Sustainable Site Design Strategies for Urban K-12 School Renovations:

Green Design Techniques in which Detroit Public Schools Is and Can Be a Leader

by

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ABSTRACT

Sustainability in the design of K-12 public schools in the United States is gaining momentum due to the environmental, educational, health, and financial benefits afforded students, staff, the district, and the wider community. Detroit Public Schools is no exception to this trend. However, as is often the case with sustainability in the built environment, Detroit Public Schools' focus has been heavily biased toward the building systems and building envelope, with little attention given to sustainability on the site. While not incorporated into these projects initially, the absence of site sustainability presents an opportunity for improved environmental stewardship at these otherwise exemplary schools. This study provides a broad overview of sustainable site design techniques available to urban K-12 school renovations, specific and quantifiable recommendations for their execution, and an example application of those recommendations at Detroit's Martin Luther King, Jr. Senior High School. Further, the study provides an evaluation of the application from the landscape architect's perspective. Site sustainability techniques focused on in the study include stormwater management, landscape and irrigation, food systems and urban agriculture, and on-site energy generation, all from the point of view and discipline of the landscape architect attempting to design a functional, aesthetically-pleasing, and environmentally-stewarded school campus. Areas where Detroit is already a leader in sustainability are noted, such as with its Food and Nutrition Program and the incorporation of urban agriculture in its food system and curriculum. Affording Detroit Public Schools the tools necessary to accomplish its next frontier of sustainability, this study seeks to help cement the district's leadership in this capacity.

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TABLE OF CONTENTS

Appendices

Sustainable Site Design Strategies for Urban K-12 School Renovations:

Green Design Techniques in which Detroit Public Schools Is and Can Be a Leader

CHAPTER 1 – STUDY OVERVIEW

INTRODUCTION

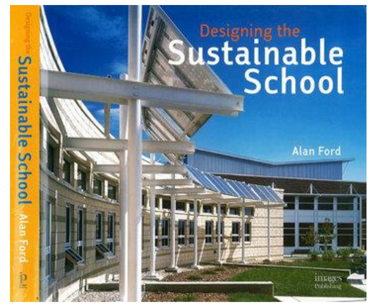


Figure 1

The implementation of sustainable design strategies in K-12 schools is a trend that is gaining momentum in the United States. Studies, as well as the experience of education professionals, have shown that the environmental, academic, health, and financial benefits of sustainably designed schools are impossible to ignore. Sustainable design, for the purpose herein, is defined as reduced or eliminated environmental impacts through thoughtful design of the built environment. An interesting phenomenon of sustainable design is the synergy that exists between and among the benefits of sustainability in schools. For example, green schools use 33% less energy and 32% less water than traditionally designed schools, yielding both reduced environmental impacts and reduced utility costs (USGBC). Likewise, the improved health of teachers and students in sustainably designed schools yields reduced absenteeism, which costs districts less and is also positively correlated to increased academic outcomes. (Miller)

While the benefits are almost universal, the disadvantages are few with the obstacle most-often cited being increased up-front costs. Even this concern is more of a perception than a reality, as a result of green building practices becoming more common, therefore less and less of a cost premium, and the payback period of green design techniques becoming better understood. In fact, the financial disincentive that once existed to implementing a sustainably designed school is coming full circle to a financial incentive, as school districts across the country reap the benefits of more efficiently designed buildings. Thus, even districts grappling with the most severe budgetary challenges are considering sustainability initiatives as *the* responsible solution for environmental, academic, health, and financial reasons. As the financial implication of any school initiative is paramount in this era of widespread strained school budgets, the financial benefit of sustainable design is fortuitous. And with urban districts being particularly hard hit by funding challenges, the financial benefit is especially crucial to such districts' ability to implement these initiatives.

THE SCHOOL FUNDING CONUNDRUM

Across the United States, school districts have been confronted by decreased funding to their operational budgets over the past decade and more. These funding cuts have taken many forms. At the federal level, crucial programs such as the Federal Enhancing Education through Technology (FEET) program, among others, have been reduced and then abandoned entirely, while programs such as No Child Left Behind have introduced new testing and performance criteria without the establishment of new funding. (Henke)

At the state level, a common policy shift has relocated the responsibility for school funding from the local level to the state level. This centralization trend is intended to even the school funding appropriation between more and less affluent communities, tying funding directly to enrollment figures. The consequences of this policy, while not entirely intentional, can be reduced funding to the more affluent districts (in order to subsidize the less affluent districts), but also reduced funding to the less affluent districts when their enrollment figures decline due to population reduction or the advent of 'school of choice' and charter school options. These unintended consequences have been particularly realized in Michigan's urban school districts. (Zimmer)

Figure 2

The reality of diminishing funding to our nation's school districts has resulted in the need for administrators to consider numerous measures of reducing operating costs. These measures often take the form of decreased programs and increased operational efficiencies. Decreased programs can include the loss of non-core curricula, such as art and music, while increased operational efficiencies may take the form of workforce reductions, larger class sizes, and building consolidations. Another form of increased operational efficiency is through the introduction of sustainable design techniques as a means of reducing the cost of operating and maintaining school buildings and campuses. For instance, minimizing a building's energy demand by improving the thermal efficiency of the building envelope is just one example of sustainable design.

While operational budgets may have been strained over the last decade or more for many of our nation's public schools, capital improvement projects in many districts remained robust. This was often the result of funding policies that allowed capital improvements to be locally financed, again the case in Michigan. In effect, as districts sought a competitive edge in order to retain in-district and attract out-of-district students and their associated per-pupil state funding, renovated or new state-of-the-art facilities became an attractive and necessary means of doing so. (Militello) Coinciding with the fiscal need for capital improvements, however, was a fiscal reality requiring operational efficiency of those new and renovated facilities. This, coupled with the green design movement becoming more mainstream in the United States, created ripe circumstances for a trend of sustainable design in K-12 schools that continues today.

STATEMENT OF THE PROBLEM

Detroit Public Schools (DPS) is perhaps an extreme example of a district that has endured severe funding cuts over the past decade or more. DPS was almost certainly intended to benefit from the State of Michigan's school funding centralization policy implemented in 1994, known as Proposal A, which aimed to bring per pupil funding of less affluent districts such as Detroit's on par with the more affluent suburban communities. However, the unintended consequences of the school-of-choice and charter school programs enacted in the years since, coupled with the City's on-going population decline, have caused the district great financial distress as it has grappled with plummeting enrollment.

Speaking in round numbers, just twelve years ago DPS had over 200,000 students and operated 300 schools. Due to the persistent trend of population decline in the City of Detroit, along with the advent of alternative education options, today the district has only 50,000 students enrolled and operates just 96 schools. (Lauzzana) The resulting per pupil funding cuts have been devastating to the district's operating budget as it attempts to shrink operations in proportion to enrollment figures that are a fraction of what they once were, a feat with which any district would almost certainly struggle.

In the face of this enrollment and funding crisis, in 2009 DPS, like many of its neighboring school districts, pursued capital improvements as a means of remaining competitive. This funding was made available to the district through the federal government's economic stimulus package introduced by President Barack Obama to stimulate the nation's economy in the midst of recession. Specifically, $500.5 million in stimulus bonds were made available to DPS in the form of no- and low-interest bonds. Voters approved this referendum, known as Proposal S, allowing Detroit Public Schools to build eight (8) new, state-of-the-art schools and to completely renovate 10 more. (Detroit Public Schools)

Sustainable design was incorporated into each project as evidence of the district's commitment not only to environmental sustainability, but also to managing its operational and maintenance costs in the future. In fact, seven (7) of the eight (8) new schools pursued and received LEED Certification through the United States Green Building Council (Lauzzana), the most widely recognized and used green building rating program in the world. However, the focus of sustainability on these projects, and to some degree within LEED, was almost exclusively on the buildings. In contrast to the buildings, the sites were designed with fairly traditional development methods and modern sustainable site design techniques were largely not pursued. Of course, these are decisions that districts must make as they balance their capital improvement budgets with their sustainability goals. While site sustainability was not incorporated into these projects initially, their absence presents an opportunity for improved sustainability at these otherwise exemplary schools.

Incorporating sustainable site design techniques into Detroit Public Schools' campuses has the potential of extending benefit beyond just the district. The City of Detroit's failing infrastructure is just one of many monumental challenges it currently faces. For instance, the majority of the City's 3,000 plus miles of water mains are between 70 and 90 years old and are failing. Cities and utility authorities, as a national average, rebuild one percent (1%) of their systems each year. Had the City of Detroit operated within this average, it would have invested approximately $25 million per year in maintenance costs for its water mains. Instead, it has only invested $3.4 million for each of the last three years. (City of Detroit) Though a plan is now in place to begin those much-needed improvements to the water mains, similar statements of disrepair can be made regarding the City's storm and sanitary sewer systems, many of which remain combined, and the City's electrical grid. Detroit Public Schools need only

Figure 3. Detroit's Overburdened Infrastructure

look to the current state of the City's infrastructure as further reason to incorporate sustainable site design techniques as a means of reducing stress on an already strained infrastructure.

As Detroit Public Schools has 1) made a clear commitment to sustainable design, 2) exists within an environment of stressed infrastructure, and 3) has stopped short of extending sustainable design outside of the building and to the site in a substantive way, this practicum provides an overview of sustainable site design strategies for urban K-12 school renovations that DPS can utilize in elevating site sustainability to a similar level as building sustainability within the district. Additionally, this practicum provides a Design Study and Application of those strategies to recently-reconstructed Martin Luther King, Jr. Senior High School. While the focus of this study is recently renovated and recently constructed or re-constructed schools that achieved LEED certification, the strategies will no doubt have applicability to renovations of older schools and campuses, as well as construction of new schools and campuses.

RECENT TRENDS OF K-12 SITE DEVELOPMENT

While much has been written about the History of School Design in academic literature, comparatively very little has been documented about the history of school campus design. Despite a lack of specific documentation on school site design trends that might provide useful insight for this study, the suburbanization of America following World War II is extensively recognized and its land-consumptive development patterns are well-known and well-documented, with clear influence on K-12 school development.

For the first half of the twentieth century schools, like the towns they served, were constructed compactly, supporting and mimicking a neighborhood's density. The school building tended to be a substantial civic structure of classical or colonial Georgian or Gothic architectural style, often multi-storied. However, after World War II, during a school-building boom to accommodate increased enrollment of the Baby Boomer generation, modern standards replaced classical standards and typical school buildings became one-story, flat-roofed structures enclosed with a combination of glass, metal, brick, and concrete. The building configuration took the form of "fingers" where corridors spread out across the site, affording each classroom access to maximum amounts of fresh air and, often, direct access to the outside through exterior doors. (Baker) Guidebooks of the era suggest that single-story buildings are less difficult to evacuate than multi-story buildings, providing a glimpse of the safety concerns that were influencing design decisions of the time.

The single-story development pattern described above vastly increased the land area requirement of many schools constructed during the era. These land consumptive trends persist today bolstered in national guidelines published by the Council of Educational Facility Planners International (CEFPI). In fact, those guidelines suggest that a suitable site for the development of a high school is at least 30 acres, plus one acre for every 100 students. (Beaumont) Sites that large are often only available in outlying areas, outside of a reasonable walking distance for students and staff. Concurrently, transporting students to school via school buses more than tripled in the last half of the twentieth century (Tull), further minimizing the incentive for neighborhood schools. Together, these trends resulted in the need for vast expanses of pavement to allow for parking and bus transportation circulation, further exacerbating sprawl and the associated negative environmental impacts. As such, mitigation methods to these impacts are key considerations of sustainable site design strategies for schools, especially new schools.

A more recent trend in school design is in the area of safety and security. As districts attempt to safeguard students and staff in the educational environment, policies are being adopted and best management practices recommended on a variety of measures. These measures are intended to not only deter criminal activity at schools, but also to provide protections to students and staff, and facilitate emergency response, when and if a crime occurs.

In Spring 2013, the Council of Educational Facilities Planners International (CEFPI) issued a planning guide, *Safe Schools: A Best Practices Guide*, that seeks to create a school environment that lends itself to emergency preparedness and response. (CEFPI) The guide offers broad advice to district officials, planners and designers on such topics as crisis communications, staffing and training, emergency procedures, and infrastructure. While the infrastructure recommendations mostly entail building design considerations, some protections are specific to site design. The site design considerations for safeguarding students and staff, as recommended by CEFPI, involve protecting exterior entrances with bollards or large, barrier-style planters; ample exterior lighting; fencing of the school property perimeter, inclusive of any playgrounds or athletic fields; gate-controlled parking lots; and exterior security cameras.

A similar guiding principal for designing the built environment with safety and security in mind is Crime Prevention through Environmental Design (CPTED). This term was coined by Ray Jeffrey in 1971 and suggests that proper design can lead to a reduction in the fear and incidence of crime. (Crowe) While CPTED was initially applied to the broader built environment, the Centers for Disease Control and Prevention (CDC) is studying how CPTED can be applied to school violence prevention and offers strategies that include providing natural surveillance, where physical features maximize visibility both into and out of the building, and by providing access management, where entrances are well-marked and limited access areas are blocked by real or symbolic barriers including landscaping. (CDC) On the whole, these recommendations from both CEFPI and CPTED are not in conflict with sustainability trends in school site design. However, designers must pay closer attention to sight-lines, visibility, circulation, and connectivity off-site than perhaps they would have if school safety and security had not become the priority that it is today.

BENEFITS OF SUSTAINABLE DESIGN PRACTICES IN SCHOOLS

In basic terms, the environmental benefits of sustainable design practices in schools, especially those that reduce consumption of limited resources such as water and energy, are well understood, and are discussed in further detail in Chapters 2 through 5. By extension, the benefits of sustainable design practices to the efficiency and long-term operating costs of facilities are also somewhat implicit. This stands to reason as reduced consumption is generally associated with reduced costs, assuming a reasonable payback period for any upfront cost premium related to the particular sustainability technique.

Perhaps not as commonly known, green design in schools is correlated with positive effects on teacher and student health, as well as learning. These positive effects manifest themselves in reduced rates of absenteeism, lower turnover, higher productivity, and improved learning and test scores. (Kats) Very compelling statistics have been generated in a number of school-specific studies related to improved learning and test scores especially, and are thought to be related to improved indoor air quality, expanded temperature control and high performance lighting of green buildings, all of which have improved the performance and test scores of office workers in similar studies.

