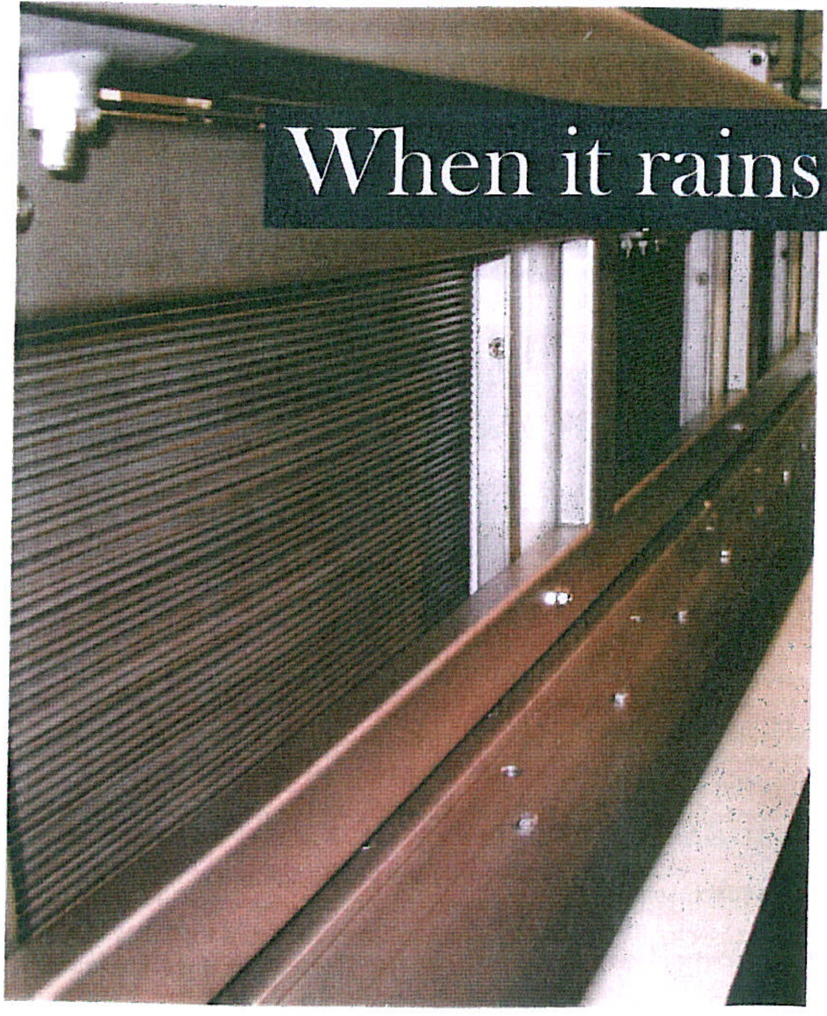
The building's parking lot includes approximately 5,500 square feet of pervious concrete pavers. Flush edge restraints made of reinforced concrete and measuring 8 inches wide were used to separate the pavers and the asphalt areas. Unlike standard concrete paving blocks, the pervious pavers have spaces at the joints that are filled with gap-graded gravel. Water enters the spaces and infiltrates the underlying gravel substrate, which consists of a 4-inch-thick leveling course of gravel, ranging in diameter from 0.5 to 1 inch, on top of an 8-inch-thick base course of gravel ranging in diameter from 1 to 2 inches. Filter fabric separates the two gravel layers. Although the pavers have only 10% effective open space, the gravel substrate's extremely high permeability rate enables the area with the pavers to accommodate rain events up to several inches per hour without creating runoff.

Because the site's clayey soils inhibit infiltration, perforated underdrains were installed beneath all the pervious parking areas to collect water. The 4-inch-diameter underdrains beneath the two sections of pervious pavers each convey water to existing, well-vegetated floodplains. Underdrains beneath the areas covered with gravel and GravelPave2 discharge to the gravel bed detention system.

