STORMWATER NATURE POCKETS: A CASE FOR USING GREEN INFRASTRUCTURE TO CREATE ENGAGING CHILDHOOD SPACES

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INTRODUCTION

Urban areas require stormwater management. Recently there has been a movement towards more nature-based, green infrastructure approaches for managing stormwater. These systems have also demonstrated additional ecosystem benefits much needed in urban areas. At the same time, decades of research support the need for access to nature for healthy childhood development. Designing and locating nature-based stormwater systems where children frequent renders systems as multi-functional spaces, providing synergetic opportunities, which benefit individuals and communities. Challenges to integrating these spaces include safety, cost, and management, all of which can be overcome by smart and appropriate design. Such design requires collaboration between different skillsets and stakeholders through some minimal, but essential changes in the consultation and design process. Ultimately, integrating nature-based stormwater practices into children's outdoor spaces will provide economic, environmental, and social benefits to urban areas.

KEYWORDS

green infrastructure, low impact development, outdoor learning environments, nature play, stormwatersoil biology, plant factor, evapotranspiration, drip irrigation, organic maintenance, hands-on workshop.

OVERVIEW

The conversion of land from natural, often forested or grassed, cover to pavement and rooftops results in an increase of stormwater runoff. Stormwater runoff and associated pollutants are detrimental to surrounding ecosystems, and ultimately result in concerns over safety and public health (Curriero et al. 2001; Gaffield et al., 2003). As such, stormwater mitigation tools, such as low impact development (LID) and green infrastructure (GI), are required in new and retrofit development. LID and GI approaches often incorporate vegetation and other natural elements to mimic performance by natural ecosystems. Such nature-based stormwater

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systems may concomitantly provide other natural benefits, including, but not limited to, air quality improvement, habitat creation, and educational enrichment.

Natural areas provide many benefits to children. Research over the past thirty years has shown that contact with nature is critical for children's physical, cognitive, and social development, and, like a vitamin, should be taken in frequent doses (Kuo and Miller, 2013). At the same time, children's access to nature is becoming severely limited. In one generation, children's play has shifted from free, unstructured outdoor play to highly structured, often indoor play (Louv 2008, Planet Ark, 2011). Incorporating natural elements into common childhood settings, including schools, parks, and even childcare centers, could provide more opportunities for children to interact with and benefit from nature.

Many of the sites that children frequent also require stormwater mitigation. Opportunities exist to extend the ecosystem benefits of LID/GI systems to also serve as nature pockets in children's play areas. Stormwater systems, traditionally buried and/or placed out of sight, can be located more conspicuously and integrated more functionally within sites to allow for different degrees of child interaction. This article explores the integration of stormwater mitigation objectives with those of childhood development by first, reviewing the stormwater and ecosystem benefits of LID/GI; second, reviewing the need for nature in the daily lives of children; and third, discussing the challenges to the integration of these two fields. Two examples are presented to illustrate both the challenges and successes of such an integration. The article concludes with recommendations for realizing integrated, nature-based stormwater systems within childhood spaces. Ultimately, this integration is a healthy, cost-effective, and wise way to provide access to nature for our children.

LOW IMPACT DEVELOPMENT AND GREEN INFRASTRUCTURE

LID/GI are evolving tools within the stormwater mitigation field. These designs focus on detaining stormwater runoff, while promoting infiltration and evaporation such that site hydrology is not affected by the conversion from pervious to impervious surfaces (Coffman, 2000). These systems tend to be small, cost-effective landscape features that are integrated throughout a site. Often, LID/GI incorporates vegetation to encourage pollutant treatment processes and infiltration and evaporation. Examples of LID/GI systems include bioretention cells (and rain gardens), stormwater wetlands, and rainwater harvesting.

Bioretention Cells

Bioretention cells (BRC), similar to rain gardens, are planted media beds designed to detain water, allowing time for media filtration, infiltration, and evapotraporation (Figure 1). Typical BRCs are able to reduce total nitrogen (TN) and total phosphorus (TP) loads by at least 40% and 65%, respectively (Davis et al., 2006; Hunt et al., 2006; Davis, 2007), while also, on average, reducing runoff volume and peak flow by 90% and 60%, respectively (Hunt et al., 2006; Davis, 2008). BRCs increase in performance when designed with a saturated zone at the bottom of the media (Brown and Hunt, 2011).

