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Cost-Effective LID in Commercial and Residential Development

Drainage designs that feature LID can be more cost-effective compared to conventional designs.

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Low-impact development (LID) represents one of the most progressive trends in the area of stormwater management and water quality. While the performance benefits of LID are well documented and continue to gain increasingly more acceptance, less is known about the economic benefits of LID-based strategies. Yet many decisions in a residential and commercial development context are made on the basis of cost.

Although better known for its capacity to limit water pollution and manage stormwater sustainably, in certain settings LID designs can also be more cost-effective as compared to conventional stormwater controls. Specifically, LID can result in project cost savings by decreasing the amount of drainage infrastructure required. It can reduce or eliminate the need for other costly stormwater management-related infrastructure including curbs, gutter, catch basins, piping, storage, and outlet control structures.

LID designs can also bring space-saving advantages by reducing the amount of land disturbance required during construction, saving money on

site preparation expenses and erosion control. Site development and stormwater management plans that incorporate LID strategies have resulted in direct construction and installation cost savings as compared to plans that are based on conventional practices alone. However, it is important to note that LID strategies do not replace comprehensive resource-based land planning. Strategies like environmental site design, porous pavements, and filtration/infiltration practices provide important water-quality and hydrologic benefits but do not replace the ecological value of conserved lands.

Recently, these types of cost-saving advantages were realized through the use of LID strategies in the designs for two separate projects in the state of New Hampshire. These projects—a residential community and a commercial retail center—featured the use of porous asphalt, infiltration systems, and treatment wetlands, which resulted in more economical stormwater management plans as compared to conventional designs. Although porous asphalt was more expensive as compared to traditional pavement, in both situations the use of this material effectively reduced the need for drainage infrastructure, in addition to other project savings.

Although, individually, LID elements may add expense to a project, at the same time cost savings are often realized on an overall project cost basis. Of course, cost savings are not observed when compared with minimal stormwater man-

agement, but rather for projects consistent with new state and federal permitting requirements addressing volume and pollutant reduction.

In the vast majority of cases, the EPA has found that implementing well-chosen LID practices saves money for developers, property owners, and communities while also protecting and restoring water quality (USEPA 2007). In northern Frederick County, MD, a number of cost-saving benefits were realized by redesigning a conventional subdivision with LID designs. This included eliminating two stormwater ponds, representing a reduction in infrastructure costs of roughly \$200,000; increasing the number of buildable lots from 68 to 70, which added roughly \$90,000 in value; and allowing the site design to preserve approximately 50% of the site in undisturbed wooded condition, which reduced clearing and grubbing costs by \$160,000 (Clar 2003). In addition, an infill site in northern Virginia was able to save over 50% in cost for infrastructure by minimizing impervious surfaces, protecting sensitive areas, reducing setback requirements, and treating stormwater at the source (VADCR 2000).

Additional economic benefits of LID include reduced flooding costs as well as lower home cooling expenses. For example, natural vegetation and reduced pavement area in the Village Homes LID development in Davis, CA, helped lower home energy bills by 33 to 50% as compared to surrounding neighborhoods (MacMullan 2007). Further economic incentives to developers for LID inclusion include the potential for higher property values as well as a reduction in permitting fees. In Dane County, WI, permit fees for development are calculated based on the amount of impervious area in a site, providing an incentive for developers to use LID. In another example, an analysis of 184 lots in one community found that conservation subdivisions were more profitable than conventional subdivisions. Lots in the conservation subdivisions cost an average of \$7,000 less to produce, resulted in a 50% decrease in selling time, and had a value of 12 to 16% more as compared to lots in conventional subdivisions (Mohamed 2006).

Boulder Hills

Boulder Hills is a 24-unit active adult condominium community in Pelham, NH, that features the state's first porous asphalt road. The development was built by Stickville LLC on 14 acres of previously undeveloped land and includes a total of five buildings, a community well, and a private septic system. In addition to the roadway, all driveways and sidewalks in the development are also composed of porous asphalt. Located along the sides and the backs of the buildings are fire lanes consisting of crushed stone that also serve as infiltration systems for rooftop runoff.

SFC Engineering Partnership Inc. designed the project site and development plan including all drainage, and the University of New Hampshire Stormwater Center (UNHSC) advised the project team and worked with Pelham town officials, providing guidance and oversight with the installation and the monitoring of the porous asphalt placements.

Prior to development, the project site was an undeveloped woodland area sitting atop a large sand deposit. Soils on the parcel were characterized with a moderate infiltration rate and consisted of deep, moderately well to well-drained soils. Wetland areas were located in the south and east sections of the parcel, with a portion of the site existing in a 100-year flood zone.