Of the site's total parking surface, 28.5% consists of plain gravel or the GravelPave2 system. WSSI decided to use both approaches for purposes of comparison. "One of our reasons for doing an LID plan in the first place was to determine differences between different products and LID methods," Brophy-Price says. Therefore, a 1,273-square-foot parking area that gets relatively little use incorporates a 3-inch layer of gravel approximately 0.5 inch in diameter on top of a 10-inch layer of gravel ranging from 1 to 2 inches in diameter. Filter fabric and geogrids separate the two gravel layers. To maintain the gravel's permeability, WSSI specified the use of gap-graded gravel that does not contain fine material that can clog the voids between the gravel.

Used in two separate parking areas that together comprise approximately 23,200 square feet, GravelPave2 was delivered to the site in rolls that then were spread out over a gravel base course. The material was connected, and gap-graded gravel was placed on top and spread to make a uniform layer. GravelPave2's grid components hold the gravel in place and prevent it from forming ruts when cars drive over it. The system's filter fabric keeps the gravel from mixing with the underlying gravel layer.

After the installation of the GravelPave2 system, WSSI had to address an unexpected problem involving "rogue trucks," Brophy-Price says. On a few occasions, cement trucks entered the firm's parking lot trying to locate a nearby shopping center. When the trucks attempted to navigate a section of the parking lot that has a tight corner, their wheels caught and ripped the plastic rings used to contain the gravel. "After the third time this



happened, we installed height restrictors at each entrance to the GravelPave2 parking area," Brophy-Price says. "We haven't had any problems since."

Other LID features at the site include a water-quality swale that extends for 265 linear feet along one side of the property. Designed to collect runoff from 12,650 square feet of impervious parking surface, the vegetated swale slows the rate at which water leaves the site and enters the adjoining wetland and stream system. Check dams constructed within the swale, coupled with native vegetation, offer a measure of filtration for the runoff.

By using retaining walls in two places, WSSI avoided slopes that would have affected existing wetlands and forested areas. All told, 1.17 acres of native vegetation were left undisturbed on the site. In areas that required landscaping, native vegetation was used to reduce the amount of water needed for irrigation.

## Assessing the Goals

With their numerous permeable surfaces, the various LID techniques reduce the site's impervious surface area by 28.8%. At the same time, the approaches have been found to lower the site's peak runoff rate 15.7% below the forested condition. Specifically, the site's predevelopment runoff rate during a 1.5-year storm was estimated to be 9.42 cubic feet per second (cfs). However, the site's post-development runoff rate for the same frequency storm is estimated to be 7.94 cfs.

The green roof shortly after planting, in the fall of 2005

Although the LID techniques helped lower the site's post-development curve number, they failed to reduce it to the predevelopment curve number of 70. Yet the site's post-development curve number of 78.0 is well below the conventional post-development curve number of 87.5, according to WSSI.

The LID approaches fared better in terms of removing pollutants from runoff. Virginia law mandates that 50% of phosphorus, considered the "keystone pollutant," be removed from runoff from sites within designated areas. Despite the fact that these requirements did not affect the project because the site is already serviced by a regional stormwater management pond, WSSI "attempted to meet this goal" using LID "just so we could prove that it can be done," Brophy-Price says. In fact, the LID technologies removed 51.3% of phosphorus from the runoff, according to WSSI.

## LEEDing the Way

To acknowledge and promote efforts to create sustainable buildings, the US Green Building Council in Washington, DC, developed the voluntary certification program known as Leadership in Energy and Environmental Design (LEED). The program includes a rating system designed to measure the extent to which a building incorporates environmentally friendly design and construction practices. As it set out to develop its headquarters, WSSI decided to undergo the LEED process and certify the new building. "The certification wasn't necessary," Brophy-Price says. "We were going to build a 'green' building no matter what, but the LEED certification gives us a way to tangibly validate that achievement."

LEED has certification programs tailored to new construction, commercial interiors (CI), and existing buildings. Additional LEED programs for core and shell buildings, residential homes, and new development are being evaluated or developed. WSSI opted to certify its building in accordance with the LEED–CI program because it most closely matches the type of project and the scope of innovation that the company devoted to the building's finished portion.