Stormwater Wetlands

Stormwater wetlands are shallow ponded, highly vegetated systems used to capture runoff and slowly release it over time. They offer natural filtration and slow water down so that pollutants are removed via sedimentation, adsorption, and biological processes. Wetlands are effective at

FIGURE 1: Children playing in a terraced bioretention system at the North Carolina Museum of Art in Raleigh, North Carolina (NC), USA (photo courtesy of Bill Hunt, NCSU).

FIGURE 2: This wetland at SAS Institute Preschool in Cary, NC receives water from shed rooftop shown in top-right corner of the photo (photo courtesy of The Natural Learning Initiative).

reducing pollutants due to regions of varying water depth (Figure 2). Stormwater wetlands can achieve 70% to 85% reduction in total suspended solids (TSS), 50% to 60% in TP, and 25% to 50% in TN (Cappiella et al., 2008; Lenhart and Hunt, 2011). Volume and peak flows are reduced by 50% and 95%, respectively (Lenhart and Hunt, 2011). Wetlands are generally used for larger watersheds, such as those greater than 4 acres (Wossink and Hunt, 2003).

Rainwater Harvesting

Rainwater harvesting (RWH) is traditionally installed in arid and semi-arid climates, but has expanded in application due to recent droughts in the Southeastern United States. RWH is used to capture stormwater from rooftops and store it for future usage (Figure 3). Often, RWH must have designated annual usage to be permitted as a stormwater mitigation tool. However, innovative designs, which slowly release unused rainwater, allowing adequate storage for upcoming storm events, are being explored (DeBusk, 2013). In addition to the volume reduction through water reuse, RWH can achieve some pollutant reductions within the tanks (DeBusk and Hunt, 2013).

Ecosystem Services in LID/GI

LID/GI systems, with the exception of RWH, function by mimicking natural ecosystem processes to provide stormwater mitigation benefits. For example, vegetated systems are able to reduce runoff more than non-vegetated systems because plants use the water for photosynthesis. Plant roots support microbial communities which transform nutrient pollutants to less mobile forms. The presence of earthworms has been shown to decrease clogging of BRC media, expanding the life span of the system (Greene et al., 2009). The natural processes occurring in LID/GI systems perform better as stormwater control measures than conventional engineered systems (Wilson, 2013).

FIGURE 3: Rainwater harvesting systems provide water play and education at (a) the Munchkin Academy in Buxton, NC (photo courtesy of Natural Learning Initiative), and (b) White Deer Park in Garner, NC

Ecosystem services are benefits that humans derive from nature (MEA, 2005). Folk et al. (1998) found that large cities across Europe depend on land area 500 to 1,200 times greater than the city themselves to function. In addition to increased stormwater mitigation performance, studies have pointed towards additional ecosystem services of nature-based LID/GI (Table 1). The presence of vegetation in a BRC or wetland reduces local temperature through evapotransporation (Streiling and Matzarakis, 2003; Bolund and Hunhammar, 2007). Stormwater wetlands are able to sequester carbon (Moore and Hunt, 2012). Trees present in a BRC can reduce air pollutants and process carbon dioxide (McPhearson et al., 1997; Taylor et al., 1998). Urban gardens are able to provide habitat for birds, bees, and other important fauna (Daniels and Kirckpatrick, 2006; Fetridge et al., 2008; Sperling and Lortie, 2011). Although RWH does not include vegetation itself, it supports natural processes by providing us with an opportunity to recycle nutrient pollution from stormwater runoff to support plant growth via irrigation. Also, these systems reduce energy demands by keeping water sources localized instead of requiring pumping to places of use (Daigger, 2009).

Traditionally, stormwater features are placed peripherally and out of the way such that some services are not actualized. Limited research exists evaluating ecosystem services of stormwater systems (Moore and Hunt, 2013), likely because many services are difficult to quantify. On the other hand, research is continuously published across many fields on the need for natural spaces accessible to children, particularly in urban settings (Matsuoka and Sullivan, 2011). LID/GI may be one way of bringing pockets of functioning ecosystems into children's spaces.

CHILDREN IN NATURE

Importance of Child Play in Nature

Children have an innate connection with nature. Kaplan and Kaplan (1973) discuss the importance of nature for cognitive respite. E.O. Wilson (1984), in his theory of *Biophilia*, claims that people subconsciously find security in nature. Whatever the theory, children universally seek out dirt, water, and natural elements (Moore and Wong, 1997; Blair, 2010). When a child plays in nature, he or she experiences an abundance of sensory experiences (Johnson and Hurley, 2002; Blair, 2010). These experiences are essential to cognitive, physical, and social development, initiating multiple senses at one time (Johnson, 2000).

