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Schoolyard Renovations in the Context of Urban Greening: Insight from the Boston Schoolyard Initiative, Boston, Massachusetts

Katherine A. Tooke
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SCHOOLYARD RENOVATIONS IN THE CONTEXT OF URBAN GREENING: INSIGHT FROM THE BOSTON SCHOOLYARD INTIATIVE, BOSTON, MASSACHUSETTS

A Thesis Presented

By

KATE TOOKE

Submitted to the Graduate School of the University of Massachusetts Amherst in partial fulfillment of the requirements for the degree of

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May 2011

Department of Landscape Architecture and Regional Planning
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ABSTRACT

SCHOOLAYRD RENOVATIONS IN THE CONTEXT OF URBAN GREENING:
INSIGHT FROM THE BOSTON SCHOOLYARD INITIATIVE, BOSTON, MASSACHUSETTS
May 2011

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Twenty years ago the public schoolyards in Boston, Massachusetts were in a deplorable state: most were entirely paved, seriously neglected and used predominantly for parking. Since 1995, the Boston Schoolyards Initiative (BSI) has worked to transform these spaces into vibrant environments of recreation and learning. Renovations typically include adding play structures, gardens, murals and seating that can engage children at recess or support an educational activity. Recent research has shown that BSI renovations have had a positive impact on student academic performance (Lopez, Jennings and Campbell, 2008), but little attention has yet focused on how these revived and greened spaces have contributed to citywide urban greening efforts and to the environmental quality of their surrounding neighborhoods. This study uses design plans and GIS data to compare pre- and post-renovation canopy cover and pervious surfaces at 12 BSI schools. Data analysis included both an examination of the percent increase in canopy cover and pervious surfacing as well as exploration of the spatial configuration of green space and play space within the newly designed schoolyards. Data indicates that overall BSI renovations have a slightly positive impact on canopy cover and pervious surfacing, but gains are not uniform and many schools are left not meeting citywide goals for canopy cover and pervious surfacing. In addition, schoolyard designs emphasized traditional play structures and paved spaces, subordinating opportunities for children to interact with vegetation. Although eight school renovations included an outdoor classroom with natural features, only one provided any space for children to interact more informally with vegetation. Schools are organized into five different typologies based on the proportions of spaces they contain and spatial configurations, and one typology is recommended as a model for future renovations. In conclusion, this study addresses the challenges and constraints facing urban schoolyard renovations and proposes a framework for integrating recommendations in an iterative experimental manner.

KEYWORDS: Urban greening, pervious surfaces, canopy cover, urban schoolyards, schoolyard reform, schoolyard design, children and nature, children and vegetation, spatial configuration in design.
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CHAPTER I
INTRODUCTION

The Schoolyard Transformation Movement

In recent years schoolyards have become an exceedingly popular topic in the world of education. Advocates of experiential and outdoor instruction have joined with nutritionists, athletes and proponents of organic agriculture to champion “outdoor classrooms” that engage students in healthy, playful learning. Recess, once banished from the school-day due to overloaded curricular mandates and the need for more “seat time,” has returned to pedagogical favor (Robert Wood Johnson Foundation, 2010). Teachers weary of test-based lesson plans are looking for opportunities to enrich lessons with activities outside the classroom. As a result, schoolyards, particularly the paved and neglected enclosures often associated with urban schools, have come into focus as places of great potential within the school landscape (Rivkin, 1997; BSI, 2010). Beyond individual schools, cities are beginning to regard public schoolyards as both important nodes in their open space and recreation network and targets of greening efforts (National Wildlife Federation, 2010).