Figure 4. Benefits of Sustainability in Schools

The financial impact of improved health and learning can be far reaching when considering that student performance is ultimately tied to annual earnings of an individual over the course of his or her lifetime. The International Money Fund, in its 2005 publication reviewing the financial benefits of education, concludes that a 34 percentile positive deviation in mathematics testing scores at the end of high school, resulted in 12 percent higher annual earnings over the course of one's lifetime. As green buildings have consistently shown a three (3) to five (5) percentile improvement in test scores, a lifetime earnings increase of 1.4% can be extrapolated. (Kats) In addition to financial gains that can be associated with green buildings, financial savings are also achieved as a result of asthma, colds and flu reduction among children; reduced teacher sick days; and increased teacher retention.

Improved learning as a result of an improved learning environment is not solely associated with the quality of the school building, however. Research has shown that students who learn through engagement with their natural environment, a form of experiential learning, have improved overall academic performance. (Barr) Experiential learning opportunities abound on sustainably-designed school sites. The surface storm water management system, on-site energy generation systems, landscape gardens, and vegetable gardens, if incorporated into the site design, can be readily utilized by teachers in many segments of the core curriculum, as well as the arts.

Experiential learning, especially when garden-based, has been shown to increase science achievement in elementary school children. (Rye) Further, these results are reinforced in studies that focus on predominately African American student populations in low-income, inner-city public schools, with some students being from disadvantaged backgrounds. (Smith) While experiential learning is certainly not unique to sustainably designed schools, the design techniques typically incorporated into sustainably designed school sites readily lend themselves to increased opportunities for experiential learning.

Figure 5. Garden-based Learning

CURRENT SITE SUSTAINABILITY TECHNIQUES AS ENCOURAGED BY LEED FOR SCHOOLS

The United States Green Building Council's LEED for Schools (2009) is the design and construction industry's most widely recognized and utilized sustainable design rating system for K-12 schools in the U.S. Furthermore, it is the system that Detroit Public Schools adopted for its recent sustainably-designed school projects. As such, it is being utilized as a basis for the sustainable site design strategies discussed herein. The following itemization identifies the sustainable design techniques outlined in the USGBC publication and reference guide, *LEED 2009 for Schools New Construction and Major Renovations*, focusing on site development with a brief explanation of each:

- Site Selection – encourages choosing a development site that would reduce the environmental impacts from building a school on that site. Such discouraged sites would include prime farmland; land that is habitat for threatened and endangered species; undeveloped land in or near a floodplain, wetland, or waterbody; public parkland; etc.
- Development Density and Community Connectivity – channels development to urban areas with existing infrastructure in order to protect greenfields and preserve habitat and natural resources.
- Brownfield Redevelopment – encourages rehabilitating damaged sites where development is complicated by environmental contamination to reduce pressure on undeveloped land and requires remediation of site contamination.
- Alternative Transportation: Public Transportation Access – encourages development of sites that allow access via public transportation, walking, or rideshare in order to reduce pollution and land development impacts from automobile usage.
- Alternative Transportation: Bicycle Storage and Changing Rooms – encourages the provision of bicycle facilities on the site in order to reduce pollution and land development impacts from automobile use.
- Alternative Transportation: Low-Emitting and Fuel-Efficient Vehicles – encourages the provision of preferred parking for low-emitting and fuel-efficient vehicles in order to reduce pollution and land development impacts from automobile use.
- Alternative Transportation: Parking Capacity – suggests minimizing the quantity of developed parking in order to reduce pollution and land development impacts from automobile use.
- Site Development: Protect or Restore Habitat – encourages limiting the site disturbance footprint or restoring a previously developed site's disturbance footprint in order to conserve existing natural areas and restore damaged areas to provide habitat and promote biodiversity.
- Site Development: Maximize Open Space – encourages the provision of a high ratio of open space to development footprint in order to promote biodiversity.
- Stormwater Design: Quantity Control – encourages increased on-site infiltration and reduced or eliminated pollution from stormwater runoff as a means of limiting disruption of the site's natural (pre-development) hydrology.
- Stormwater Design: Quality Control – encourages stormwater management that ultimately limits disruption and pollution of natural water flows.
- Heat Island Effect: Nonroof – encourages the provision for shade, highly-reflective materials, and/or open-grid pavement systems that will result in reduced heat islands thereby minimizing impacts on microclimates and human and wildlife habitats.

- Heat Island Effect: Roof – encourages the use of green roofs or highly reflective roofing materials as a means of reducing heat islands, thereby minimizing impacts on microclimates and human and wildlife habitats.
- Light Pollution Reduction – encourages project lighting design that minimizing light trespass from the building and site, reduces sky-glow to increase night sky access, improves night visibility through glare deduction, and reduces development impact from lighting on nocturnal species.
- Site Master Plan – encourages site master planning to ensure that the environmental site issues included in the initial development of the site and project are continued throughout future development caused by changes in programs or demography.
- Joint Use of Facilities – encourages the school facility to be utilized as a more integrated part of the community, by enabling the building and playing fields to be used for non-school events and functions.
- Water Efficient Landscaping – encourages the use of native and adapted landscape species in the planting design in order to limit or eliminate the use of potable water or other natural surface or subsurface water resources available on or near the project site for landscape irrigation.
- On-Site Renewable Energy – encourages the use of on-site renewable energy self-supply to reduce the environmental and economic impacts associated with fossil fuel energy use.

Synergies often exist between multiple sustainable design techniques. For instance, a green roof is not only a heat island reduction strategy, but also a storm water management strategy. Likewise, native bioretention basins are not only a storm water management strategy, but also a water efficient landscaping strategy. For that reason, and in light of the necessarily limited scope of this study, the following broad concept sustainable design techniques will be discussed in greater detail in subsequent chapters: Stormwater Management (Chapter 2), Landscape and Irrigation (Chapter 3), Urban Agriculture (Chapter 4), and On-Site Renewable Energy Generation (Chapter 5). Within each chapter, strategies for achieving the techniques will be recommended and, where appropriate, measurable goals will be suggested and outcomes articulated.

CHAPTER 2 – STORMWATER MANAGEMENT

BACKGROUND

According to the Environmental Protection Agency (EPA), stormwater runoff occurs when precipitation from rain and melted snow flows over the surface features of a site. An undeveloped site that is heavily vegetated will produce less stormwater runoff than a developed site, as the vegetated surface allows the stormwater to be absorbed into the ground instead of running off. When rainwater and melted snow absorb into the ground, they are filtered by the soil matrix below grade and replenish aquifers or nearby streams and rivers. On the contrary, developed sites that consist of large quantities of impervious surfaces do not allow the water to infiltrate into the ground, but instead force increased amounts of stormwater to flow onto neighboring properties or be collected into storm drains that ultimately, collectively discharge large quantities of rainwater into nearby lakes and streams. This excess rain water, rapidly entering natural waterbodies can result in downstream flooding, stream bank erosion, increased turbidity, habitat destruction, changes in the stream flow hydrograph, sanitary overflows (in the case of combined storm and sanitary sewers), and infrastructure damage. (EPA 1)

Further, stormwater generated by developed sites tends to be contaminated with a myriad of pollutants from debris to chemicals to heavy metals to bacteria. Polluted stormwater runoff can have many adverse effects on people and the environment. Excess sediments can cloud the water, negatively impacting aquatic plants and in some cases destroying aquatic habitats. Excess nutrients from fertilizers can also negatively impact aquatic habitats due to algae blooms that ultimately decrease oxygen in the water, depriving aquatic species from this life-sustaining gas. Bacteria and other pathogens can create health hazards for humans, and are often the culprit for closed recreational beaches. Chemicals such as insecticides, paints, and auto fluids can poison aquatic life, as well as the organisms that feed on them including humans. (EPA 2) Given the negative potential effects of stormwater runoff, stormwater management is a top priority of any sustainable site design.

The approach to stormwater management has evolved over time. Early stormwater management was focused on collecting stormwater in piped networks and transporting it off site as quickly as possible. Given the flooding and stream channel erosion issues that this process created, this initial approach was modified to one of detention, or collecting stormwater on site and delaying its ultimate discharge to a later time when the stream was not under the initial stress of the storm. However, the detention method did little to address the contaminant load of the runoff. Current storm water management strategies employ Low Impact Design (LID), including strategic site design to control, minimize and even naturally cleanse the runoff on the project site. LID seeks to restore natural watershed functions through small-scale treatment at the source of the runoff, thereby producing a hydrologically functional site that mimics predevelopment conditions. These approaches often rely heavily on designs and technologies that infiltrate, evapotranspirate, capture, and re-use stormwater to maintain or restore natural hydrologies. (EPA 2)

SUSTAINABLE SITE DESIGN TECHNIQUES FOR STORMWATER MANAGEMENT

As with all site design projects, landscape architects are challenged with balancing the limitations and natural resources of the site with the owner's desired program for development. A site's natural drainage pattern is perhaps the most highly impacted feature as a result of development. Sustainable site design for storm water management seeks to utilize natural systems, or mimic natural systems, that capture, cleanse, and reduce stormwater runoff using natural processes, such as plants, microbes, evaporation, and evapotranspiration. When done well, these techniques provide beautiful landscapes that improve water quality while providing recreational opportunities, educational opportunities, wildlife habitat, along with air quality and urban heat island benefits. On a school site, the educational opportunities expand to experiential learning opportunities and its associated positive by-products.

Perhaps the most impactful sustainable site design technique for managing storm water is minimizing impervious surfaces, or surfaces that do not allow stormwater to infiltrate into the soil matrix. Impervious surfaces at school sites often consist of the school buildings, access driveways and other vehicular/bus circulation routes, parking lots, and sidewalks. Locating a high school, for example, within walking distance of a large portion of its student body, can result in significant reductions in the need for student parking and even bus circulation and queuing space. Thus, in the development of a new school, site selection is paramount, as is a site design that encourages transit, shared or reduced parking, and non-motorized access.

In many cases, the area of building or paving simply cannot be reduced as a means of reducing impervious surfaces. The Americans with Disability Act (ADA) dictates that surfaces providing access must be firm and stable and hence cannot minimized indiscriminately. When this is the case, alternative surface materials should be considered in the site design, but can also be considered in the building design. Traditional roofs can be replaced with vegetated or green roofs. Green roofs consist of an impermeable roof membrane overlaid with a highly-infiltrating, lightweight planting mix and vegetated with highly tolerant plants. Green roofs offer many synergies for sustainability. Not only does the green roof reduce or in many instances eliminate roof run-off, but green roofs also provide an effective insulation layer to the roof by regulating temperature extremes, increase the longevity of the roofing membrane, and mitigate the urban heat island effect. (Cockshull) While a green roof is significantly more expensive than a traditional roof, its myriad benefits can collectively result in a reasonable payback period, especially on urban sites where space is limited for land-based storm water management strategies. Given the added structural requirements of a green roof, this strategy is most often employed in new construction rather than in renovations.

Figure 6. Green Roof

A means of reducing impervious surfaces without reducing the amount of usable pavement on site for driveways, service areas, parking lots, and sidewalks is through the introduction of pervious pavements. Pervious pavements may take a number of forms: porous pavers, pervious concrete, and pervious asphalt. While gravel surfaces might be perceived to be more pervious than traditional pavements, in actuality their runoff coefficient is nearly the same. Thus, landscape architects must look to newer technologies in pavements to truly achieve a pervious surface.

Porous pavers are a functional and decorative product of traditional brick or concrete pavers with larger than normal gaps between them, often achieved by spacing lugs cast into the pavers, allowing water to infiltrate between the units. Pervious concrete and asphalt are modifications in the mix design of traditional concrete and asphalt limiting or reducing the content of fine aggregate resulting in a finished product that allows water to pass through. Both pervious asphalt and pervious concrete have limitations for their use in high or heavy vehicular traffic areas. Thus, replacing all pavement with pervious pavements is not recommended, though sidewalks and other non-vehicular areas, as well as all or parts of parking lots should be considered for pervious pavements.

A key consideration for pervious pavements is whether or not the on-site soils allow for favorable infiltration rates. Soils with a higher sand content afford higher infiltration rates than soils with a higher clay content. The amount of infiltration that can be anticipated determines the depth of the pavement cross section and, thus, the expense of the measure. The pervious pavement cross section includes a layer of uniformly graded gravel, sometimes referred to as a stone reservoir, in contact with the native subgrade soil. This uniformly graded gravel results in air voids in the cross section where runoff is stored as it infiltrates into the soil. Where soils do not allow for expedient infiltration, the depth of the stone reservoir will be much greater (or cover a larger area) than where soils allow the water to readily infiltrate. In especially difficult soils that are not conducive to complete infiltration, underdrains may be introduced beneath the stone reservoir that outlet to a piped system, but the key is to attempt to infiltrate as much surface runoff as possible from the paved surfaces.

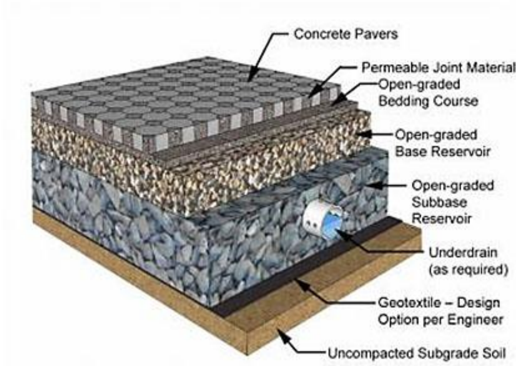


Figure 7. Porous Pavers

The make-up of on-site soils is a key consideration for other stormwater management techniques as well. Land-based measures such as bioretention basins, rain gardens, and bioswales are facilitated by soils with a high infiltration rate. However, they are worthwhile strategies even in less favorable soils with modest amendments. Bioretention basins, and their smaller counterpart rain gardens, are depressed areas under a vegetated surface. Bioswales are also depressed areas, but they are designed to convey stormwater through them, rather than to capture the stormwater as is the case with bioretention basins and rain gardens. In all cases, the area typically overlays porous backfill of a depth dependent upon the infiltration capacity of the on-site soil. They may include an underdrain to encourage infiltration, especially in clay soils.