Cognitive Development

Nature provides abundant benefits that are important to healthy child development. When outdoors, multiple senses are softly stimulated by nature, in a way that is both restorative (Kaplan, 1995) and experiential (Blair, 2000). Children's engagement with nature changes over time, both seasonally and physically (plant an acorn, climb the adult oak), offering variety to their educational experiences. Nature allows children to interact with it and within it in a variety of ways (Moore, 1996; Letser and Maudsley, 2007). For example, a tree can afford activities such as climbing, resting in the shade, collecting loose parts, growing food, chasing around, and etcetera. Such experiences with nature are not only fun for a child, but provide meaningful learning interactions essential for childhood development.

Cognitive development improves when children have contact with nature. Wells (2000) observed improvement in the ability to focus when urban children were relocated to areas in more natural settings. Kuo and Taylor (2004) have also reported improved Attention Deficit Hyperactivity Disorder (ADHD) symptoms when children have performed an activity in natural areas. When nature is incorporated into classrooms, schools have reported observable and measurable improvements in classroom performance (Harvey, 1989; Lieberman and Hoody, 1998; AIR, 2005; Blair, 2010; Matsuoka, 2010).

Physically

Several studies have linked outdoor play to physical health. Grahn et al. (1997) (as described in Moore and Cooper Marcus, 2008) showed that children who played in wooded outdoors areas of their preschool exhibited advanced gross motor skills, higher fitness levels, and lower sickness rates than their traditional school counterparts. Liu et al. (2007) found vegetation around a child's house to be predictive of a healthy weight in children living in dense neighborhoods. These interesting correlations may be related to the attractiveness of the natural world to children. Vegetative areas are likely more attractive for outdoor play than expansive concrete surfaces present in many schoolyards.

Recently, the medical field has acknowledged the health values of exposure to nature. Dr. Howard Frumkin, Dean of the School of Public Health at the University of Washington and former director at the U.S. Center for Disease Control (CDC), calls his field to action, using nature conservation as a public health strategy to disease prevention (Frumkin and Louv, 2012). In late 2013, the American Public Health Association adopted Policy Statement 20137, which "Calls on public health, medical and other health professionals to raise awareness among patients and the public at-large about the health benefits of spending time in nature and of nature-based play and recreation," and "promote[s] natural landscaping," thus emphasizing further the essential need for childhood access to nature.

Social

Contact with nature also improves children's social behavior. Teachers of at-risk 6th graders in California schools saw significant social and emotional improvements after students attended a one-week outdoor residential science course. Students were reported as having increased self-esteem, improved behavior, and more positive peer relationships (AIR, 2005). Students in Toronto Schools also demonstrated more cooperation and inclusion with their peers after the greening their school grounds (Dyment, 2005). The incorporation of trees and plant patches offered different spaces for the children so that they could have small group or personal space. One teacher in Toronto commented that Special Education students found a space in an area of shade trees where they were comfortable and accepted by other kids.

Children raised in frequent contact with nature then grow up to be more environmentally conscious. Thompson et al. (2007) found that frequent childhood visits to wooded areas or green space correlated to increased frequency of visits as adults. When children are exposed to nature, they are also more able to see the interconnectedness of the world (Dyment, 2005), which in turn, will bring a new perspective to human interaction with nature—the soil grows the plant, I eat the plant, I compost the scraps, the scraps nourish the soil. On the other hand, if children miss exposure to the natural world, they may lose their bond with nature as adults (Hansen, 1998), which could be detrimental to the human relationship with the natural environment. Ultimately, Rivkin (1997) states that knowing nature will lead to caring for nature. Caring for nature, in turn, is a keystone for stewardship behavior in adulthood

(Chawla 1999; Chawla, 2006). Thus, raising our children to give nature a voice is critical to the future of innovative approaches to support our increasingly urban populations.

Children's Access to Nature

Children have increasingly less access to nature. Many studies have attempted to articulate the causes of limited access. Cultural changes have occurred in the past 30 years, including a reduction in children's independent range related to parent's concerns for their child's safety (Lester and Maudsley, 2007). This may be related to an increase in media depicting dangers, increased traffic, and less community interaction within neighborhoods. Additionally, children's schedules are more and more structured, hindering free play and exploration (Johnson, 2000; Lester and Maudsley, 2007). With increased access to technologies, play is more sedentary and technology-based (Lester and Maudsley, 2007).