In this social climate, projects transforming schoolyards are incredibly diverse, ranging from the installation of a few play structures to the planting of an “edible schoolyard” that serves an educational and nutritional function (Center for Ecoliteracy, 1999). Most projects engage members of the school community, local residents and design professionals in the process of deciding what elements to include and how to include them. Although resources are available for independent schools or towns, numerous non-profit organizations now partner with municipalities to aid in the process of transforming schoolyards. These partner
organizations identify priority sites, mobilize funding, facilitate meetings, advise design
development and act as a clearinghouse for resources and information. The city of Boston
claims one of the oldest such collaborations: the Boston Schoolyard Initiative (BSI). Established
in 1995 to consolidate many grassroots efforts happening throughout the city, the BSI has
completed over 78 schoolyard renovations to date (BSI, 2010). Similar organizations in New York
City, Washington DC, Chicago, Denver, the San Francisco Bay area and other urban centers are
operating with equal industry (Rivkin, 1997).

**The Urban Greening Movement & Boston**

At the same time degraded environmental conditions in many urban centers has caught
society’s eye. Worldwide, the percentage of people living in cities is growing, and the UN
projects that more than two-thirds of the world’s population will live in an urban area by 2050
(UN, 2008). This increasing urbanization puts tremendous pressure on urban ecosystems (REF).
A relatively new scientific field called “urban ecology” has recently sprung up aiming to
understand the natural systems of urban areas, the services they provide for humans and the
threats that face them (Urban Ecology Institute, 2010). Research in this burgeoning field has
brought recognition that planting shade trees, rain gardens and other vegetation provides
valuable ecosystem services such as decreasing heat island effect and stormwater runoff (EPA,
2008; Stormwater Center, 2011), which in turn has brought political attention to urban greening
efforts. Although cities vary significantly in their leadership of these efforts, most US
municipalities are now spending some political (if not always financial) capital on tree planting
projects, vacant lot transformation, park additions and improvements and other greening
initiatives.
The city of Boston, Massachusetts, has a long and illustrious history of urban greening. In the late 19th century, Frederick Law Olmsted’s Emerald Necklace park system put Boston on the map as one of the first cities to establish a comprehensive greenway system. Although the park system still exists as a tremendous resource for Boston residents, by the late 20th century attention began to focus on the many neighborhoods of Boston without easy access to these large green spaces. Non-profit organizations such as the Boston Natural Areas Network (BNAN), Earthworks and the Urban Ecology Institute (UEI) have spearheaded the formation of community gardens and pocket parks as well as the maintenance of urban wild areas in underserved neighborhoods of the city for the past several decades. In 2006, the Urban Ecology Institute initiated a several-year study documenting the state of the urban forest in Boston, mapping canopy cover in each of Boston’s neighborhoods and creating detailed records of the health of all public street trees (UEI, 2008). This research, and the ensuing report, inspired a collaborative between dozens of local environmental non-profit organization and the city of Boston called Grow Boston Greener (GBG). Officially announced in 2007 by Boston’s Mayor Menino, GBG’s goal was to plant 100,000 trees by the year 2020 in order to increase the city’s tree canopy to 35% by 2030. Although the program installed 4,000 trees within the first two years, unfortunately it lost funding in early 2009 and the work has been continued piecemeal by several area environmental non-profits.

Despite the slowing of the Grow Boston Greener initiative, Boston’s urban forest has recently become the focus of two separate teams of academic researchers. Both teams have received funding from the National Science Foundation (NSF) as part of their Urban Long Term Research Area exploratory (ULTRA-Ex) grant program. One team, BUM-ULTRA-Ex which is based at Harvard University, is looking primarily at the carbon sequestration potential of Boston’s urban forest. The other, BMA-ULTRA-Ex which is based at the University of Massachusetts
Amherst, aims to understand how urban greening projects like Grow Boston Greener and the Urban Ecology Institute’s Cityroots program are impacting the ecological and public health of the city. The BMA-ULTRA-Ex team includes ecologists, hydrologists and social scientists who are currently conducting studies as diverse as bird and bug counts, behavioral observations, water quality monitoring, land cover mapping and volunteer surveying. Both research teams are hoping to leverage the research generated during this two-year exploratory grant to win a longer 15-year grant enabling the continued study of urban ecology in Boston.