The benefits of implementing an LID design as compared to a conventional development included cost savings and positive exposure for the develop-

Figure 1. Comparison of two designs, LID design (above) and conventional (below), for Boulder Hills, Pelham, NH



ers, improved water quality, and runoff volume reduction, as well as less overall site disturbance. Over time, the porous asphalt placements are also anticipated to require less salt application for winter deicing, resulting in additional economic and environmental benefits. By the end of the first winter (2009–2010), the project owners reported using substantially less salt for winter ice management.

Design Process. Initially, the engineers began designing a conventional development and stormwater management plan for the project. However, according to David Jordan, P.E., formerly of SFC Engineering Partnership, difficulty was encountered because of the site's layout and existing conditions. "The parcel was burdened by lowland areas, while the upland areas were fragmented and limited," says Jordan. "Given these conditions, it was challenging to make a conventional drainage design work that would meet town regulations. We found ourselves squeezing stormwater mitigation measures into the site design in order to meet criteria. The parcel also did not have a large enough area that could serve as the site's single collection and treatment basin. Instead, we were forced to design two separate stormwater detention basins, which was more expensive. This approach was also cost prohibitive because of the necessity of installing lengthy underground drainage lines."

When LID and, specifically, porous asphalt emerged as a possible stormwater management option for the site, the developer, Stickville LLC, was receptive. Stickville was aware of the advantages of LID and porous pavement and was interested in using these measures as a possible marketing tool that could help differentiate it as a green-oriented developer. Jordan was supportive of this option, having previously attended a seminar on porous pavement presented by the UNHSC. He advised Stickville to pursue this approach.

"Per regulations, the amount of stormwater runoff from the site after development could not be any greater than what it was as an undeveloped parcel," says Jordan. "In addition to controlling runoff, stormwater mitigation measures also had to be adequate in terms of treatment. Porous pavement allows

Item	Conventional Option	Low-Impact Development Option	Cost Difference
Site Preparation	\$23,200.00	\$18,000.00	(\$5,200.00)
Temporary Erosion Control	\$5,846.50	\$3,811.50	(\$2,035.00)
Drainage	\$92,398.00	\$20,125.00	(\$72,273.00)
Roadway	\$82,054.00	\$127,972.00	\$45,918.00
Driveways	\$19,722.00	\$30,108.00	\$10,386.00
Curbing	\$6,464.00	\$0.00	(\$6,464.00)
Permanent Erosion Control	\$70,070.00	\$50,610.00	(\$19,460.00)
Additional Items	\$489,700.00	\$489,700.00	\$0.00
Buildings	\$3,600,000.00	\$3,600,000.00	\$0.00
Project Total	\$4,389,454.50	\$4,340,326.50	(\$49,128.00)

Item	Conventional Option	Low-Impact Development Option	Cost Difference
Mobilization / Demolition	\$555,500	\$555,500	\$0
Site Preparation	\$167,000	\$167,000	\$0
Sediment / Erosion Control	\$378,000	\$378,000	\$0
Earthwork	\$2,174,500	\$2,103,500	(\$71,000)
Paving	\$1,843,500	\$2,727,500	\$884,000
Stormwater Management	\$2,751,800	\$1,008,800	(\$1,743,000)
Additional Work-Related Activity (utilities, lighting, water & sanitary sewer service, fencing, landscaping, etc.)	\$2,720,000	\$2,720,000	\$0
Project Total	\$10,590,300	\$9,660,300	(\$930,000)

* Costs are engineering estimates and do not represent actual contractor bids.

us to do both. For a difficult site such as Boulder Hills, that represents a huge advantage."

According to Jordan, the Town of Pelham responded very favorably to the idea of incorporating LID with the project. "The planning board was on board from the very beginning," he says. "They were very supportive of utilizing porous asphalt and recognized the many benefits of this option."

Economic Comparisons. SFC Engineering Partnership designed two development options for the project (Figure 1). One option was a conventional development and drainage plan that included the construction of a traditional asphalt roadway and driveways. The other option, an LID approach, involved replacing the traditional asphalt in the roadway and driveways with porous asphalt and using subsurface infiltration for rooftop runoff, essentially eliminating a traditional pipe and pond approach.

Although porous asphalt was more costly as compared to traditional asphalt, the engineers found that by using this material, cost savings in other areas could be realized. For one, in-

stalling porous asphalt significantly lowered the amount of drainage piping and infrastructure required. Using porous asphalt also reduced the quantity of temporary and permanent erosion control measures needed while cutting in half the amount of riprap and lowering the number of catch basins from 11 to three. Additionally, the LID option completely eliminated the need to install curbing, outlet control structures, and two large stormwater detention ponds. Another benefit was a 1.3-acre reduction in the amount of land that would need to be disturbed, resulting in lower site-preparation costs.