The key to these measures is the plant material in the bioretention/bioswale treatment. As will be discussed in greater detail in Chapter 3 Landscape and Irrigation, utilizing native grasses, sedges, and forbs will produce a much deeper root structure that has the capacity to not only take up significant quantities of runoff following a rain event, but also to withstand drought conditions. Further, these plants have the potential to provide cleansing to the storm water as it recharges the aquifer. (Koester) Thus, bioretention basins, rain gardens, and bioswales are ideal considerations for addressing both the quantity and quality of stormwater generated by a school site.

For many reasons that will also be discussed in greater detail in Chapter 3, mowed turf lawn should be minimized in general, including on a school campus, as a means of increasing stormwater management on site. Just as native grasses and forbs in bioretention and bioswale applications uptake runoff due to their deeper root structure, native meadow vegetation accomplishes the same outcome, far outperforming turf lawn in this capacity. Some areas will certainly require turf lawn, such as sports fields and other necessarily manicured portions of the site design. However, maintaining a minimum of turf lawn will afford positive results to stormwater management, as well as other maintenance and management considerations.

Detention and retention ponds continue to be necessary considerations in stormwater management, though their contribution to sustainability is mixed. Detention ponds are designed to slowly release the detained stormwater off site; whereas, retention ponds do not have an outlet and rely instead on infiltration and evaporation. As retention ponds successfully retain all or a portion of a site's stormwater, they are considered an LID solution. However, a challenge with retention ponds is that they must be sized to accommodate more than one storm event and, therefore, they tend to be less feasible on tight urban sites, though a combination of retention and detention may be feasible. On the other hand, unless detention ponds are coupled with other LID strategies, they do not on their own adequately address the sediment and contaminant load of the storm water. Thus, detention ponds should be utilized sparingly and always in conjunction with other LID strategies.

Figure 8. Hydrodynamic separator

When on-site cleansing and filtration of stormwater is not feasible due to space constraints, a quality-control technique that can be implemented in conjunction with a separate quantity control technique (such as a detention pond), is a structural device such as a hydrodynamic separator. Hydrodynamic separators are flow-through structures with a settling or separation technology that removes sediments, oil and grease, debris, and some other pollutants. Often referred to as a structural best management practice (BMP), these units can provide pre-treatment for other stormwater management techniques.

Retention ponds have the potential to create synergies with other LID strategies when they facilitate re-use of stormwater for another purpose, thereby reducing the burden on the potable water source. Retention ponds can be utilized for on-site irrigation or for grey water uses inside of the building such as for flushing toilets or equipment cooling. On a smaller scale cisterns and rain barrels can provide the same benefit.

These strategies incrementally reduce the volume of storm water produced by a developed site, and in doing so reduce or sometimes eliminate the amount of conventional stormwater infrastructure required. The preservation or introduction of natural processes on a school site is an ideal location for educating students about such topics as the hydrologic cycle, plant/animal and aquatic habitats, water quality, weather, and climate. Given the environmental benefits of sustainable stormwater management and the educational benefits of experiential learning, land-based stormwater mitigation techniques should be maximized on both new construction and renovations of K-12 schools.

LOCAL CHALLENGES

Detroit Public Schools operates under the utility jurisdiction of the Detroit Water and Sewerage Department (DWSD). DWSD provides all of Detroit Public Schools with drinking water, sanitary sewer service, and storm sewer service. In many cases, the storm and sanitary sewer systems are combined. Combined sewer systems have the propensity of outletting raw, pre-treated sewage to the receiving water body during storm events when the system is overloaded. As a result, any reduction in storm water contribution to the combined system is worthwhile. The fact that DWSD infrastructure is known to be stressed due to years of deferred maintenance is yet another incentive to reduce storm water contribution to the off-site storm water conveyance system.

The community benefits of not further taxing an already stressed utility infrastructure and the environmental benefits of addressing a development's stormwater management on site are clear. However, the financial incentive to reduce stormwater runoff is also significant. The financial incentive stems from the fact that DWSD charges Non-Residential Drainage Rates on a graduated scale based on percentage of imperviousness of $133.44 (10-24%), $290.43 (25-49%), $486.66 (50-74%), and $686.83 (75-100%) per acre *per month*. On a K-12 site, which can easily exceed 25 acres and be 50% impervious, the drainage charges would exceed $6,000 per month, or $73,000 per year.

In a district that operates nearly 100 school building sites (and owns many more that are not currently in operation), the on-going financial implication of the DWSD Drainage Charge is staggering. But this fee also presents a unique opportunity. Reducing that same 25-acre K-12 site to 30% imperviousness would reduce the annual commitment to approximately $26,000 per year. Thus, a tangible financial incentive to implement sustainable stormwater exists. Even when considering a modest payback period of five years, the example above would generate over $235,000 to put toward sustainable stormwater management techniques.

RECOMMENDATIONS

DWSD and the City of Detroit do not have modern, best-management-practice-oriented storm water management requirements for development projects under their jurisdiction. Instead, they limit the allowable stormwater discharge pipe size based on the development's acreage, thereby restricting runoff in peak flow circumstances, but ultimately accepting all runoff without requirement for any type of cleansing. In other communities / jurisdictions, much more robust storm water management requirements are in place and would be prompted by the site plan review of the development or by the permitting of utility services. The City of Detroit Stormwater Management Program Plan (SWMPP) of November 2013 includes the recommendation of requiring more comprehensive post-construction storm water controls and long-term operations and maintenance plans for new and redevelopment projects. As comprehensive requirements do not currently exist, site development in the City of Detroit often excludes sustainable storm water management and instead implements conventional stormwater infrastructure that quickly conveys runoff to the combined, piped system without strategies for minimizing the quantity or mitigating the poor quality of the runoff.

The exception to this rule is any new or re-development within Wayne County's jurisdiction in Detroit's storm sewer area. This would occur if the public storm sewer utility was owned by Wayne County instead of the City of Detroit, such as the case in a Wayne County Road Right-of-Way. Wayne County's Stormwater Management Program (2006) is reasonably progressive and addresses both quantity and quality control of the runoff. For larger sites of 5 acres or more, which most school sites would exceed, it imposes a maximum flow rate that could be accomplished with the implementation of a combination of BMP's or simple detention. For quality control, it requires that 80 percent of the total suspended solids be removed from the runoff. While these requirements are well-defined, Wayne County's Stormwater Management Program lacks specific criteria and allowances for measuring the contribution of LID techniques. This is an area in which Washtenaw County's Stormwater Rules and Guidelines (2014) is far more robust and could serve as a technical resource in applying LID techniques while working within the Wayne County Stormwater Management Program. While many school sites fall outside of Wayne County's jurisdiction within the City of Detroit, and therefore its rules do not technically apply, its stormwater guidelines are the closest example of a local standard and, thus, should be followed given the lack of standards currently available from the City of Detroit and DWSD.

The LEED for Schools Reference Guide also provides criteria for stormwater quantity and quality control, with various options for each. In regards to quantity control, one option for sites with 50% or less existing imperviousness is to prevent the post-development peak discharge rate and quantity from exceeding the predevelopment peak discharge rate and quantity for the 1- and 2-year, 24-hour design storm events. This is a fairly modest requirement, though it exceeds Wayne County's guidelines in that it precludes the release of some runoff, whereas Wayne County allows all runoff to be released, but at a controlled rate. For quality control, LEED matches Wayne County's requirement of reducing total suspended solids by 80%.

The recommended approach to stormwater quantity management on DPS K-12 sites is to, at minimum, follow the overarching guidelines of the Wayne County Stormwater Management Program, with an added goal of preventing the post-development peak discharge rate and quantity from exceeding the pre-development peak discharge rate and quantity for the 1- and 2-year, 24-hour design storm events, following the LEED for Schools Reference Guide. For quality management, the recommended approach is to follow the identical requirements of Wayne County and LEED, which result in an 80% reduction of total suspended solids. In addition to this recommendation, wherever possible, reduce impervious surfaces by an increment that would compel the next lower imperviousness Drainage Rate threshold at minimum. These recommendations should be achieved through the use of a combination of stormwater BMP's and LID techniques discussed herein.

CHAPTER 3 – LANDSCAPE AND IRRIGATION

BACKGROUND

Landscape design is often considered merely a means of beautifying a building's surroundings, whether it be a residential, commercial, or an institutional structure such as a school. Because landscaping is largely considered an aesthetic element, rather than a functional element, it is often viewed as superfluous to a project. Further, the ability to add landscaping as a future phase, well after the completion of a building, provides building owners, even well-intentioned ones, an excuse to postpone landscaping, aside from the bare minimum, to a future date when additional funds become available, though they often never do. In the meantime, institutional sites, including modern urban schools that are developed with suburban standards, are frequently established with large expanses of mowed turf grass punctuated by a sparse dappling of trees, with perhaps a paltry shrub bed near the building entrance for good measure.

This treatment provides the minimum restoration of unpaved areas of the site to encapsulate bare soil and control erosion. However, the extensive use of mowed turf grass as the default land cover for unpaved surfaces, while least expensive to install, is comparable in cost to maintaining a native landscape over time, despite perceptions the contrary. (Helfand) Mowed lawn, however, is far more costly to the environment over time as compared to native landscape treatments. (Palliser) Mowed lawn is a notoriously high consumer of natural resources, especially water and fossil-fuel-derived fertilizers. Further, maintaining turf grass results in significant air pollution owing to the high emission rates of gas-powered lawn mowing and maintenance equipment and water pollution owing to the application pesticides and fertilizers that can end up in the waterways, especially when misapplied or mishandled. (Palliser)

Maintenance costs and externalities are not the only disadvantages of turf grass. Mowed lawns are the least effective of all the options for landscape surfaces to facilitate storm water infiltration, due to having the highest runoff coefficient among the various landscape options. Further, mowed lawns are the least effective of all the other options for landscape treatments surrounding a building to reduce that building's energy usage. (Meier) Lastly, turf lawn is often a monoculture or near-monoculture of non-native grass species that provides minimal habitat support for biodiversity, not to mention fewer educational opportunities on a school campus. Given that the status quo of a typical school site is to rely heavily on turf grass for its ground cover despite the negative environmental consequences, this chapter will provide recommendations for alternative landscape treatments and associated irrigation that provide both environmental and educational benefits, while also facilitating school safety and security

SUSTAINABLE SITE DESIGN TECHNIQUES FOR LANDSCAPE AND IRRIGATION

There are many reasons to implement sustainable landscaping and irrigation on school sites. Sustainable landscapes, as described by the American Society of Landscape Architects (ASLA), are responsive to the environment, regenerative, and can actively contribute to the development of healthy communities. They do so by sequestering carbon, cleaning the air and water, increasing energy efficiency, restoring or creating habitats, and creating economic, social, educational, and environmental benefits. (ASLA) An urban school site is an ideal venue for a sustainable landscape that will provide not only environmental benefits, but also benefits to students, educators, and the larger community as well.

As discussed in Chapter 1, studies have shown that when students learn though engaging with their natural environment, often referred to as environment-based education, overall academic performance is improved. (Barr) Moreover, research suggests that high school students who participated in environment-based programs were more skilled in critical thinking than their peers who did not, with critical-thinking skills exceeding those of college students. (Ernst) These student benefits extend to the teachers, schools and districts when considering that the benefit of environment-based learning can include improved standardized test scores, reduced classroom management problems, and increased enthusiasm for learning. (Lieberman) While not the only way to provide environment-based learning, a sustainably designed landscape provides students far more and immediate-proximity opportunities to engage with a natural environment and participate in environment-based education than does a site developed with a non-sustainable, traditional school landscape.

Perhaps the first priority in designing and establishing a sustainable landscape is to replace as much turf grass as is possible and practical with native meadows. These can be in the form of either dry or wet meadows, depending on the site's topography and the design of the stormwater management system. A dry meadow would be utilized in upland areas, whereas a wet meadow would be utilized in lower or depressed catchment areas that serve bioswale or bioretention purposes for the storm water management system. Both wet and dry meadow treatments would incorporate native grasses, sedges and forbs, with seed or seed/plug mixes comprised of a dozen or more different species (see Appendix 3), affording seasonally-evolving textures and colors.

Figure 9. Native Meadow Lawn

A primary benefit of meadow lawn over turf lawn is its extensively deeper root structure that both affords the plant material the ability to withstand the normal hydrologic variation of a site and its propensity for drought- and inundation-conditions, and the ability of that more extensive root system to uptake more stormwater, thereby reducing runoff. Further, stormwater that infiltrates, but is not absorbed by the root system, gains the cleansing benefit of the roots before recharging the groundwater. And, being a far more diverse plant mix than turf, meadowlawns are capable of supporting habitats for bird, insect and small animal species. A meadowlawn's ecosystem services through its inherent provision for biodiversity, habitat support, and mitigation of factors related to a development's environmental degradation present excellent topics for integration into the environment-based academic curriculum.

The maintenance of meadowlawn is most intensive in the first two to three years of establishment when it is vulnerable to the introduction of invasive species, also known as weeds. This period, however, is critical to the establishment of a healthy meadow and must not be spared for long-term success. An education of the public will also be in order during this time to ensure that realistic expectations of the aesthetic are in place, especially when transitioning from a manicured mowed lawn to a meadow. During the two- to three-year establishment period, people may criticize a recently-planted meadow as being akin to a "weed patch." However, with proper establishment maintenance to mitigate invasive species, as the meadow fills in and plant materials grow to their mature size and begin to evolve through their unique seasonal growth and blooming cycles, an appreciation of the aesthetic tends to emerge. This positive outcome is typically best achieved with a process that provides public education prior to a meadow's installation, secures buy-in from administrative and maintenance staff at the facility, and provides the necessary establishment-period maintenance to ensure a healthy meadow. (Booth)

Long-term maintenance of a meadow following the establishment period generally consists of, ideally, prescribed burning at a frequency of every one to three years, typically in the spring. If burning is not possible, the meadow should be mowed instead once per year, again typically in the spring. Where meadows are maintained through prescribed burns, a safe distance shall be preserved between the meadow and any building structure. Where meadows are maintained through mowing alone, that distance may be reduced, however a maintenance strip adequate to allow maintenance vehicles access to the building is still recommended. This maintenance strip may consist of gravel within the first one to two feet of the building and mowed lawn beyond that, of adequate width to allow full access surrounding the building by service and emergency vehicles.