**Thesis Goals**

Although data regarding both the educational benefits of quality schoolyards and the environmental benefits of urban greening projects abounds, little scholarly research has focused on connecting these two themes. By studying the renovation of urban public school grounds in Boston, Massachusetts, this thesis aims to understand the way in which schoolyard transformation projects affect their surrounding city environment. It explores changes in overall pervious surfacing and canopy cover on school sites that have engaged the Boston Schoolyard Initiative program, asking specifically what configurations of play structures and vegetation most contribute to urban greening efforts. The goals are (1) to establish a benchmark for how ecologically beneficial current urban schoolyard renovations are and (2) to develop sound recommendations to policy-makers and designers for creating schoolyards that not only support children, but also truly advance urban environmental and public health.
**Thesis Organization**

The body of this thesis begins with a literature review which explores the relationships between children and the natural environment as well as the impacts of play activities on child development and then applies these theories to understand the potentials of and challenges facing green schoolyards. The literature review also addresses current thinking about urban ecology, urban greening efforts and what is known about how canopy cover and pervious surfacing affect urban environmental and public health. The literature review concludes with the specific research questions that spring from the literature and guide the study. Chapter III, Methodology, first gives readers an understanding of the Boston Public School system and the Boston Schoolyard Initiative before explaining how specific schools were chosen for this study. It then explains how data about pervious surfaces, canopy cover and spatial configurations were generated for the selected schools. Chapter IV, the Results and Discussion, present the data generated for pervious surfaces, canopy cover and spatial configurations and evaluate this data in the context of scholarly literature and current thinking. Finally, the Conclusions offer recommendations to the Boston Schoolyard Initiative and similar organizations about how to use and build upon this research.
CHAPTER II

LITERATURE REVIEW

This literature review explores the relationships between children and the natural environment as well as the impacts of play activities on child development and then applies these theories to understand the potentials of and challenges facing green schoolyards. It concludes with a discussion of urban ecology, urban greening efforts and what is known about how canopy cover and pervious surfacing affect urban environmental and public health.

Children and Nature

In the past decade the term “nature deficit disorder” has come into vogue to describe the relative disassociation that many children, particularly those growing up in urban areas, have with the natural environment (Louv, 2005). Although the disconnect between children and nature is partially attributed to the largely built character of our surroundings, child advocates are increasingly identifying television, video games, computers and other indoor entertainment media as the primary culprits. A recent study by the Kaiser Family Foundation and Stanford University found that children ages 8-18 now spend an average of 7.5 hours per day using entertainment media and less than an hour outside (2010). Youth who spent more time using media also reported lower grades and lower levels of personal contentment than those who engaged in more diverse activities. Although nature deficit disorder is not officially recognized as a disease by the American Medical Association, child advocate and founder of the Children and Nature Network, Richard Louv (2005) has gathered research that links nature deficit to some of the most troubling childhood trends, including increases in obesity, attention disorders and depression.
The growing clamor and concern over what happens to children who don’t get enough of nature begs the question: what benefits do natural environments give children? A growing body of research addresses exactly this question. Yale University child psychologist Stephen Kellert (2005) asserts that nature is important to children’s development in every major way – intellectually, emotionally, spiritually, socially and physically. First and foremost, children exhibit an innate preference for nature (Simmons, 1994; Nabhan and Trimble, 1994). They identify with and express preference for scenes of trees, parks and other vegetated spaces because they perceive opportunities for recreation, exploration or creative play. Having positive youthful experiences in natural settings builds environmental ethic and can contribute to a lifelong commitment to maintaining a healthy environment (Tanner, 1980; Nabhan and Trimble, 1994). In fact, any affirmative exposure to vegetation as a child has been shown to have a positive influence on lifelong attitudes towards plants and the environment (Harvey, 1989).