Table 1 shows the construction estimate cost comparisons between the conventional and the LID options. As shown in Table 1, the LID option resulted in higher costs for roadway and driveway construction. However, considerable savings were realized for site preparation, temporary and permanent erosion control, curbing, and most noticeably drainage. Overall, the LID option was calculated to save the developers \$49,128 compared to a conventional design (\$789,500 versus LID

cost of \$740,300), or nearly 6% of the stormwater management costs as compared to the conventional option.

Greenland Meadows

Greenland Meadows is a new retail shopping center built by Newton, MA-based Packard Development along Route 33 in Greenland, NH, that features the largest porous asphalt installation in the Northeast. The development is located on a 55.95-acre parcel and includes three one-story retail buildings (Lowe's Home Improvement, Target, and a future supermarket); paved parking areas consisting of porous asphalt and non-porous pavements; landscaping areas; a large gravel wetland; and advanced stormwater management facilities.

The total impervious area of the development—mainly from rooftops and non-porous parking areas—is approximately 25.6 acres, considerably more as compared to predevelopment conditions. Prior to development, the project site contained an abandoned light bulb factory, with a majority of the property vegetated with grass and trees.

Framingham, MA-based Tetra Tech Rizzo provided all site engineering services and design work for the stormwater management system, which included two porous asphalt installations covering a total of 4.5 acres along with catch basins, subsurface crushed stone reservoir, sand filter, and underground piping and catch basins. The UNHSC provided guidance and oversight with the porous asphalt installations and supporting designs.

This project showed how a combination porous asphalt and standard pavement design with a subsurface gravel wetland was more economically feasible compared to a standard pavement design with a conventional subsurface stormwater management detention system. Additionally, the use of advanced LID-based stormwater management designs at Greenland Meadows was instrumental in addressing the project's site-specific challenges and environmental issues. Three years after installation, the site continues to perform exceptionally well.

Environmental Concerns. During the initial planning stage, concerns arose about potential adverse water-quality

impacts from the project. The development would increase the amount of impervious surface on the site, resulting in a higher amount of stormwater runoff as compared to existing conditions. These concerns were especially heightened given the fact that the development is located immediately adjacent to Pickering Brook, an EPA-listed impaired waterway that connects the Great Bog to the Great Bay, recently listed for nitrogen impairment. One group that was

particularly interested in the project's approach to managing stormwater was the Conservation Law Foundation (CLF), an environmental advocacy organization.

According to Austin Turner, a senior project civil engineer with Tetra Tech Rizzo, CLF feared that a conventional stormwater treatment system would not be sufficient for protecting water quality. "Since there was interest in this project from many environmental groups, especially the CLF, permitting the project

proved to be very challenging,” says Turner. “We were held to very high standards in terms of stormwater quality because Pickering Brook and the Great Bay are such valuable natural resources. CLF wanted this project to have the gold standard in terms of discharge.”

To ensure a high level of stormwater treatment as well as gain project approval, Tetra Tech Rizzo worked closely with Packard Development, the UNHSC, the New Hampshire Department of Environmental Services, and CLF on the design of an innovative stormwater management system with LID designs.

Hydrologic Constraints. Brian Potvin, P.E., director of land development with Tetra Tech Rizzo, says one of the main challenges in designing a stormwater management plan for the site was the very limited permeability of the soils. “The natural underlying soils are mainly clay in composition, which is very prohibitive towards infiltration,” he says. “Water did not infiltrate well during site testing, and the soils were determined not to be adequate for receiving runoff.” Therefore, Tetra Tech Rizzo focused on a stormwater management design that revolved around stormwater quantity attenuation, storage, conveyance, and treatment.

Economic Comparisons. Tetra Tech Rizzo prepared two site work and stormwater management design options for the Greenland Meadows development:

- Conventional. This option included standard asphalt and concrete pavement along with a traditional sub-surface stormwater detention system consisting of a gravel subbase and stone backfill, stormwater wetland, and supporting infrastructure.
- LID. This option included the use of porous asphalt and standard paving in addition to a sub-surface crushed stone reservoir, sand filter beneath the porous asphalt, a subsurface gravel wetland, and supporting infrastructure.

The western portion of the property would receive a majority of the site’s stormwater prior to discharge into Pickering Brook. Table 2 compares the total construction cost estimates for the conventional and the LID options.

As shown, paving costs were estimated to be considerably more expen-

sive (by \$884,000) for the LID option because of the inclusion of the porous asphalt and pavement sub-base materials. However, the LID option was also estimated to save \$71,000 in earthwork costs as well as \$1,743,000 in total stormwater management costs, primarily due to the elimination of almost 15,000 linear feet of piping for storage. Overall, comparing the total site work and stormwater management cost estimates for each option, the LID alternative was estimated to save the developers a total of \$930,000 compared to a conventional design, or about 26% of the overall total cost for stormwater management.