Just as mowed lawn is an appropriate material immediately surrounding a building for access and maintenance purposes, it is also an appropriate material at a building's entrance and, in some cases, surrounding paved surfaces. Further, mowed lawn is often necessary for playgrounds or for sports fields. Some districts prefer artificial turf for sports fields, especially fields that serve double duty for both practice and game play or for multiple sports, such as football and lacrosse, thereby overtaxing a natural turf field. In any event, an approach that limits the use of turf grass and introduces meadowlawn wherever possible is preferred. With that said, it is recognized that mowed lawn provides a reasonable transition from the natural, less manicured aesthetic associated with a meadow to a more manicured aesthetic associated with the traditional built environment. The key is to minimize the amount of turf grass and the associated environmental costs it imposes.

Trees are another crucial tool in the sustainable landscape. Trees are known to reduce the urban heat island effect due to their introduction of shade and their natural process of evapotranspiration. Trees serve as a stormwater management tool given that the urban forest is estimated to reduce annual runoff by two to seven percent due to the precipitation capture effect of the tree canopy alone. (Arbor Day Foundation) Perhaps even more impressive, whenever one inch of rain falls on a tree, the first 30 percent of the precipitation is absorbed by the leaves and never touches the ground. (Speck) Further, trees are the most effective

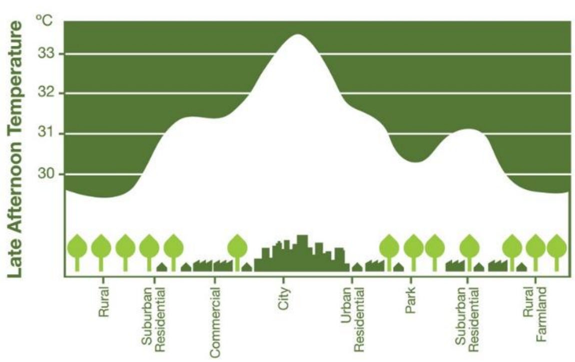


Figure 10. The Urban Heat Island Effect

landscape material at reducing the peak surface temperature on west-facing building walls among the principal forms of landscaping: trees, ivy, combination shrubs and trees, and turf (in order of efficacy). This reduction in peak surface temperature, which research has measured at 20 degrees Celcius, as a result of strategic tree placement, has been correlated to energy savings related to air conditioning of approximately 50 percent. (Meier) As such, tree placement becomes far more than an aesthetic endeavor, but a definitively sustainable landscape element.

Like trees, shrub and perennial beds are another tool in the sustainable landscape. While they do not command the supreme role that trees do in impacting the urban heat island effect, storm water runoff, and energy savings, their contribution to sustainability is worthwhile nonetheless. Their use can be strategic such as for the buffering or screening of unsightly views on or off-site, as an ornamental treatment at the site or building entrance, or for use in the environment-based learning program. Flexibility should be incorporated into the design of shrub and perennial beds, such as with the use of raised planters in certain locations to facilitate the modifications in the offering of the environment-based learning program over time. Whatever the case, trees, shrubs and perennials utilized on the school site should be a combination of hardy native and adapted species suitable for the unique soil conditions and microclimate of a given site. Consult with a landscape architect for specific recommendations.

Green roofs are the exception to the statement that trees command the supreme role of impacting the urban heat island effect, storm water runoff, and energy savings. Green roofs provide similarly far-reaching, if not greater, sustainability benefits to the built environment. However, as mentioned in Chapter 2, green roofs have greater structural requirements than traditional roofs and, therefore, are a more feasible alternative to new construction than renovations. They should be strongly considered for new school construction or additions, but will likely be cost-prohibitive in school renovations and, therefore, are not studied further in this report.

Irrigation is a sustainable design technique that must be used judiciously. Ideally, little or no irrigation, aside from what is available naturally by precipitation would be necessary in the sustainable landscape design, except for during the initial establishment period of the plantings. The primary purpose of utilizing native meadowlawns and native and adapted trees, shrubs and perennials is to establish plant material that withstands periods of drought and inundation naturally occurring in the local hydrology. With that said, irrigation most definitely provides a benefit to the health and vigor of even those hardy plant materials, resulting in faster-growing and more fully-established planting beds that are not as subject to weed and pest infestation.

Figure 11. Cisterns

The key to incorporating irrigation into the sustainable site design is identifying irrigation as a strategy to utilize excess water generated on the site. This may be in the form of grey water re-use from sinks and HVAC condensate from the building, or in the form of excess storm water use generated from the site's impervious surfaces. In the former case, this reduces sanitary sewer discharges from the site, but requires a separate piping system for grey water. While separate piping is not typically cost prohibitive, it is more feasible during new construction than in renovations. In the latter case, storm water runoff generated from roofs and pavements can be diverted from the storm water discharge to a storage pond or underground storage tank and then held for later use as irrigation. This sustainability strategy has the potential to greatly reduce or even eliminate storm water discharges from the site, which has significant financial implications as outlined in Chapter 2.

The design of the irrigation system introduces a number of options for sustainability, given that irrigation technology has improved substantially in recent years. Perhaps the most significant technological advancement has been in the form of 'smart' controllers. 'Smart' controllers utilize either recent weather data, soil moisture content data, or rain sensors to mediate irrigation usage. These data-driven controllers can preclude operation of the irrigation system in the event that natural precipitation has provided the plants' water needs. Other design techniques to promote sustainability through increased irrigation efficiency include greater use of drip irrigation technology over traditional spray head technology. Drip irrigation systems are around 90 percent efficient, as compared to traditional spray systems, which are 75-85% efficient.

In the event that an excess amount of storm water runoff is generated beyond what can legitimately be utilized to irrigate the on-site landscaping, an alternative irrigation system can be designed to dispose of excess runoff through evaporation. This is especially effective on a site that has expansive parking. In this technique, specific zones of the irrigation system can be designed to spray onto the paved parking surfaces during peak afternoon temperatures with the express intent of maximizing evaporation, the opposite intent of the portion of the irrigation system that directs water to the plant material. With this irrigation treatment, excess stormwater is diverted from being piped off site and the evaporation process serves to mitigate the urban heat island effect.

RECOMMENDATIONS

The LEED for Schools Reference Guide provides limited criteria specifically for landscape and irrigation design. Landscape and irrigation design are addressed most directly in the Water Efficiency category with options offered to either reduce potable water used for irrigation by 50% or eliminate potable water used for irrigation altogether. These reductions must be achieved through the use of a combination of techniques, such as native/adapted plant species, irrigation system efficiency, use of captured rainwater, and/or use of recycled wastewater or grey water. The recommended approach to irrigation on a renovated K-12 urban school site is to follow the more restrictive of the two options: eliminate potable water use for irrigation altogether. If irrigation is implemented on the site, it should utilize captured rainwater and a highly efficient control system should be used for delivery of the irrigation.

Thus, tangentially, landscape design can have a significant impact on the stormwater quantity and quality controls already discussed in Chapter 2 and to the greatest extent possible, those quantity and quality control measures should be accomplished with landscape and irrigation sustainability techniques discussed herein. Beyond that, it is recommended that a maximum of 75% of pervious surfaces, excluding athletic fields or playgrounds, be designed as mowed turf grass, with the remaining minimum of 25% designed as meadowlawn and/or shrub

Figure 12. On-site Trees at 30' On-center Spacing

and perennial beds. Finally, to the greatest degree possible, implement deciduous street shade trees at a 30 foot on-center spacing along any street or road frontages and along any internal circulation drives or parking lots. Implement deciduous site trees in a strategic manner that provides a maximum amount of shade on any west or south building face. Utilize conifer trees, canopy trees, shrubs, and perennials to buffer unpleasant views on and offsite, screen prevailing winter winds, and provide ornamentation in the vicinity of the site and building entrance. Finally, be cognizant of cross-campus sight lines and sight lines into and out of the building's public entrance(s) and avoid blocking those views with plant material in the interest of school safety and security.

CHAPTER 4 – FOOD SERVICES AND URBAN AGRICULTURE

BACKGROUND

Though much of this study focuses on finite and site-specific sustainability techniques and design practices that can be implemented on an individual school campus to protect and restore natural resources, certain administrative programs play into that narrative directly, and one of those programs is food services. Further, much of this study discusses site sustainability techniques that Detroit Public Schools has not, thus far, prioritized in its development practices and, therefore, has much opportunity to improve. However, food services is an area of site-oriented sustainability where DPS is quite advanced and considered a national leader. This chapter discusses DPS' successful School Nutrition Program, and its multi-pronged district-wide approach, as an important tool among a school's potential site sustainability techniques.

DETROIT PUBLIC SCHOOLS AS A LEADER

Though DPS' School Nutrition Program is now considered a national model, this was not always the case and, in fact, it is a fairly recent phenomenon, beginning just seven (7) years ago in the midst of the district's financial crisis. After eight years with an outsourced food service contractor, the District brought food preparation back in-house beginning in 2008 and placed it under the direction of the current DPS Food Service Executive Director, Ms. Betti Wiggins, a school food visionary who has testified before Congress for better nutrition and sustainability in public school food programs. Ms. Wiggins and her staff have implemented a number of food initiatives such as on-campus gardens, a farm-to-school program, fresh fruit and vegetable program, and others. (School Food Focus) Enthusiasm for such initiatives extend far beyond Detroit and converges around the public's interest in healthy eating and simultaneous concern about distance (physical and psychological) from our food sources. (Bagdonis) Thus, the sustainability initiatives of DPS' food service program extend well beyond those afforded to the site or even the school district itself, but to the health and education of the children who benefit from the programs, to the local farmers, and many others.

Ms. Wiggins would identify these outcomes as good for both education and the community, an opinion supported by academic literature, and she has made achieving them her life's work. With an extensive background in community food and nutrition in both educational and health care settings, owing to her years in food service private consulting, Ms. Wiggins came to Detroit Public Schools with the experience and skills to manage the state's second largest purchaser and provider of food (second only to the Michigan Department of Corrections). (Wiggins) But she also brought a vision for how food and food security can change the lives of people, and most importantly the most vulnerable people among us: children. Combined, Ms. Wiggins' talent and vision, along with the professionalism of her staff to whom she gives great credit, have created the exemplary School Nutrition Program that is an under-reported bright spot among the flood of negative press that Detroit Public Schools typically receives.

Figure 13. Ms. Betti Wiggins

The kindergarten through twelfth grade students of the Detroit Public Schools receive universal free breakfast and lunch, and those who participate in after-school tutorial and enrichment programs also receive free supper. While universal free lunch is a relatively recent addition, the universal free breakfast program has been in place since 2000, and is served in the classroom as part of the daily routine, rather than before the day begins, as is the case in most schools resulting in less participation. The universal free breakfast program was introduced with the recognition that children who are not hungry are ready to learn, produce better test scores, and display fewer behavioral problems. As such, educational and behavioral outcomes could be considered a primary driver of this program.

The universal free lunch program was made possible by the United States Department of Agriculture's Community Eligibility Option Program. DPS participated in this program during its pilot phase in 2011 and has continued with it into its full roll-out. The program essentially extends universal free lunch and breakfast in any school or district with seventy-five percent (75%) or more free and reduced-price meal certified students. Detroit Public Schools readily exceeds this threshold with over eighty-seven percent (87%) of its students qualifying for free and reduced-price meals. Ms. Wiggins is passionate about the program's benefit to students, noting the stigma that exists (sometimes resulting in meal avoidance) for those who participate in traditional free or reduced-price meal programs, especially at the high school level. Further, she noted that even those who do not qualify for free or reduced-price meal programs often experience significant food insecurity as evidenced by the poor quality of lunches being brought from home, or lack of lunch altogether, even by those "from the cul-de-sacs," a term Ms. Wiggins used to describe the relatively socioeconomically more advantaged among the students.

Detroit Public Schools also offers a Summer Food Program, though it is not nearly as well-funded as the universal free breakfast and lunch programs. Also funded by the United States Department of Agriculture, the Summer Food Program works as a lottery system, where 16,000 students of those eligible for free and reduced-price meals receive $30-$60 per month in essentially food stamp or Supplemental Nutrition Assistance Program (SNAP) benefits. While the programs indicated above do not specifically pertain to sustainability, they are undeniably part of the School Nutrition Program for Detroit Public School children and were considered, therefore, worthy of inclusion herein.

Moving on to sustainability, several programs that Ms. Wiggins has implemented have been specifically related to urban agriculture, which in an urban district such as Detroit contributes to sustainability by local-sourcing food ingredients. First, the Farm-to-School program was implemented in 2010 and entails identifying and purchasing produce and dairy products from local farmers (and has been extended to bread, as well, from local bakeries). During the school year, classroom visits by the farmers afford students greater knowledge about fresh fruits and vegetables and overall exposure to the food system. This results in increased nutritional food awareness and food system literacy. Additionally, this program benefits local and regional farmers by retaining DPS' purchasing power in the region, while also curbing the detrimental environmental effects of transporting food over long distances.

Since 2011, Detroit Public Schools has operated the School Garden Collaborative with seventy-two (72) school gardens now in existence in the district. Unlike the Farm-to-School program whose primary role is feeding the students with the secondary benefit of education, the School Garden Collaborative has a primary role of educating the students with a secondary role of nourishing them. The School Garden Collaborative, as the name implies, is a collaboration of the Offices of School Nutrition, Science Education, and Facilities and Site Management. Each office serves a crucial role in the success of this program. As they serve a

Figure 14. School Garden at a DPS Elementary School

primarily educational role, the gardens are small at each school and would not supply the quantity of produce necessary to fulfill the cafeteria's needs. Further, the primary harvest period is outside of the academic school year window and, thus, the timing does not allow for significant input of the garden produce into the school menu. Nevertheless, efforts are made to grow certain vegetables, such as zucchini squash, greens, summer squash, and cherry tomatoes that can supplement produce from other sources, such as in the often-served "stop light salad," allowing students to readily see the connection between garden and plate.