Beyond general preferences and experiences, children develop particular attachments to specific natural places (Hart, 1979). In a comprehensive review of literature examining place use and place attachment in children ages six to seventeen, Chawla (1992, p.81) finds that “in behavior mapping, children and adolescents are rarely observed to spend even as much as 15% of their time in neighborhood woods, fields, undeveloped waste places or waterways, yet these are their most frequently elected favorite places.” This place attachment to nature despite infrequent use indicates that children hold certain natural places dear.

Finally, a growing body of research has suggested that nature has restorative benefits for the human brain, which improves cognition (Kaplan, Ryan and Kaplan, 1998). Experiences in nature and views of nature reduce stress, clear one’s head and make it easier to concentrate on difficult tasks (Hartig et al, 1991; Tenneson and Cimprich, 1995). Although much of this research has focused on adults, a recent study of 100 high schools found higher standardized test scores
and graduation rates among students whose classrooms had views including larger quantities of nature, i.e. trees, shrubs and other vegetation (Matsuoka, 2008). Similar studies of elementary students have discovered that proximity to, views of and daily exposure to natural settings reduced stress in children (Wells and Evans, 2003) as well as increased children’s ability to focus, improving their cognitive functioning (Wells, 2000). Contact with nature may have particular benefits for special populations: children with attention deficit disorder (ADD) have reduced symptoms after activities in natural environments and when they have regular access to greener environments (Taylor, Kuo and Sullivan, 2001).

**Children and Play**

Common sense and a wide body of research supports the notion that play facilitates physical development (Burdette and Whitaker, 2005). But what is the relationship between playing and cognitive or emotional development? The answer to this question may lie partially in evolution: a significant difference between humans and other primates is the length of time human children engage in play behaviors while growing up (Washburn, 1972). Humans play, on average, 2-4 times as long as our primate counterparts, and evolutionary scientists maintain that this longer play period contributes to the greater plasticity and complexity of our brains (Washburn, 1972). In other words, engaging in play is the original human school, the tool by which human children challenge their brains to grow. Psychologists agree that children learn by exploring their world and each other in play activities (Moore, 1986). Jean Piaget’s sensorimotor/adaptive model of intellectual development has long been a standard framework for understanding the way in which children learn from play. Piaget argued that children first assimilate, i.e. transform objects into items that fit their own needs and conceptions. As children
continue to explore through play, they accommodate, i.e. modify some of their mental structures to meet the demands of the environment (Piaget, 1954). Children’s understanding of reality is based on this iterative process of using fine and gross motor skills to explore the environment, adjusting their mental perceptions of what surrounds them and then re-exploring (Piaget, 1954 as noted in Herrington, 1997). A current theory in pediatric medicine holds that the problem solving that occurs in free play promotes the integration of attention and other cognitive functions such as planning, organizing, sequencing and decision making, all of which are key to later academic success and independent life (Burdette and Whitaker, 2005).

In addition to the cognitive advantages, there is some consensus that play is an important tool for developing social skills, culture and community (Hart, 1979; Burdette and Whitaker, 2005). In fact, as far back as the 1890’s, popular psychology held that play was the “work” of young people: children who engaged in active playful exploration grew into good citizens while those who disengaged from their “profession” would stray into delinquency (Solomon, 2005). Children foster both creativity and negotiation skills in cooperative play while independent playing activities support the development of feelings of competence (Huttenmoser, 1995; Moore, 1986).

In the school environment, most free play opportunities traditionally occur at recess. Unfortunately, recess has become a somewhat rare commodity in American public schools: 40 percent of US school districts have reduced or eliminated recess in order to devote more time to core academics (Robert Wood Johnson Foundation, 2010). New evidence is emerging to refute this logic. A recent study of 11,000 third graders found that those who had more recess time behaved better in the classroom and were likelier to learn more (Barros et al, 2009). In addition, school principals overwhelmingly believe that recess has a positive impact on academic
achievement in their schools because students listen better after recess and are more focused in class (Robert Wood Johnson Foundation, 2010).