As part of the LEED process, a building earns credits depending on the extent to which it incorporates certain environmentally friendly features. For example, the LEED–CI program includes six categories for evaluating a building: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation and design process. Depending on the number of credits, or points, a building earns within these categories, it is designated as "certified," "silver," "gold," or "platinum."

WSSI's headquarters achieved a gold certification, the first such designation for a structure in Virginia. Within the sustainable sites category, WSSI received credit for such efforts as its innovative LID techniques, its efficient irrigation system, and efforts to reduce the site's contribution to the urban heat island effect, the name for the phenomenon whereby heat from roofs and paved surfaces such as parking lots causes higher temperatures in cities than in surrounding areas. The main building and a small outbuilding have high-albedo roofs to reflect sunlight and minimize the amount converted to heat. Together with the green roof, pervious surfaces, and native vegetation, these roofs help lower the site's heat-island effect.

In the water efficiency category, WSSI earned the maximum three points by installing low-flow faucets, toilets, and showerheads; waterless urinals; and sensor-based faucet controls. WSSI estimates that it will use less than one-half the potable water and one-tenth the irrigation water that a typical building of the same size would use. Annually, the firm expects to use 30% less electricity and gas than would a typical building.

Earning eight of the 14 possible credits in the energy and atmosphere category, WSSI took such steps as optimizing the performance of its heating, ventilation, and air-conditioning system; using daylight-responsive lighting controls in regularly occupied areas of the building within 15 feet of windows; using energy-efficient appliances; and purchasing "green energy credits" equivalent to the building's estimated energy consumption for two years.

In the materials and resources category, WSSI accrued points by conducting such measures as using certain percentages of recycled content and regional materials. Within the indoor environmental quality category, WSSI earned points in a number of ways, including monitoring its ventilation system to ensure it works properly; providing more ventilation than is typically required; and using paints, coatings, carpets, furniture, and seating that emit low amounts of volatile organic compounds.

## Evaluating Costs

Construction began in May 2005 and was completed the following December. All told, WSSI's headquarters cost nearly $6.1 million to design and construct. As might be expected, use of the many LID features cost more than a typical curb-and-gutter approach to removing stormwater from WSSI's site. The total cost to install the native landscaping and drip irrigation system and construct the rain garden, cistern, green roof, pervious concrete pavers, gravel pavement, GravelPave2 system, gravel bed detention system, and swale was $620,705, according to WSSI. (See Table 1 for a breakdown of what each LID approach costs per square foot of impervious surface that contributes water.) By contrast, the company estimates that a standard asphalt parking lot with curbs and gutters would have cost $360,115.

Although not the most expensive LID approach overall, the green roof by far cost the most to install when examined on the basis of cost per square foot of impervious surface treated. With a total cost of $115,316, the green roof cost $31.80 per square foot, more than four times the cost of the next expensive item, the pervious concrete pavers. Though it amounted to nearly 20% of the project's total LID cost, the green roof treats an area of less than 3,700 square feet. Although immensely proud of their green roof, WSSI representatives readily concede that it was not cost-effective in a strict sense. "The green roof was definitely not an economically practical decision with regards to its stormwater management capabilities," Brophy-Price says.

However, the roof has far more ecological benefit than simply filtering stormwater, Rolband notes. "Seeing the green roof vegetation blooming and being visited by birds, butterflies, and bees makes you realize how much more biologically productive this area is in comparison to a conventional, biologically barren roof," he says.

As suppliers and contractors become more familiar with LID techniques, the costs associated with these approaches likely will decrease, Brophy-Price says. As an example, she notes that the initial estimate for installing the concrete pavers was $16 per square foot. However, the final cost amounted to $7.10 per square foot, of which $2.55 was for the cost of the pavers themselves. The initial estimate was provided by a company that typically installs patios and other small areas that require a variety of intricate cuts and shapes. As such companies become more involved with LID projects that employ concrete pavers on a larger scale, "The cost is going to come down a lot," Brophy-Price says. "The materials themselves aren't too expensive. It's mostly the installation."