When children do have access and time for playing outside, artificial play structures, open green fields, and asphalt jungles can dominate their play spaces (Figure 4). For instance, a baseline assessment of childcare centers in North Carolina showed three times as many manufactured components as natural components within the outdoor play areas (Moore and Cooper Marcus, 2008). It is a common misconception that if you pay a lot of money for a play structure, the quality of play will also be more valuable.

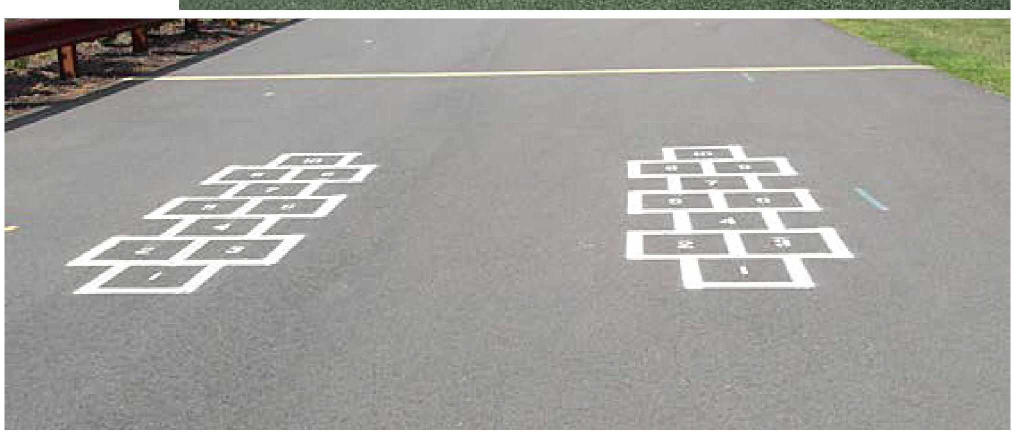

FIGURE 4: Manufactured play features provide few or no linkages to nature, and (b) sterile, pavement-dominated "play" areas typically serve singular uses and do little to inspire the imagination (photos courtesy of Stephen Mosberg).

Ironically, sustainable development has focused intently on technology and the buildings themselves, and very little on the outdoor space surrounding the buildings. Rating systems have only recently been geared towards the quality of outdoor spaces (i.e., Sustainable Sites Initiative™ (SITES™) and Envision™). Conventionally, most outdoor space, when referenced, is categorized as "green space". However, not all green space is equal. Although closer to nature than concrete, open grass patches can hardly be considered a functioning ecosystem. Gardens, trees, and water all contribute to the biodiversity of a space and, therefore, are requisite to achieve the multi-benefit potential of a functional ecosystem. When the natural world becomes the focus of the design of outdoor spaces, little effort is required to connect children with these spaces (Moore and Cooper Marcus, 2008).

LID/GI AS NATURE POCKETS

The benefits of childhood contact with nature are thoroughly documented, as well as the consequences of childhoods without. The medical, educational, ecological, and public health fields agree that children need to be in contact with nature. Like other beneficial nutrients, exposure to nature via green space, or 'Vitamin G' (Kuo and Miller, 2013), should be a regular and frequent part of every child's daily routine. Exposure to Vitamin G can be achieved via different routes, from digging in the dirt to viewing it from a distance. The caveat: one must have access to it to receive benefits from it. Therefore, nature should be prevalent in places where children frequent—parks, childcare facilities, streets, and schools.

Nature-based stormwater practices, like LID/GI, when integrated into children's outdoor play spaces, offer opportunities for children-nature interaction. Many places children frequent have impervious surfaces and required stormwater control measures. Using stormwater systems to serve needs beyond that of stormwater mitigation is an example of "functional integration" (Fox, 2008). These multi-functioning landscapes can offer economic, environmental, and social value at very little cost beyond our conventional landscapes (Table 1).

Challenges to Integration

Designing integrated LID/GI systems into play and learning environments for children has to overcome multiple challenges. LID/GI systems are only now becoming standard tools in the engineering toolbox. These systems require some more design integration, require more upfront cost, and require collaboration outside of the traditional engineering disciplines. On the other hand, child outdoor learning environments continue to be designed using manufactured play equipment in spaces of very little landscape diversity. The integration of these two concepts has unique challenges including safety concerns, cost, and management.