Tables 3 and 4 further break down the differences in stormwater manage-



Right: Greenland Meadows

Bottom: Boulder Hills



Table 3. Conventional Option Piping

	Type	Quantity	Cost
Distribution	6- to 30-inch piping	9,680 linear feet	\$298,340
Detention	36- and 48-inch piping	20,800 linear feet	\$1,356,800

Table 4. Low Impact Development Option Piping

	Type	Quantity	Cost
Distribution	4- to 36-inch piping	19,970 linear feet	\$457,780
Detention*	--	0	\$0

*Costs associated with detention in the LID option were accounted for under “earthwork” in Table 2.



The use of advanced LID-based stormwater management was instrumental in addressing the project's site-specific challenges and environmental issues.

ment costs between the conventional and LID designs by comparing the total amount of piping required under each option.

Although distribution costs for the LID option were higher by \$159,440, the LID option also completely removed the need to use large-diameter piping for subsurface stormwater detention. The elimination of this piping amounted to a savings of \$1,356,800. "The piping was replaced by a gravel reservoir beneath the porous asphalt in the LID alternative," says Potvin. "Utilizing void spaces in the porous asphalt subsurface crushed stone reservoir to detain stormwater allowed us to design a system using significantly less-large-diameter pipe. This represented the most significant area of savings between each option."

Conservative LID Design. Although the developers were familiar with the benefits of porous asphalt, Potvin says they were still concerned about the possibility of the systems clogging or failing. "The developers didn't have similar projects they could reference," he says. "For this reason, they were tentative about relying on porous asphalt alone."

To resolve this uncertainty, the Tetra Tech Rizzo team equipped the porous pavement systems with relief valve designs—additional stormwater infrastructure including leaching catch basins. "This was a conservative 'belt and

suspenders' approach to the porous asphalt design," says Potvin. "Although the porous pavement system is not anticipated to fail, this design and strategy provided the developers with a safety factor and insurance in the event of limited surface infiltration."

To further alleviate concerns, a combination paving approach was used. Porous asphalt was limited to passenger vehicle areas and installed at the far end of the front main parking area as well as in the side parking area, while standard pavement was put in near the front and

more visible sections of the retail center as well as the loop roads and delivery areas that were expected to receive truck traffic. "This way, in case there was clogging or a failure, it would be away from the front entrances and would not impair access or traffic into the stores," says Potvin.

LID System Functionality. The two porous asphalt drainage systems—one in the main parking lot and one in the side parking area—serve to attenuate peak flows, while the aggregate reservoirs, installed directly below the two porous

asphalt placements, serve as storage. The aggregate reservoirs are underlain by a filter layer of course sand, which provides an additional means of stormwater treatment. Stormwater flows through the filter course and into perforated underdrain pipes that converge to a large header pipe. Peak flow attenuation is attained by controlling the rate at which runoff exits the header pipe with an outlet control structure.

After being collected in catch basins, a majority of the stormwater runoff from rooftops and nonporous pavement areas flows to particle separator units, which treat stormwater prior to discharging into the crushed stone reservoir layers below the porous asphalt.

Outlet from the smaller aggregate reservoir, located underneath the side parking area, flows to an existing wetland on the east side of the site, and outlet from the larger aggregate reservoir flows to the gravel wetland on the west side of the site. The gravel wetland is designed as a series of flow-through treatment cells providing an anaerobic system of crushed stone with wetland soils and plants. This innovative LID design works to remove pollutants as well as mitigate the thermal impacts of stormwater. The greatest benefit of the gravel wetland is its treatment capacity for nitrogen. A gravel wetland has the capacity to remove nearly all of the bioavailable nitrogen (in the form of nitrate). The downstream receiving waters were recently listed as impaired for this contaminant.

Conclusions

Although the use of LID in residential and large-scale commercial development is still a relatively new application, both projects showed how LID, if designed correctly and despite significant site constraints, can bring significant water-quality and economic benefits. With Boulder Hills, cost savings were achieved in the site development design through a significant reduction in the amount of drainage infrastructure and catch basins required, in addition to completely eliminating the need for curbing and stormwater detention ponds. Moreover, with considerably less site clearing needed, more economic and environmental benefits were realized.

With Greenland Meadows, an advanced LID-based stormwater design was implemented because of the proximity of the development to the impaired Pickering Brook waterway. But in addition to helping alleviate water-quality concerns, the LID option featuring porous asphalt systems effectively eliminated the need to install large-diameter drainage infrastructure. This was estimated to result in significant cost savings in the site and stormwater management design.

The information provided in this article is part of a project titled *Forging the Link: Linking the Economic Benefits of Low Impact Development and Community Decisions*. More information is available from Robert Roseen at the UNHSC or Todd Janeski at Virginia Commonwealth University.

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