Drew Farms is another urban agriculture program introduced by Detroit Public Schools in 2012. It consists of a 4.5 acre site and 3,600 square foot hoop-style greenhouse. Drew Farms operates at Drew School, which is a transitional center for students with cognitive or other impairments, age eighteen (18) to twenty-six (26). The instruction is focused on vocational and life skills, with the farm being just one of the programs there. Drew Farms is already proving to be quite successful with 40,000 pounds of non-genetically modified sweet corn produced in 2014, resulting in 70,000 servings to the students. The success of the operation has resulted in the need to identify a supply chain manager to process and package the harvest for later use in the schools. With two years of harvest having come to fruition, Ms. Wiggins' office is now developing a more considered crop plan strategy to target specific produce and production goals, rather than the "plant and see" approach that was taken early on, understandable given that DPS is truly on the cutting edge of this school farm initiative. While most of the produce from Drew Farms grows is used in the schools, Drew Farmstand was debuted in 2014, affording the students the opportunity to participate in not only tilling, planting, and harvesting, but also in the sale of the produce, for a fairly complete representation of the food delivery system.

Figure 15. Drew Farm Hoop House

Even with all of these new and varied programs, DPS' Office of School Nutrition continues to look for additional ways to improve the delivery of fresh, local food to its students. Currently in the planning stages is Kettering Urban Agriculture Campus. This is Ms. Wiggins vision for the adaptive re-use of the former site of Kettering High School, which was closed due to budgetary constraints in 2012. Ms. Wiggins anticipates hoop houses and open crops on the former athletic fields, but is searching for a partnership with a private entity, such as Farmed Here, a Chicago firm that specializes in building integrated agriculture (BIA), in the development of that agricultural campus. Given Ms. Wiggins' success on previous endeavors, there is reason to be hopeful that the Kettering campus will become a productive asset to the Detroit Public Schools once again, as can other underutilized properties in any school district.

A major obstacle to food sustainability initiatives that had to be overcome with a more local approach to the food system is in the food supply chain. As such a large district with large purchasing needs, DPS is unable to work directly with the farmers because the district does not have the storage and distribution facilities to aggregate orders from multiple sources, a necessity when ordering very large quantities of produce. This adds an administrative layer between the Office of School Nutrition and the farmers. Fortunately for DPS, their purchasing power affords the district a degree of latitude with the distributors that perhaps a smaller district would not enjoy, but their leadership on buying local will normalize the process such that smaller districts will ultimately benefit.

Other challenges, on a smaller scale, pertain to the timing of the harvest, as mentioned above, especially related to the school gardens, which unlike Drew Farms, do not have full-time staff assigned. This has been ameliorated through the hiring of part-time garden attendants who work from April 15 through October 30. This ensures that the gardens are ready to serve their experiential learning purpose when school begins in September. But throughout the summer, when the gardens are producing prior to school being in session and no immediate school use for the harvest, the attendants simply set the food out on the curb so that members of the community can help themselves to what is available, or they contact families whom they know to have a specific need. This is an excellent example of a program that has primarily educational intentions, with a benefit of providing some produce for the lunch room, but also providing for the larger community. Ms. Wiggins believes that this type of community building is responsible for, or at least contributes to, the fact that none of the school gardens have been vandalized to date, as the community recognizes the gardens as an asset. She extends this belief to Drew Farms where the hoop house has no lock on it. Her philosophy is that if someone from the community wishes to take produce, she would like for them to have it.

These initiatives contribute positively to sustainability by localizing food production and minimizing related transportation costs, but also to the improved health and education of the students, as well as the community. These benefits are both tangible and intangible, and are directly and indirectly afforded by urban agriculture in a micro-sense (school gardens for learning) as well as in a macro-sense (local farmers selling their goods). Providing students with access to the full pendulum swing of micro- and macro-urban agriculture will contribute to their agricultural literacy as it relates to food production and post-production, which has been identified as lacking in the urban primary student population. (Hess)

EDUCATIONAL OUTCOMES

The synergy of sustainable food initiatives with educational outcomes in schools is extensive and, therefore, worthy of discussion. As touched on in previous chapters, perhaps the most widely documented benefits of urban agriculture related to schools pertains to experiential or garden-based learning, shown to increase science achievement including that of predominately African American student populations in inner-city schools from disadvantaged backgrounds. (Rye, Smith) While this is compelling on its own, it is important to note that elementary school is a particularly critical time for children in the development of an interest, or disinterest, in science. Studies have shown that hands-on learning promotes a positive attitude toward science and a tendency for those students to function at higher levels of learning, including the ability for analysis, synthesis, and problem evaluation. (Klemmer) Further, studies have found that garden-based learning has specific benefits for students with disabilities, as the hands-on

Figure 16. Garden-Based Learning

nature of garden-based learning is thought to be one avenue for unlocking the learning potential of students whose physical or cognitive disabilities may not lend themselves to traditional classroom instruction. (Rye)

Similarly, students with disruptive behavior have shown evidence of increased academic success and reduced disruptive episodes with the introduction of garden-based learning. (Ruiz-Gallardo) The benefits to the classroom, teacher, educational system, and community cannot be overstated, when considering that a less disruptive student is more likely to graduate, with greater knowledge and skills, and contribute productively to society, a form of personal and community sustainability in its own right. Further, a student with fewer disruptive tendencies tends to be more sociable, work better in groups, and have higher levels of self-esteem.

Of course, these social and psychological benefits are not limited to at risk youth. Research of school garden programs, including a one-year long study, showed that the youth who participated self-reported increased overall life skills, improved teamwork skills, and enhanced self-understanding. (Robinson) These skills are believed to ensure socially responsible and productive citizens. Gardens present an opportunity for youth to gain self-confidence through taking on responsibility, completing tasks, and finding success. These are the building blocks for skills that provide success through all aspects of life, again an undeniable contribution to personal and community sustainability.

Figure 17. Agriculture in the Classroom

The Detroit Public Schools has a model School Nutrition Program, giving its students the advantages of access to whole foods, good nutrition, local food, food system literacy, and garden-based learning. The success of the program is evidenced by its very sustainability and contributes to the district's sustainability initiatives and site sustainability techniques. The program boasts achievement even in the face of economic crisis. The academic literature supports that the outcomes for students and community are real with the programs implemented there. In time, perhaps the ongoing success of this program will begin to shift the narrative surrounding Detroit Public Schools in a more positive direction as a reflection of the exemplary work being done on behalf of the students, community, and environment.

RECOMMENDATIONS

The LEED for Schools Reference Guide does not specifically address a school's food system sustainability or the role urban agriculture can play in this measure. Further, Detroit Public Schools is already considered a leader in this respect. Thus, the recommendations for sustainability herein are mostly geared toward applying the DPS model to other urban school renovations.

At the site-specific level, this entails the introduction, at the very least, of school garden plots to supplement the garden-based learning program. The extent of the garden plots need not be excessive to contribute to experiential learning. Many DPS school sites are already providing this with the modest provision for six (6) to ten (10) four-foot by eight-foot (4'x8') raised beds constructed of lumber on-grade to achieve a minimum 12" depth of planting medium. The raised beds are necessary to ameliorate any potential soil contamination concerns in the urban soil matrix, but also to ease the physical effort of planting and harvesting.

Similar to garden plots, an on-site greenhouse should be provided, which extends the growing season more definitively into the school year. A modest hoop house of a minimum dimension of 24' by 48' will accommodate a classroom size of 20 to 25 students, and can be purchased as a package kit from numerous manufacturers, and installed for minimal upfront costs. DPS already operates greenhouses at about one-third of its schools. Many of these greenhouses were part of the original building, but were decommissioned and turned into storage space over the years. Today, they are being restored to their original use, often with assistance from private entities such as DTE Energy. Ideally, the magnitude of garden plots and greenhouses on any given site would grow to support a robust and thriving science, technology, engineering, and math (STEM) curriculum, as DPS is currently advancing, given that the learning possibilities are nearly endless. But ultimately, the extent of the garden plots will hinge on the availability of staff resources to maintain the beds and greenhouses, during and outside of the school's academic calendar. Thus, the competing curricular and maintenance needs must be considered when determining the size and magnitude of both garden plots and greenhouses.

Figure 18. Greenhouse

Also at the site level, though selectively, other urban agriculture initiatives could be instituted including on-site farming where the district has the programs in place or desired, such as after-school skills development programs, vocational programs, transitional programs for cognitively-impaired students, or the like which will provide the necessary labor resources to make such a farming initiative viable. A minimum amount of suitable land availability would also be necessary with five (5) acres minimum recommended to provide for a reasonable urban farm site, inclusive of a greenhouse and farmstand. Traditional, non-raised fruit and vegetable plots would be anticipated, along with the possibility of an orchard. As such, soil testing must be performed to identify any potentially harmful soil contaminants, which may limit the crop selection, or preclude farming at the site altogether without remediation.

An alternative to on-site farming where vacant land is unavailable or land is available but the soil matrix is contaminated, as is common at many urban school sites, is building integrated agriculture (BIA). One means of introducing BIA to an existing building is through the placement of a rooftop greenhouse. Unlike greenroofs, rooftop greenhouses can typically be added to an existing flat roof without structural modifications or enhancements, thus making them economically feasible. (Gould) Further, such greenhouses can include rainwater harvesting for the needs of the greenhouse plant material, thus providing a stormwater management benefit. As such, BIA should be strongly considered where land based garden plots, greenhouses, and/or on-site farming are desired, but not viable. And on a smaller scale, vertical

Figure 19. School Building Integrated Agriculture

gardens on exterior walls and container gardens can also serve this purpose where space is limited.

Urban agriculture initiatives at the district level, such as farm-to-school programs, partnering with local farms and partnering with community gardens have inherent sustainability benefits from a local food and transportation perspective. As such, they are also highly recommended but given that they do not have site or school campus design implications, instead being more programmatic in nature, specific recommendations fall outside of the scope of this study.

CHAPTER 5 – ON-SITE RENEWABLE ENERGY GENERATION

The primary sustainable site design strategies discussed in previous chapters are limited to the scope of site design that fall most clearly under the design realm of the landscape architect, which defined the necessarily limited scope of this study. Other sustainability strategies that extend beyond the realm of the landscape architect, yet impact site design, exist, though they have not been reviewed in great detail herein. One such strategy is on-site renewable energy generation, and by extension harnessing passive energy. While these strategies can have significant site design impacts, owing to the spatial needs of the particular renewable energy technique, the intrinsic design and feasibility of such features fall outside of the landscape architectural discipline, and are typically performed by the mechanical and electrical engineering disciplines. With recognition that a truly sustainable project is collaborative in nature, an overview of on-site renewable energy generation and harnessing passive energy is provided in this chapter. In effect, a truly sustainable project employs an integrative process in which all design disciplines (architecture; landscape architecture; and mechanical, electrical, structural, and civil engineering at minimum) collectively work toward the goal of reducing or eliminating environmental impacts through thoughtful design of the built environment. This chapter discusses the broad concepts of on-site renewable energy generation and harnessing passive energy from the narrow standpoint of its impact on site design.

On-site renewable energy generation and harnessing passive energy are promising sustainable design strategies. Their use is growing rapidly and signaling a trend away from long distance grid-connected fossil fuel power generation. This paradigm shift toward on-site renewable energy generation is often referred to as The Third Industrial Revolution. (Rifkin) Renewable energy has become an important consideration of any sustainably designed project because our reliance on traditional fossil fuel energy sources, such as coal, oil, and natural gas is unsustainable due to their finite quantities. As we have relied on these energy sources for a long period of time, they are now diminishing to the point of becoming too expensive and/or environmentally degrading to continue to extract as a long-term solution. Further, the burning of fossil fuels results in carbon emissions and increased greenhouse gases in the atmosphere, contributing to global climate change. In contrast, renewable energy resources are inherently replenished, will never run out and, by comparison to fossil fuels, are much cleaner sources of energy to utilize. Further, many renewable energy options can be implemented into a building project as a means of providing some or all of the building's energy needs. This is becoming more and more attractive to building owners and operators, not only for the environmental benefits, but also to control the rising costs associated with traditional energy sources.

Figure 20. Wind Energy Harvesting

Most renewable energy comes from the sun, either directly or indirectly, just as fossil fuel energy originated from the sun, but built up over millennia into a highly concentrated, though finite, fuel source. Sunlight can be used in the form of solar energy to generate electricity for a building's energy needs; and excess generated energy, if any, can be stored for later use or fed back to the electrical grid, often referred to as net metering. In this application on a development project such as a school, photovoltaic panels would be placed on the building, or on the site, to collect sunlight and generate electricity. The size of the panels would be dependent on the amount of energy attempting to be generated. A small quantity of photovoltaic panels would only serve to supplement electricity from traditional sources, whereas expansive photovoltaic panels would be necessary to provide most or all of a building's electricity needs. In any case, maximizing the energy efficiency of the building is a crucial sustainability technique to be used in tandem with solar power, or any on-site renewable energy generation method for that matter.

Figure 21. Photovoltaic Panels

Another form of solar energy is passive solar energy in which heat from the sun is utilized to passively heat a building's air or water to satisfy all or part of a building's heating or hot water needs. Trombe walls and solar hot water heaters are examples of passive solar energy. Passive solar techniques are typically integrated directly into the building architecture with site design implications limited to the orientation of the building to maximize solar gain.

Wind energy is also driven by the sun and captured through the use of wind turbines. Smaller turbines today, on the site scale, are quite efficient and can quietly produce electricity in winds as low as seven (7) to ten (10) miles per hour. However, in urban areas, local ordinances may not allow them and, even if allowed, their placement must be sensitive to neighboring sites. Wind energy typically supplements traditional electricity sources, allowing the availability of energy even when the wind is not blowing. In order to determine if a site is a good candidate for wind energy generation, a wind study is typically undertaken to identify the predicted electrical output and resulting monetary value of the wind-generated electricity, ascertaining the financial implications and payback period, based on a forecasted cost of electricity.

Geothermal energy is a renewable energy source that does not come from the sun. Instead, it taps the Earth's internal heat for a variety of uses, including electricity production and the heating and cooling of buildings. Most typically, geothermal systems are used on site developments such as schools not for producing energy, but instead for minimizing energy use in the building's systems. Specifically, geothermal energy is most often used as a high efficiency means of providing a building's heating and air conditioning. Geothermal systems implement a series of either vertically or horizontally looped pipes underground, where the soil temperature is a constant 50 to 60 degrees Fahrenheit. The geothermal system consists of a heat pump and heat exchanger, using the constant, warmer underground soil temperature in winter to heat a building's warm air supply, such that the furnace has less temperature difference to make up on its own. The opposite occurs in the summer time, such that the constant, cooler underground soil temperature removes heat from the indoor air reducing the efforts of the air conditioner. Geothermal heat pumps use much less energy than conventional heating systems and are also more efficient for cooling. They have been used successfully on urban school projects including several for Detroit Public Schools. The site design considerations typically include the need to set aside a land area equal to or larger than the building footprint for the geothermal well field.