Safety Concerns

Several misconceptions exist about the integration of nature into children's spaces—some merely perceived and some requiring careful consideration. Toxin exposure has been the impetus to many regulations restricting childhood environmental exposure. Frumkin (2001) argues that the positive health effects of exposure to nature often far outweigh the negative effects. LID/GI systems are designed to retain pollutants, and as such, should be designed appropriately for the space. Woodchips, for example, play an important role removing metals in BRCs. Therefore, BRCs located in childcare centers should not receive runoff from pavement with heavy vehicle traffic because very young children may consume the mulch and be

TABLE 1. Benefits of specific LID/GI strategies.

LID/GI	Benefits for Children	Additional Ecosystem Services
Bioretention (BRC)/ Rain	• Science, writing, art curriculum development • Opportunities for unstructured exploration • Diversity of sensory stimulation • Learning through seasonal, life-cycle changes • Incorporates all nature's ingredients (i.e., sun, rain, bugs, birds) • Naming and categorizing species • Develop a sense of familiarity and pride related to outdoor environments	• Reduces peak stormwater flows • Recharges groundwater table • Microclimate regulation and reduction in urban heat island • Provides habitat for beneficial species • Attracts pollinators • Opportunity for increasing biodiversity • Reduces nutrients and metals in rainwater • Improve air quality • Promote seed propagation • Opportunity for food production
Wetlands	• Fosters positive and cooperative relationships with others • Promotes inclusion • Promotes creative play • Creates multi-generational settings • Fosters environmental awareness	• Critical to carbon cycling and carbon sequestration • Reduce microbial pollution during base flow and stormwater flow • Manage stormwater pollution • Reduce peak flow and runoff volumes during storm events • Provide flood mitigation • Regulate microclimate in terms of temperature • Improve air quality because host a variety of vegetation • Provide opportunity for food and resource production • Provide habitat for beneficial species • Source of biodiversity
Rainwater Harvesting (RWH)	• Science, writing, mathematics, and art curriculum development • Demonstrates important concepts like water cycle, water resource conservation, etc. • Hands on water play • Sense of local, environmental context • Foster positive and cooperative relationships with others • Promotes inclusion • Promotes creative play • Fosters environmental awareness	• Opportunity for energy savings when water is reused • Nutrients in reuse water may reduce need for additional soil amendments when used for irrigation • Uses the more appropriate resource of non-potable water in place of potable water

exposed to a metal toxin (Brown and Peake, 2006). Rather, a series of small BRCs could be designed with children only having access to the most downstream BRC such that the metal toxins were removed upstream, and therefore not present in the water entering this cell.

Most stormwater systems will, at some point, have ponding. In most cases, this will only occur during a rain event. In stormwater wetlands, the ponding is intended to be permanent. Standing water in children's spaces is often viewed as a drowning hazard, and therefore prohibited. Access to permanently ponded water could be a safety concern where very young children are playing, such as childcare centers. In these cases, flexibility in the maximum depth of the wetland may overcome this concern while maintaining some stormwater benefits (see Figure 1 above). When the credited minimum depth of 18" is used for the deepest parts of wetlands, wetlands should not pose concern at parks or elementary schools. Restrictions, in this case, are likely due to conservative risk management (Moore and Cooper Marcus, 2008), ignoring the many benefits of such systems. Successful applications within children's environments do exist. For example, Harry K. Hamilton Elementary School in Nova Scotia restored a stagnant pond into a thriving amphibian habitat (Evergreen, 2001). The pond only needed to be 18" deep for a functional habitat, and parents and stakeholders were comfortable with this depth.

Natural areas provide habitat to a variety of plant and animal species that live side by side. Snakes and spiders are essential to the food chain, keeping creatures from overrunning the ecosystem and deteriorating its function. Some predators, such as snakes or wasps, may be viewed as dangerous when located in or near children's play spaces, but this is often a misconception based on our lack of knowledge about the ecosystem. As opposed to the "fear of the unknown," the presence of these creatures within their own habitat can offer a learning opportunity for children to develop healthy interaction skills to foster cohabitation. In many cases, the presences of habitat for such critters can be a much safer alternative to spraying chemically-based pest controls or poisons to regulate other unwanted pests. For example, First Environments, a childcare center in Durham, North Carolina, reported less fire ant activity when they restored their outdoor space to have more natural diversity (personal communication, October 9, 2012).

EXAMPLES OF LID/GI IN CHILDREN'S PLAY SPACE

As this concept becomes more accepted, it is important to share the successful stories, as well as the stories that offer opportunities for learning. Several of these integrated systems already exist, and much can be gleaned from them.