**The Evolution of Playgrounds**

Beliefs in the importance of play for the development of youth came to the surface in the late 19th century when social activists within increasingly dense American and European cities began to fund the construction of playgrounds. The year 1906 saw the formation of the Playground Association of America, which launched playgrounds into the public realm and fielded the first debates over safety (Solomon, 2005). Standard playgrounds included features like swing sets, seesaws, slides, monkey bars, and jungle gyms on a flat dirt, paved or grassy surface surrounded by a fence. Despite dynamic proposals such as Play Mountain by Isamu Noguchi in 1933, the landscapes of urban playgrounds and schoolyards remained almost entirely static though the second world war.

During the German occupation of Denmark in the early 1940s, Danish architect C. Th. Sorenson proposed and implemented a series of Adventure Playgrounds in Denmark. Meant to serve as an antidote to the climate of political control, these urban spaces were almost entirely fluid; children were free to creatively manipulate the environment and build whatever they wished with the tools and recycled materials on hand (Solomon, 2005). The idea of Adventure Playgrounds spread abroad post war, gaining particular momentum in England in the 1950’s. Although the term gathered some currency in the United States, and a few Adventure Playgrounds were constructed, the idea never fully flourished on this side of the Atlantic. The reason has much to do with American (mis)perceptions of what constitutes safety and risk (Solomon, 2005). As Americans became more risk-adverse, safety guidelines emerged and
manufacturers stepped in with commercial products. Unfortunately, “Americans put so much trust into equipment that they failed to realize that the equipment alone did not constitute a playground.” (Solomon, 2005, p.43) Although a limited artistic movement supported by the Museum of Modern Art (MoMA, New York) and several independent sculptors emerged in the 1950’s, the eclectic modern play installations they put forth remained very much the exception, and most playgrounds “remained blacktopped, uninspiring accumulations of the same equipment that had been around for decades” (Solomon, 2005, p. 42).

In the late 1960s and early 1970s, some designers began to call attention to the dismal conditions of American playgrounds. Architect Richard Dattner, a prominent playground activist, charged,

“...The typical New York Playground (which is typical of 99 percent of all the playgrounds in the United States) could not be a more hostile environment for children’s play if it had been designed for the express purpose of preventing play. Characteristically, it is an unbroken expanse of concrete or asphalt pavement, punctuated by the forlorn presence of metal swings, a slide, and some seesaws. Not only does this design lack any possibility for real play, the most interesting activities are prohibited anyway by signs saying “NO” in huge letters, followed by a list of all the things children like to do.” (As quoted in Solomon, 2005, p.54)

Dattner went on to design and install an Adventure Playground in Central Park as well as several other non-conventional playgrounds (Solomon, 2005). A collaborator of Dattner’s, landscape architect Paul Friedberg designed and installed derivatives of the Adventure playground at several public housing developments in New York City. Again, these “designer playgrounds” remained very much the exception rather than the norm. In fact, as the 1970s ushered in big business and ever growing concerns over “safety” and liability, playground reform was generally reduced to the installation of a generic commercial “post and platform” structure. Playground historian Susan Solomon calls this the “McDonald's model” in which ubiquitous,
uniform, sterile equipment is cordoned off from the world by a “menacing fence” which proclaims to adults and children that “today’s playground has no real setting” (Solomon, 2005, p.82). In addition, many educators agree that the homogenization of play environments has decreased the educational and developmental value of play (Herrington, 1997).

The Potential of Greened Schoolyards

Within this climate, a groundswell of educators, parents, social activists and non-profit advocacy agencies have begun clamoring for change in our nation’s playgrounds and schoolyards (Solomon, 2005). Some have merged with the food security movement to create dynamic, edible environments that engage children in the process of growing food (Centre for Ecoliteracy, 1999). Others have adopted the original tenants of the Adventure Playground or joined forces with muralists, mosaic artists and sculptors to craft vibrant, unique spaces (Solomon, 2005). A significant arm of the playground reform movement advocates for the “greening” of playgrounds and, more specifically, schoolyards. The Washington Environmental Yard in Berkeley, CA became a pioneer in the 1970s, illustrating the potential of green environments surrounding schools (Moore and Wong, 1997). Although the green schoolyards movement is still in relative infancy, a growing body of research is delving into the contexts, impacts and implications of re-thinking school grounds. This research is beginning to tell a promising story of benefits for students, teachers and broader communities.