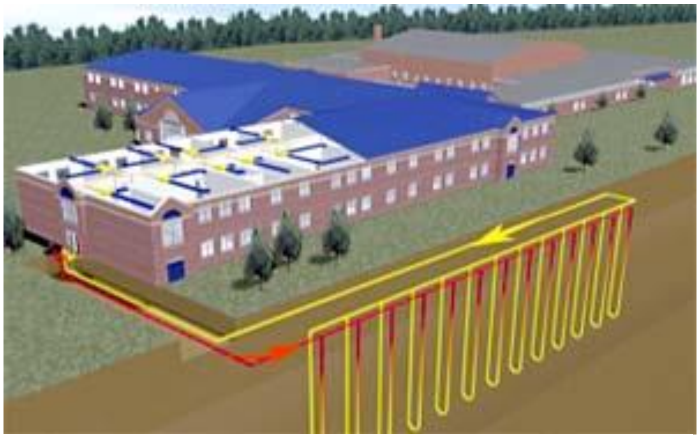


Figure 22. Georthermal Heating and Cooling of a School

On-site renewable energy generation and harnessing passive energy are sustainable design techniques that provide schools more than just a reduction in the costs of and reliance on non-sustainable fossil fuel energy supplies. As with other sustainability methods discussed in previous chapters, they also afford schools an opportunity for experiential learning and enhanced environmental education. Further, many systems have been implemented in schools across the country that allow students access to data associated with monitoring the systems' real-time energy generation and use, which promotes awareness of the feasibility, variability, and limitations of renewable power generation in the context of power use. Any urban K-12 school renovation should consider the implementation of on-site renewable energy generation and harnessing passive energy as valuable techniques toward achieving its larger sustainability goals.

CHAPTER 6 – DESIGN STUDY AND APPLICATION OF RECOMMENDATIONS

SUMMARY OF PROPOSED DESIGN

The site for the Martin Luther King, Jr. Senior High School currently exists of nearly an entire city block. Except for a private light industrial development that carves out the north central portion of the block, the remainder of the U-shaped site is utilized by the High School. The school has existed on this site since 1967 (though originally as Eastern High School). It was reconstructed and re-opened in 2011 as part of Detroit's $500.5 million bonds associated with the 2009 economic stimulus package. The project received LEED Gold Certification from the USGBC. However, most sustainable design techniques were incorporated into the building, rather than site, design.

The school's re-construction left several elements of the previous campus in place: the renovated sports fields remain on the eastern portion of the site and the performance auditorium remains untouched on the northwest corner. The school itself was reconstructed from a central location on the site, to a more southwesterly position, providing a semblance of critical mass at the intersection of McDougall and Larned Streets. The parking, bus and drop-off circulation occur on the north and west sides of the building, primarily accessed from Lafayette and secondarily accessed from Larned. The existing site plan provides for a large open lawn with frontage to Lafayette Street, circumnavigated by the vehicular circulation and parking that lays out in a horseshoe shape. (See Appendix 1 for the Existing Site Plan)

In considering a more sustainably designed campus (see Appendix 2 for the Proposed Site Plan), the primary site design element affording the most potential for sustainability improvements is the reduction of impervious surfaces. A large driver of impervious surface quantity is that related to parking and parking quantity, and the King High School campus was determined to be well in excess of what is required.

Minimum parking quantity for public K-12 schools is, in fact, regulated by the State of Michigan's Department of Licensing and Regulatory Affairs. According to their publication, the Public School Site Plan Review Reference Guide, parking on a high school campus is dictated by the greater of two separate calculations. The first calculation pertains to the number of students and staff, with a fraction thereof depicting the number of parking spaces necessary. The second calculation pertains to the number of seats in assembly spaces such as auditoriums, gyms, or stadiums, with a fraction thereof depicting the number of parking spaces necessary. Whichever calculation results in the greater quantity determines the minimum number of parking spaces required on the site, with recognition that parking use on a high school site for the school day and sports/performance events are not typically concurrent.

While the Department of Licensing and Regulatory Affairs only dictates the minimum amount of parking required on a school site, they do not preclude a district from providing greater than the minimum number at its discretion. Such discretion is often exercised at a high school based on bus utilization and student driver rates. Though Detroit Public Schools may have desired more-than-the-minimum parking spaces during the planning for the current King High School site, the proposed design modifications are made with the understanding that the district will embrace the sustainability goals of this study, as they did with sustainable building improvements, and will see the loss of parking as a reasonable trade-off in its overarching sustainability pursuits. Further, having visited the site on multiple occasions over the course of the study and during school hours, the author saw evidence of ample excess parking available that led to the belief that parking reduction was a valid means of reducing impervious surface. Toward that end, the following chart indicates the minimum number of off-street parking spaces that the State of Michigan requires for public high school sites, with the grey-highlighted text identified as the dictating quantity.

Enrollment/Staff Calculation Method

	Number	*Multiplier*	*Resulting Qty*
Teachers	56	1	56
Principals	1	1	1
Asst. Principals	4	1	4
Counselors	3	1	3
Clerical	4.5	1	4.5
Students	1725	1/10	172.5
			241

Assembly Calculation Method

	Number	*Multiplier*	*Resulting Qty*
Auditorium	1191	1/6	198.5
Gym	1181	1/5	236.2
Football Stadium	1281	1/5	256.2

With a minimum required off-street parking space quantity of 256 spaces, as compared to the existing parking space quantity of 353, an immediate and significant reduction of impervious surfaces is presented. The proposed design, therefore, eliminates most of the easternmost parking near the tennis courts, as well as some central parking on the campus providing a final parking count of 258 spaces. The design also reorients the central parking, proposed to be reconstructed with porous asphalt, to an east-west alignment as a means of consolidating it and allowing more contiguous pervious surfaces that will serve student environmental education and stormwater management purposes (discussed in greater detail below). In addition to the parking reduction, the design eliminates the second driveway to Lafayette, whose primary purpose appears to be bus circulation. By eliminating the easternmost parking near the tennis courts and reconfiguring that pavement to driveway status, the bus and vehicular circulation are maintained, albeit with a significant reduction in impervious surface for the overall site.

Sidewalk surfaces have also been reduced overall, including at the main building entries on the southwest and northeast corners of the building. The general sidewalk widths have been reduced from 10’ to 8’, still adequate for a bustling school site, but not overly generous, recognizing the need to reduce impervious surfaces. Additionally, the design of the entry sidewalks have been modified to provide a consistent design vocabulary, while also providing the necessary ingress and egress surfaces for a school with an enrollment capacity of nearly 2,000 students.

Opposite the school's main entrance on the northeast corner, the proposed design makes use of the newfound pervious surface with provisions for an expanded Environment-based Education Subcampus. Immediately adjacent the parking and driveways is the relocated raised garden plots, and supplementing those are a proposed greenhouse and orchard. Collectively, these elements will provide the science, technology, engineering, and mathematics (STEM) curriculum of King High School with added opportunities for experiential learning.

North of the Environment-based Education Subcampus, the large mowed lawn has been replaced with an expansive native meadow. The southern portion is a wet meadow that will serve as bioretention for a significant portion of the site's stormwater management needs. The northern portion is a dry meadow. Both the wet and dry meadow will support unique native plant habitats of Michigan, as well as other wildlife species, again providing a broad level of potential environmental education to the students. Similar to the wet meadow, rain garden pockets are introduced in many locations, including along the building frontage on McDougall and Larned Streets. These are intended to provide infiltration opportunities for the roof leads that currently take stormwater directly to the piped system off site. While these rain gardens are an important feature of the stormwater management system, mown turf has been maintained in the immediate vicinity of the building's main entrances in deference to the need for a more manicured aesthetic in a heavily pedestrian travelled area.

Tree plantings have been greatly supplemented on the site. Street trees along the city street rights-of-way have been supplemented to achieve the 30' spacing recommended. Trees along the school's driveways and within parking lot islands have also been supplemented greatly. Deciduous trees along the school's west and south facing walls have been added to assist with energy reduction associated with building air conditioning. Lastly, in the area of removed bus circulation and parking near the tennis courts, the tree planting design is in the form of urban reforestation, yet another potential component of the environmental education offering on campus, and a further means of providing stormwater management benefits, species biodiversity and habitat support, and reduced heat island effect at this urban campus.

EVALUATION OF SUSTAINABLE DESIGN TECHNIQUES APPLICATION

Stormwater Management

As excerpted from Chapter 2: "*The recommended approach to stormwater quantity management on DPS K-12 sites is to, at minimum, follow the overarching guidelines of the Wayne County Stormwater Management Program, with an added goal of preventing the post-development peak discharge rate and quantity from exceeding the pre-development peak discharge rate and quantity for the 1- and 2-year, 24-hour design storm events, following the LEED for Schools Reference Guide. For quality management, the recommended approach is to follow the identical requirements of Wayne County and LEED, which result in an 80% reduction of total suspended solids. In addition to this recommendation, wherever possible, reduce impervious surfaces by an increment that would compel the next lower imperviousness Drainage Rate threshold at minimum. These recommendations should be achieved through the use of a combination of stormwater BMP's and LID techniques discussed herein.*"

The proposed design readily provides stormwater quantity control following the guidelines of the Wayne County Stormwater Management Program. Using bioretention through rain gardens, Wayne County requires the storage of the ten-year storm, which on this site and with the combination of pervious and impervious surfaces indicated, results in the need for storage of a 97,043 cubic feet of water. With a surface area of 60,480 square feet, this volume is easily achieved with a modest depth of less than 2.5 feet. This calculation does not take into account the smaller rain gardens intended to capture roof and surface water on the west and south sides of the building, which would only serve to further improve the stormwater mitigation techniques beyond that required by Wayne County (i.e., to more than the 10-year storm). As the 2-year, 24-hour design storm event would generate less runoff than the 10-year storm event, or 27,824 cubic feet of storm water, it is evident that the stormwater management provided in this site design also satisfies the requirements of LEED for Schools as outlined in the LEED for Schools Reference Guide, with one caveat.

Soils testing would be required to verify that the underlying soils do, in fact, allow for sufficient infiltration of the storm water, as without such infiltration, the bioretention would serve to primarily detain, rather than retain, the quantity of water that enters it and the rain gardens. Should the infiltration rate of the subsoils prove to be less than ideal, a larger area of infiltration substrate would be recommended through the introduction of a stone reservoir in order to ensure that the design accomplishes the proposed storm water management recommendations herein. If the subsoils prove especially problematic, capturing the stormwater in underground cisterns and reusing it for on-site irrigation would be the worst-case scenario back-up plan, again ensuring that the design accomplishes the proposed stormwater management recommendations herein.

Regarding reduction of 80 percent total suspended solids, the storm water best management practices exercised in this design are widely held to provide this level of stormwater quality mitigation. (Brown) Bioretention, infiltration basins, dry swales, wet swales, shallow wetlands, wet meadows, and the like, have been studied extensively and have been shown to meet or exceed the 80 percent threshold of solids removal. In the event that existing subsoils do not readily allow for the type of infiltration that would provide the necessary cleansing, amendment of the soil cross section to facilitate improved infiltration woud be necessary, as described above. While this increases the cost of the overall installation, it ensures that the stormwater, even if ultimately discharged through an underlying underdrain, is cleansed before leaving the site and ultimately entering the receiving waterway.

The final recommendation herein was to reduce impervious surfaces by an increment that would compel the next lower imperviousness Drainage Rate threshold by Detroit Water and Sewerage Department (DWSD), through the use of a combination of stormwater BMP's and LID techniques. Because this site enjoys ample space for sports fields and a generous open lawn currently, its impervious surface area is a surprisingly low 37.8 percent. The next lower threshold requires that the impervious surface area drop significantly to 24 percent. The proposed design, which removes notable amounts of paved surfaces and replaces a portion of existing parking with porous pavement, only brings the impervious surface area to 32 percent. While this is a sizable reduction and will result in a reduced stormwater fee to the district, DPS will maximize these decreased costs by further reducing impervious surfaces.

Fortunately, DWSD allows that capturing runoff from impervious surfaces and retaining them on-site provides the same benefit to their storm water infrastructure as changing to a pervious surface because ultimately it diverts the stormwater from ever reaching its infrastructure. Thus, by merely capturing 75% of the roof area, or 30% of the pavement area, in rain gardens and/or the bioretention basin, a quantity that equates to approximately 30,184 cubic feet of water in the 100-year storm event, the bioretention basin, again, clearly exceeds that threshold by providing 97,043 cubic feet of infiltration capacity. Thus, the proposed design is able to justify impervious surface reduction to the next lower threshold of 24 percent, and actually beyond. The financial implication of this design improvement to DPS is the reduction of the monthly stormwater fee from $3,552 per month to $1,035 per month, a savings of over $30,000 per year at this school site alone. (Calculation assumes theoretical 24 percent impervious surface remains, which is conservative, on account of not having soil infiltration data. Actual theoretical impervious surface reduction could be much greater with highly infiltrating soils.) Similar improvements at each of its 97 school sites would generate savings of nearly $3,000,000 per year.

A notable advantage of this site for stormwater management is its availability of land area not otherwise programmed for sportsfields, the school building, or parking and circulation. Other school sites may not enjoy this benefit, in which case more extensive and invasive (less land-based) storm water management techniques may be necessary such as green roofs, storage cisterns and greater areas of porous pavements. Each school site is unique and will require the judicious application of best management practices commensurate with the distinctive qualities of the individual site and its particular limitations.