The Montessori School of Winston-Salem, NC

The Montessori School of Winston-Salem had a stormwater dry pond on its grounds. Over time, the pond outlet structure became clogged, thus causing permanently ponded water. Eventually, a shallow wetland environment began to form. The wetland became a part of the school's outdoor classroom, with students exploring and learning about the ecosystem. The school was later informed that converting the system back into a dry pond via unclogging of the outlet structure was required. The dry pond area, again, became a single-function space, no longer a place of student interaction. It is easy to understand the need for onsite stormwater mitigation. But, in practice, dry ponds offer few pollutant removal benefits compared to wetlands (Lenhart and Hunt, 2011; Wilson, 2013) and very few additional ecosystem benefits. It would have been interesting to investigate what sort of stormwater benefits were being achieved by the wetland, and to consider how the benefits may outweigh the loss in storage volume due to the clogging. However, it was not in a stormwater regulator's skillset, mindset, or prerogative to do this. This example illustrates the value and potential of nature-based stormwater systems are to childhood spaces, but also the consequences of regulation and professional practice that focus solely on single-purpose systems.

First Environments Childcare Center

If the previous example offered some insight to the challenges of integrating LID/GI systems into children's outdoor spaces, First Environments Childcare Center in Durham, NC provides a hopeful model for what could be. The space just outside the building includes BRC capturing runoff from one roof, and raised garden beds watered by RWH. Children learn about water as a resource, and the role of rainwater in replenishing our groundwater and nourishing our plants. They complete the lesson by eating snacks and lunch from their garden. First Environments is constantly improving their outdoor space, choosing one or two small projects at a time. Families, children, and staff play a large roll in managing the space through suggesting and refining ideas, and workdays. The site shows that with the motivation and hard work of a community of people, the integration of RWH, BRC, as well as many other pockets of nature can be integrated into not only childhood spaces, but more importantly into the lived experience of childhood.

ACTIONS AND RECOMMENDATIONS

As engineers, landscape architects, ecologists, gardeners, etc., it is often difficult to think beyond the design objectives that we are paid and trained to address. However, addressing multiple programmatic and functional objectives creates synergistic opportunities to benefit individuals, groups and organizations, and communities-at-large. Papers written on naturalizing children's spaces unanimously call for collaboration between skillsets and stakeholders (Johnson, 2000; Johnson and Hurley, 2002; Brink and Yost, 2004; Dyment, 2005; Moore and Cooper Marcus, 2008; Blair, 2010). The case of creating LID/GI as nature pockets in childhood play spaces is no different. Engineers should discuss the potential placement of LID/GI systems such that they become the focal points of outdoor spaces. They should call upon their horticulture colleagues to help choose site appropriate plants for their systems. They should work closely with their landscape architecture colleagues to organize the site in ways that maximize programmatic function and choreograph the interaction(s) between people and the system(s). They should work with public health officials to understand what pollutants should be a concern for children. The logistics of these collaborations are currently difficult, as our contracting structure is designed such that each of the colleagues is located in different specialized offices. Despite this, the consulting process can be proactively organized to facilitate collaboration. First, developing a well-articulated design vision (concept) and project goals (intent) will help to identify disciplinary overlaps and to synthesize project outcomes into a seamless, integrated whole. A rating system, such as Sustainable Sites Initiative™ or Envision™, can be used to help provide guidelines and examples for integrating goals. Second, any professional should know their own skills and expertise, and pursue contacts with different skills and expertise. When you have "go-to" experts, collaboration becomes a very natural part of design. Third, instead of a compartmentalized, step-by-step design process, consider the design as a more iterative process. All the disciplines should be involved for each phase of the project, such that each has a stake in the design as a whole. Ultimately, as more companies design multi-functional spaces by collaboration, the more multi-functional spaces will be built.

CONCLUSIONS

Nature is invaluable. Research quantifying and valuating the benefits of integrating nature into engineering designs has demonstrated a value greater than that of any manmade market. Similarly, decades of research on childhood contact with nature shows us that this interaction is essential for childhood development. It is therefore prudent to consider how to optimize the services that nature freely offers us through the wise design and arrangement of space. Nature-based stormwater systems, like LID/GI, should be located where and designed so that children have access to play, explore, and enjoy them. Initially, the vision of integrating stormwater systems and children's play spaces into unified amenities may pose challenges, but smart, appropriate design, achieved through the interdisciplinary efforts of many different fields, allows the benefits to far outweigh the costs. Ultimately, these multifunctioning nature pockets offer economic, environmental, and social value needed to sustain our urban and suburban societies.

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