If it had to do it over again, WSSI would use more pervious pavers in place of gravel surfaces in the parking areas. "We like the look of [the pavers], and they are more durable in many cases," Brophy-Price says. Last winter the company also experienced difficulties trying to plow snow from the gravel-covered lots. When it snows but the ground does not freeze, a plow tends to catch on the gravel, she notes. However, a Swedish visitor to the site suggested attaching small, ski-shaped skids to plows to minimize this problem, an approach that WSSI intends to try this winter.

**Table 1. Cost of WSSI's Low-Impact Development Features**

| Item | Cost per square foot impervious surface that contributes water | Cost |
|---|---|---|
| Rain garden | 2.60 | $90,000 |
| Cistern | 1.23 | $31,000 |
| Green roof | 31.80 | $115,316 |
| Pervious concrete pavers | 7.90 | $39,000 |
| Gravel pavement | 4.32 | $5,500 |
| GravelPave2 system | 6.00 | $143,500 |
| Gravel bed detention | 0.32 | $24,000 |
| Swale | 3.68 | $46,525 |
| Native landscaping and drip irrigation | N/A | $125,864 |
| | **Total** | **$620,705** |
| Estimated cost of standard asphalt, curb-and-gutter approach | | $360,115 |

*Source: Wetland Studies and Solutions Inc. (WSSI)*

## Ensuring Successful Partnerships

The overall LID concept plan was developed in-house by WSSI. The Peterson Companies of Fairfax, VA, conducted project management. Civil engineering was handled by Urban Engineering and Associates Inc. based in Annandale, VA. The Herndon, VA, office of E.E. Reed Construction LP served as the general contractor. Site work was conducted by S.W. Rodgers Co. Inc. of Gainesville, VA.

Although E.E. Reed Construction has worked on projects with LID aspects before, the WSSI headquarters was on a different level, says Brian White, a senior project manager with E.E. Reed Construction. "This was a pretty extraordinary case," he says. WSSI "wanted to make a statement" with its building, White notes. Initially, the project appeared as if it might prove quite challenging, White says, but that turned out not to be the case. "It really went a lot easier than expected," he says.

E.E. Reed Construction expects to see increased use of LID techniques in northern Virginia, especially as local governments there are starting to require more in the way of stormwater management as part of development, White says. Contractors involved with LID projects must work closely with the designers to ensure that all participants realize the overall purpose behind the stormwater features, he notes. "My main recommendation is having everybody on board understand what the intent is and why we are going toward a certain goal."

For the S.W. Rodgers Co., the WSSI building was its first involvement with an LID project. "While it was new to us, it wasn't that difficult," says Earl Lillard, a project manager for S.W. Rodgers. Some of the work, such as installing the drainage elements, had to be conducted "more precisely than what we do in normal land development," Lillard says. Although the firm initially had concerns about the amount of time that would be required for the project, Lillard says, it completed the work on schedule. "We were really pleased with the outcome."

## Monitoring Performance

Well aware of the relative dearth of information available regarding LID techniques, WSSI intends to monitor its LID approaches to see how well they perform and assess their maintenance requirements. This past summer, WSSI hired two engineering students as interns to oversee the task of installing flow meters and other monitoring equipment at the site.

Initially, the objective is to measure the amount of rainfall occurring at the site and note how much water enters and leaves the different LID practices. "Our goal with this project is to provide continuous flow information on a public domain Web site" for use by researchers, Brophy-Price says. Eventually, the monitoring efforts will be expanded to assess water-quality improvements associated with the LID techniques, she notes.

In the meantime, WSSI conducts frequent tours of its building and grounds for stormwater professionals, construction industry representatives, regulators, and the general public. Although LID practices have been around for years, many in the construction industry still consider them novel or view them warily. Perhaps a visit to WSSI's LID laboratory will convince them of the benefits to be gained by employing such techniques.

***Jay Landers** is a writer and editor based in Austin, TX.*