Landscape and Irrigation

As excerpted from Chapter 3, related to irrigation: "*The recommended approach to irrigation on a renovated K-12 urban school site is to follow the more restrictive option: eliminate potable water use for irrigation altogether. If irrigation is implemented on the site, it should utilize captured rainwater and a highly efficient control system should be used for delivery of the irrigation.*"

As Detroit Public Schools does not typically irrigate its school sites and land-based practices related to storm water management provided significant reductions in stormwater runoff, exceeding the thresholds required by the appropriate review agencies and the recommendations in this study, the use of irrigation was not employed at the King High School site. Moreover, per the recommendation, potable water is not being used for irrigation whatsoever. This recommendation is easily applied when the palette of landscape plantings is limited to hardy native and adapted species that do not rely on supplemental irrigation beyond that provided by the site's natural hydrology. Though the King High School proposed site design did not readily suggest the need for irrigation as a stormwater mitigation technique, urban K-12 renovations that do not have the advantage of ample land area to provide for bioretention and rain gardens, however, may very well benefit from the use of an irrigation system that is employed for the purpose of storm water management, as previously discussed.

Also excerpted from Chapter 3, related to landscape: "*it is recommended that a maximum of 25% of pervious surfaces, excluding athletic fields or playgrounds, be designed as* *mowed turf grass, with the remaining minimum of 75% designed as meadowlawn and/or shrub and perennial beds. Finally, to the greatest degree possible, implement deciduous street shade trees at a 30 foot on-center spacing along any street or road frontages and along any internal circulation drives or parking lots. Implement deciduous site trees in a strategic manner that provides a maximum amount of shade on any west or south building face. Utilize conifer trees, canopy trees, shrubs, and perennials to buffer unpleasant views on and offsite, screen prevailing winter winds, and provide ornamentation in the vicinity of the site and building entrance. Finally, be cognizant of cross-campus sight lines and sight lines into and out of the building's public entrance(s) and avoid blocking those views with plant material in the interest of school safety and security."*

The landscape recommendations were applied to the site easily, with the exception of providing a maximum of 25% mowed turf grass and a minimum of 75% meadowlawn and/or shrub and perennial beds for the site's pervious surfaces, excluding athletic fields. Though this may have been achieved by replacing some turf grass with tall fescues that would minimize the need for mowing and maintenance, such a treatment does not meet certain sustainability goals such as providing biodiversity and species habitat. Thus, the solution seemed disingenuous given the overarching goals herein. Ultimately, the designer chose to allow a 50/50 ratio of turf lawn to native meadow and planting beds rather than to force a 25/75 ratio. This departure from the recommendations came with the understanding that even a 50/50 ratio will be a very different aesthetic from that to which the public is accustomed on a school site and, thus, it may be worthwhile to begin incrementally. The 50/50 ratio approach allowed all native meadow and rain garden plantings to be bordered by a manicured lawn, an aesthetic depicting a level of care to the public, students, staff, and even maintenance personnel that will more likely evoke appreciation and ultimately engagement in the overall stewardship of the design. (Nassauer) As native landscapes become a more typical part of the 'normal' landscape aesthetic, perhaps the ratio can be adjusted accordingly to further promote sustainability.

Food Service and Urban Agriculture

As already discussed, Detroit Public Schools is a model in its Food Service Program generally and in its urban agriculture programs specifically, both internally and externally. Thus, the recommendations herein, and their application, are mostly promoting a continuation of these programs and through their description, other districts can glean insight into a more sustainable food system. The recommendations made for King High School build upon the programs already in place there, with an understanding of the STEM-focused curriculum particular to King High School. The recommendations stop short of expanding to a production-oriented urban farm at this particular site due to the knowledge that the District has already identified other underutilized properties for such programs.

As excerpted from Chapter 4, recommendations include: "*school garden plots to supplement the garden-based learning program. The extent of the garden plots need not be excessive to contribute to experiential learning. Many DPS school sites are already providing this with the modest provision for six (6) to ten (10) four-foot by eight-foot (4'x8') raised beds constructed of lumber on-grade to achieve a minimum 12" depth of planting medium. The raised beds are necessary to ameliorate any potential soil contamination concerns in the urban* *soil matrix, but also to ease the physical effort of planting and harvesting."* The proposed design relocates existing school garden plots to an expanded Environment-based Education Subcampus.

Also excerpted from Chapter 4: *"Similar to garden plots, an on-site greenhouse should be provided, which extends the growing season more definitively into the school year."* The central focal point of the Environment-based Education Subcampus is an on-site greenhouse, where experiential learning can weave easily into the STEM-focused curriculum of King High School. The greenhouse structure can be a relatively inexpensive, basic package kit, or a more elaborate architectural feature of the campus. The greenhouse provides a backdrop for the adjacent fruit tree orchard, which can be utilized in teaching about Michigan's fruit cultivating history, in addition to the vegetables associated with the garden plots. The greenhouse is supplemented with an outdoor classroom space to complement the indoor learning area and to provide greater flexibility in its instructional use.

The application of the Food Service and Urban Agriculture recommendations were easily made on the King High School site, owing to the fact that a fairly generous amount of underutilized or non-programmed land space existed on the site. Other urban school sites that do not benefit from the availability of ample land space will find the execution of these recommendations more challenging. Such sites may be limited to the raised garden plots only, or those plus a small greenhouse attached to the building. Especially limited sites may benefit from the execution of building integrated agriculture (BIA) with the addition of a roof-top greenhouse. Regardless of the space challenge, however, food service and urban agriculture are fundamentally program considerations of the district and the individual school. Thus, the site design constraints are somewhat secondary to the level of commitment that the particular school district makes to food system sustainability and the individual school makes to experiential learning.

On-site Renewable Energy Generation

As indicated in Chapter 5, on-site renewable energy generation intrinsically falls outside of the landscape architectural discipline, being designed primarily by the mechanical and electrical engineering disciplines, with the landscape architect's collaboration related to positioning such elements on the site. Given the need for such collaboration with outside disciplines, specific recommendations for on-site renewable energy generation are not provided herein. As with any sustainability project, however, collaboration among the disciplines is not only recommended but required in order to ensure that a project's overarching sustainability goals are met.

CHAPTER 7 – CONCLUSION AND FUTURE RESEARCH

The benefits of sustainable site design on K-12 campuses are nearly universal, with environmental, financial, academic, and health incentives. While environmental advantages are readily understood and the financial benefits are becoming more so, the human and educational advantages are only beginning to be widely understood and accepted. The limitations of sustainable site design on K-12 campuses tend to be restricted to space and budgetary constraints. While budgetary constraints are diminishing given the long-term financial gains of sustainability initiatives, the public's expectations of sustainably-designed buildings are increasing, and public schools are responding accordingly. These expectations can and should shift beyond the school building, to the school campus, for a truly comprehensive sustainably-designed school.

This study provides K-12 districts with a broad explanation of sustainable site design techniques, specific recommendations for their execution, and an example application of those recommendations at Detroit's Martin Luther King, Jr. Senior High School. Further, the study provides an evaluation of the application from the landscape architect's perspective. The study is not an evaluation of the outcome of specific sustainability techniques, but instead an evaluation of the application. The limited nature of this study, within the broad context of sustainable design, leaves significant capacity for further research, which could include such topics as the effectiveness of individual techniques, the long-term benefits to students and the environment, the nature of stewardship, maintenance implications, public acceptance, cost-benefit considerations, ADA implications, and intrinsic trade-offs, among others. Other important sustainability topics not touched on in this study, but certainly impacting site design include recycled and re-used materials, on-site composting programs, and on-site recycling programs, which also have important applications at schools and, thus, while relevant, simply exceeded the necessarily limited scope of this study.

Detroit Public Schools has embraced sustainability as evidenced by its seven LEED-certified projects over the past six years in spite of, or perhaps because of, its recent budget crisis. While those projects focused their sustainability initiatives within the building, extending sustainability initiatives outside of the building walls is both necessary and justified when considering the broader benefits to students, educators, the community, and the environment. What better place than a school to teach future generations the importance of sustainability in all aspects of our built and programmed world. This study affords DPS the necessary tools to accomplish its next frontier of sustainability, cementing its leadership in this capacity, providing another positive means of changing the narrative to what is 'right' with Detroit Public Schools.

Appendix 1: Existing Site Plan

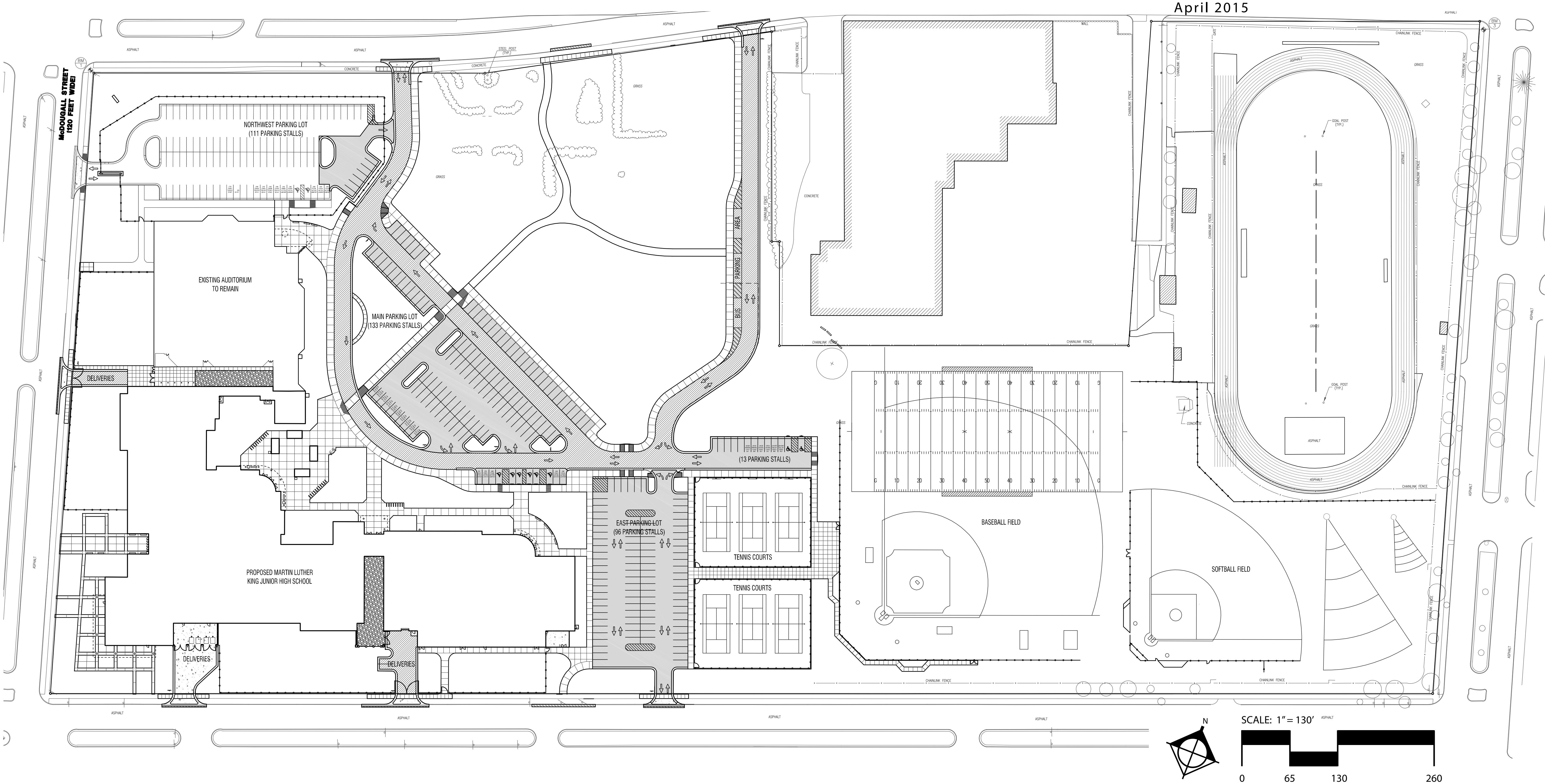
MARTIN LUTHER KING, JR.
SENIOR HIGH SCHOOL

Sustainable Site Design Strategies for Urban K-12 School Renovations

Existing Conditions

DETROIT PUBLIC SCHOOLS

Christy Summers Tremewan
April 2015



Appendix 2: Proposed Site Plan

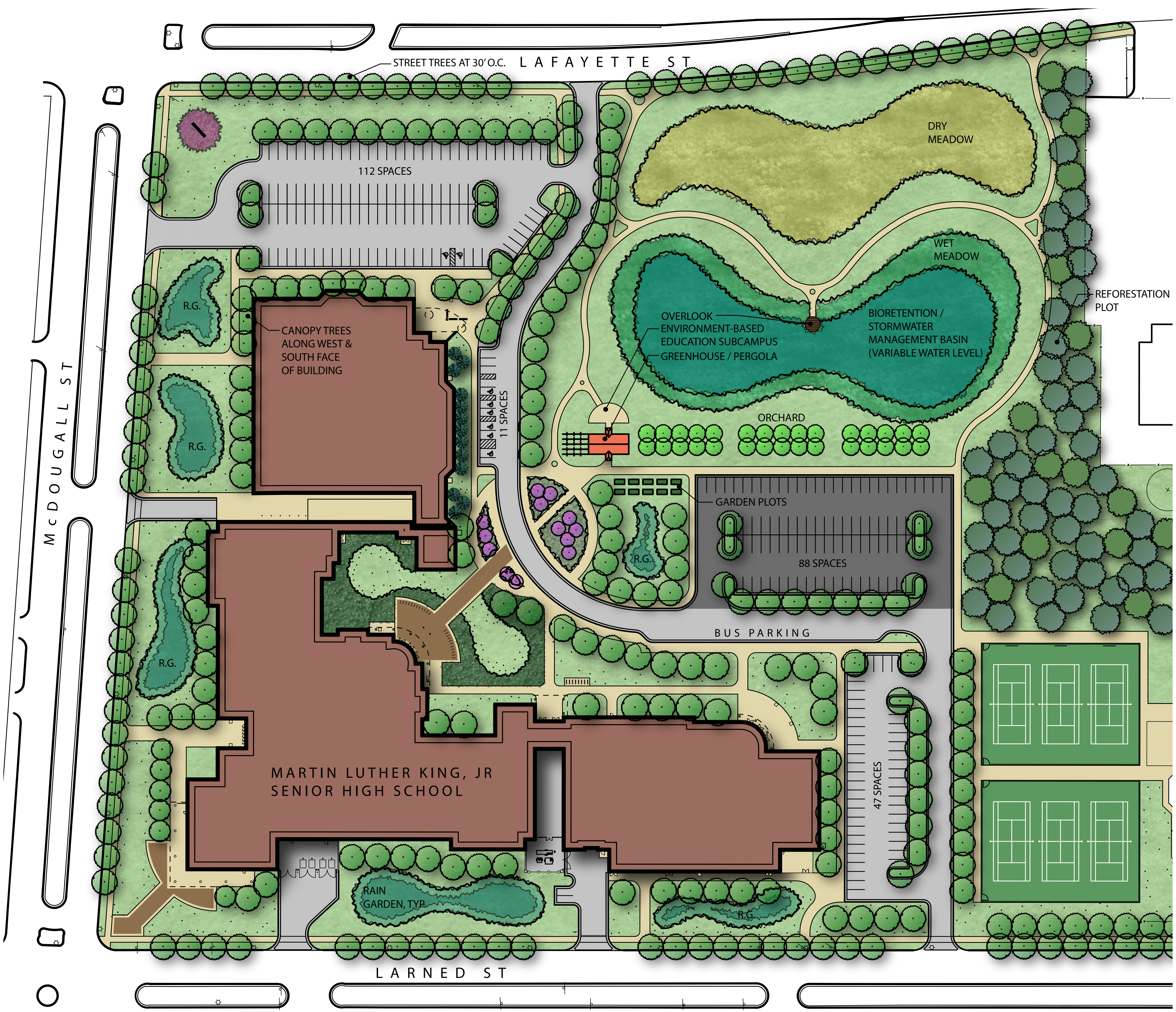
MARTIN LUTHER KING, JR.
SENIOR HIGH SCHOOL

Sustainable Site Design Strategies for Urban K-12 School Renovations

Proposed Site Plan

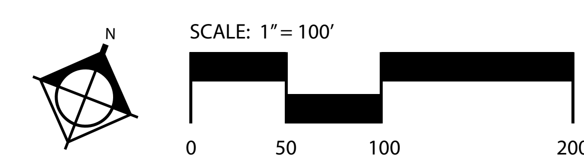
DETROIT PUBLIC SCHOOLS

Christy Summers Tremewan
April 2015



LEGEND

- BIORETENTION / RAIN GARDEN
- WET MEADOWLAWN
- DRY MEADOWLAWN
- MOWED TURF LAWN
- SIDEWALK
- PERVIOUS PAVERS
- ASPHALT PAVEMENT
- POROUS ASPHALT PAVEMENT



Appendix 3: Native Meadow Planting Mix

WET MEADOW MIX

Type	*Application Rate (oz Per 1,000 s.f.)*
Big Bluestem *(Andropogans gerardii)*	1.5 ounces
Indian Grass *(Sorghastrum nutans)*	1.5 ounces
Switch Grass *(Panicum virgatum)*	0.25 ounce
Virginia Wild Rye *(Elymus virginicus)*	1.5 ounces
Joe Pye Weed *(Eupatorium maculatum)*	0.5 ounce
Boneset *(Eupatorium perfoliatum)*	0.5 ounce
Golden Alexander *(Zizea aurea)*	0.25 ounce
Marsh Blazingstar *(Liatris spicata)*	0.25 ounce
White Turtlehead *(Chelone glabra)*	0.25 ounce
Cardinal Flower *(Lobelia cardinalis)*	0.25 ounce
Great Blue Lobelia *(Lobelia siphilitica)*	0.25 ounce
New England Aster *(Aster novae-angliae)*	0.25 ounce
Ironweed *(Vernonia missurica)*	0.25 ounce
Cup Plant *(Silphium perfoliatum)*	0.25 ounce
Blue Vervain *(Verbena hestata)*	0.25 ounce
Swamp Milkweed *(Asclepias incarnata)*	0.5 ounce
Culver's Root *(Veronicastrum virginicum)*	0.25 ounce
Awl-fruited Sedge (*Carex stipata*)	0.5 ounce
Fox Sedge (*Carex vulpinoidea*)	0.5 ounce
Dark Green Rush (*Scirpus atrovirens*)	0.25 ounce
Wool Grass (*Scirpus cyperinus*)	0.5 ounces

DRY MEADOW MIX

Type	*Application Rate (oz Per 1,000 s.f.)*
Little Bluestem *(Schizachrium scoparius)*	2 ounces
Prairie Dropseed *(Sporobolus heterolepis)*	0.5 ounce
Canada Wild Rye *(Elymus canadensis)*	2 ounces
June Grass *(Koeleria cristata)*	0.25 ounce
Butterfly Weed *(Asclepias tuberosa)*	0.5 ounce
Hoary Vervain *(Verbena stricta)*	0.25 ounce
Black-Eyed Susan *(Rudbeckia hirta)*	0.5 ounce
Roundleaf Ragwort *(Senecio obovatus)*	0.25 ounce
Rough Blazingstar *(Liatris aspera)*	0.25 ounce
Showy Goldenrod *(Solidago speciosa)*	0.25 ounce
Spiderwort *(Tradescantia ohiensis)*	0.25 ounce
Common Milkweed (*Asclepias syriacas*)	0.5 ounce
Yellow Coneflower (*Ratibida pinnata*)	0.5 ounce
Beardtongue (*Penstemon digitalis*)	0.5 ounce
Bergamot (*Monarda fistulosa*)	0.5 ounce
Prairie Dock (*Silphium terebinthinaceum*)	0.5 ounce
Smooth Aster (*Aster laeris*)	0.5 ounce

WORKS CITED

Arbor Day Foundation (2010). How Trees Can Retain Stormwater Runoff, *Tree City USA Bulletin No. 55*. Arbor Day Foundation, Nebraska City, NE

ASLA (2013). Designing our Future: Sustainable Landscapes. What are Sustainable Landscapes? Retrieved on March 8, 2015 from http://www.asla.org/sustainablelandscapes/about.html.

Bagdonis, Jessica M., et al (2009). The Emergence and Framing of Farm-to-School Initiatives: Civic Engagement, Health and Local Agriculture. *Agriculture and Human Values*. 26:107-119.

Baker, L. (2012). A History of School Design and its Indoor Environmental Standards, 1900 to Today. National Institute of Building Sciences, National Clearinghouse for Educational Facilities. January, 2012.

Barr, S., et al. (2011). Green Schools that Teach: Identifying Attributes of Whole-School Sustainability (Master's thesis). Colorado State University, Fort Collins, CO.

Beaumont, C.E. and Pianca, E.G. (2002). Why Johnny Can't Walk to School: Historic Neighborhood Schools in the Age of Sprawl. National Trust for Historic Preservation. 2nd Edition. October 2002.

Booth, A. and Skelton, N. (2011). Anatomy of a Failed Sustainability Initiative: Government and Community Resistance to Sustainable Landscaping in a Canadian City. *Sustainability: Science, Practice, & Policy*, 7(1), 56-68.

Brown, W. and Schueler, T. (1997). National Pollutant Removal Performance Database for Stormwater BMPs. Center for Watershed Protection. Chesapeake Research Consortium. 220 pp.

CDC (2006). Youth Violence: Using Environmental Design to Prevent School Violence. Centers for Disease Control and Prevention. Retrieved on February 8, 2015 from http://www.cdc.gov/ViolencePrevention/youthviolence/cpted.html.

CEFPI (2013). Safe Schools: A Best Practice Guide. Council of Educational Facilities Planners International; Spring 2013.

City of Detroit 1 (2014). Agreement to Create Water Authority Guarantees Funding to Rebuild Regional System and to Assist Customers in Need. September 2014. Retrieved on February 7, 2015 from http://www.detroitmi.gov/GreatLakesWaterAuthority.aspx.

Cockshull, K. (2007). Research Matters….The Benefits of Green Roofs. *Horticulture Week*, 24. September 6, 2007.

Crowe, T.D. (2000). *Crime Prevention Through Environmental Design: Applications of Architectural Design and Space Management Concepts*. Boston: Butterworth-Heinemann; 2000.

Detroit Public Schools (2009). About Proposal S. September 2009. Retrieved on February, 7, 2015 from http://detroitk12.org/proposal_s/docs/2009.10.30_proposal_s_newsletter.pdf.

EPA 1 (2012). Stormwater Management. November 2012. Retrieved on March 1, 2013 from http://www.epa.gov/oaintrnt/stormwater/index.htm.

EPA 2 (2003). After the Storm, EPA 833-B-03-002. January 2003. Retrieved on March 1, 2015 from http://water.epa.gov/action/weatherchannel/stormwater.cfm.

Ernst, J. and Monroe, M. (2006). The Effects of Environment-Based Education on Students' Critical Thinking Skills and Disposition Toward Critical Thinking. *Environmental Education Research*, 12(3-4), 429-443.

Gould, D., and Caplow, T. (2012). "Building-Integrated Agriculture: A New Approach to Food Production." *Metropolitan Sustainability: Understanding and Improving the Urban Environment*, edited by F. Zeman, 147-170. Cambridge: Woodhead Publishing Ltd.

Helfand, G., et al. (2006). The Economics of Native Plants in Residential Landscape Designs. Landscape and Urban Planning, 78(2006), 229-240.

Henke, K. A. (2006). Diminishing Resources, Increased Demands: What funding trends can educators expect for the year ahead? *Technology & Learning*, 26(12), 2.

Hess, A.J. and Trexler, C.J. (2011). A Qualitative Study of Agricultural Literacy in Urban Youth: What do Elementary Students Understand about the Agri-food System? *Journal of Agricultural Education*. 52 (4),1-12.

Kats, G. (2006). Greening America's Schools: Costs and Benefits. Washington, DC: Capital E; October 2006.

Klemmer, C.D., et al (2005). Growing Minds: The Effect of a School Gardening Program on the Science Achievement of Elementary Students. *HortTechnology*. 15(3), 448-452.

Koester, H. (2008). Native Plants and Urban Sustainability. *Native Plants Journal*, 9(3), 323-333.

Lauzzana, E., Director of Energy and Sustainability, Detroit Public Schools: interview. September 26, 2014.

Lieberman, G. and Hoody, L. (1998). Closing the Achievement Gap: Using the Environment as an Integrating Context for Learning, San Diego, CA, State Education and Environment Roundtable.

Meier, A. (1991). Strategic Landscaping and Air-conditioning Savings: A Literature Review. *Energy and Buildings*, 15-16(1), 479-486.

Militello, M., et al. (2008). The High School “Space Race:” Implications of a School-Choice Market Environment for a Michigan Metropolitan Region. *Education and Urban Society*, 41(1), 26-54.

Miller, R., et al. (2007). Do Teacher Absences Impact Student Achievement? Longitudinal Evidence from One Urban School District, August 2007.

Nassauer, J.I. (2011). Care and Stewardship: From Home to Planet. *Landscape and Urban Planning*, 100(4), 321-323.

Palliser, J. (2010). How Green is Your Lawn? *Science Scope*, 33(9), 8-12.

Rifkin, J. (2004). *The European Dream: How Europe’s Future is Quietly Eclipsing the American Dream.* Tarcher, Penguin.

Robinson, C.W., Zajicek, J.M. (2005). Growing Minds: The Effect of a One Year School Garden Program on Six Constructs of Life Skills of Elementary School Children. *HortTechnology*. 15(3), 453-457.

Rye, J.A., et al (2012). Elementary School Garden Programs Enhance Science Education for All Learners. Teaching Exceptional Children. 44(6), 58-65.

Ruiz-Gallardo, Jose-Reyes, et al (2013). Garden-Based Learning: An Experience with “At Risk” Secondary Education Students. *The Journal of Environmental Education*. 44(4), 252-270.

School Food Focus (2011). Betti Wiggins Knows It Takes More Than Books for Detroit Public Schools Students to Learn. March 2011. Retrieved on October 5, 2014 from http://www.schoolfoodfocus.org/2011/03/betti-wiggins-knows-it-takes-more-than-books-for-detroit-public-schools-students-to-learn/.

Smith, L.L., Motsenbocker, C. E. (2005). Impact of Hands-on Science through School Gardening in Louisiana Public Elementary Schools. HortTechnology. 15(3), 439-443.

Speck, J. (2012). *Walkable City: How Downtown Can Save America, One Step at a Time*. New York: Farrar, Straus and Giroux.

Tull, H. (2002). Transportation and School Busing. *Encyclopedia of Education*.

USGBC (2009). *LEED 2009 for Schools New Construction and Major Renovations.* Washington, D.C., 2009.

Wiggins, B., Executive Director Office of School Nutrition, Detroit Public Schools: interview. October 13, 2014.

Zimmer, R. and Jones, J.T. (2005). Unintended Consequences of Centralized Public School Funding in Michigan Education. *Southern Economic Journal*, 71(3), 534-544.

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CHAPTER 1

Figure 1. Image of *Designing the Sustainable School* by Alan Ford. Available from: http://www.ebook3000.com/Designing-the-Sustainable-School-_106015.html (accessed April 2015).

Figure 2. Graphic referencing school funding. Available from: http://www.wgal.com/news/susquehanna-valley/lancaster/Corbett-links-school-funding-pension-reform/18327540 (accessed April 2015).

Figure 3. Detroit's overburdened infrastructure. Available from: http://greatlakes.org/detroit (accessed April 2015).

Figure 4. Benefits of sustainability in schools. Available from: http://celfeducation.org/About.html (accessed April 2015).

Figure 5. Garden-based learning. Available from: http://www.mlive.com/news/detroit/index.ssf/2014/10/detroit_kids_become_environmen.html (accessed April 2015).

CHAPTER 2

Figure 6. Green roof. Available from: http://secretaryofinnovation.com/2010/08/08/sustainability-boston-students-growing-green-roofs/ (accessed April 2015).

Figure 7. Porous pavers diagram. Available from: http://www.dot.ca.gov/hq/LandArch/ec/lid/lid-permeable-paving-new.htm (accessed April 2015).

Figure 8. Hydrodynamic separator. Available from: http://www.conteches.com/knowledge-center/pdh-article-series/designing-for-lid.aspx (accessed April 2015).

CHAPTER 3

Figure 9. Native meadow lawn. Available from: http://mnfi.anr.msu.edu/communities/community.cfm?id=10657 (accessed April 2015).

Figure 10. The Urban heat island effect. Available from: http://healthyurbanhabitat.com.au/wp-content/uploads/2011/12/GTW_UHI-Graph1.jpg (accessed April 2015).