As might be expected, the bulk of research focuses on students. Children who attend schools with greened schoolyards have more volume and variety of play opportunities (Barbour, 1999; Moore, 1996; Tranter and Malone, 2004) because vegetated environments are more fluid and support a diverse range of dramatic and creative play (Kirkby, 1989; Tranter and Malone,
These diverse play opportunities foster cooperation, collaboration and communication that build valuable social skills (Titman, 1994) and create more welcoming, inclusive social environments for children of all types (Dyment and Bell, 2008). Conversely, children and teachers report less boredom in greened schoolyards and less negative and aggressive behaviors than are typical of paved schoolyards (Dyment, 2005). In terms of physical health and safety, the increased level of play activity associated with greened schoolyards may account for decreased levels of obesity among these populations (Bell and Dyment, 2006; Dyment, Bell and Lucas, 2009) and greened schoolyards are generally considered safer than their asphalt counterparts (Chesky, 2001; Dyment, 2005). Finally, the opportunity to explore and manipulate green school environments builds stronger relationships with the natural world, leading to the formation of lifelong environmental awareness and stewardship (Bell, 2001; Tranter and Malone, 2003; Dyment, 2005) and stimulating higher levels engagement and reflection as citizens (Mannion, 2003).

Perhaps most important in today’s social climate are the potential cognitive benefits of greened schoolyards. Several studies have shown that children who attend greened schools perform better academically than their peers who play in un-renovated schoolyards (Lopez, 2009; Leiberman and Hoody, 1998; Simone, 2002) and are generally more engaged in learning (Dyment, 2005). Improved academic performance is likely due in large part to teacher reports of increased opportunities for learning and curriculum development in outdoor environments (Dyment, 2005; Center for Ecoliteracy, 1999; Moore and Wong, 1997) and reduced problems with classroom management (Leiberman and Hoody, 1998). It may also be related to the way that natural environments encourage diverse types of activities that child psychologists believe support cognitive development in children (Herrington, 1997).
Finally greened schoolyards can play a significant role in the surrounding community. In most cases, the process of schoolyard renovation has taken a bottom-up approach, engaging students, teachers, parents, neighbors, local civic organizations and other stakeholders in the planning initiative. An analysis of the Boston Schoolyard Initiative’s public-private partnership model found that although overcoming civic cynicism was difficult, the bottom-up, citizen-driven approach ultimately created a better schoolyard and strengthened the school and neighborhood community (Lopez et al, 2008). Once renovated, the school grounds can become a significant community resource, providing space for children to play when school is not open and offering healthy green space for neighbors to gather (Barker, 1994). These green spaces can contribute to overall urban greening efforts by connecting wildlife corridors or greenways and adding habitat that supports biodiversity (National Wildlife Federation, 2010).

Although the potential benefits of greened schoolyards are clear, the context of the schoolyard, implementation of the plan or ongoing management issues can raise challenges that can suppress the full realization of benefits. Concluding a study of 45 greened schools in Toronto, Dyment (2005, p39) writes: “Many [informants] believed that important aspects of greening initiatives remained ‘untapped’, ‘under-realized’ or ‘under-explored’.” She continues, “Not surprisingly, what was a challenge for one project proved to be an opportunity for another...the most commonly reported barriers were: 1) availability of funding, 2) demands on time, 3) difficulty in maintenance, and 4) lack of teacher involvement [while] the key factors [enabling] projects were: 1) human resources (students, teachers, parents and principals), and 2) funding.” Using comments from interviews as well as policy analysis, Dyment creates a long list of recommendations for ameliorating these challenges applicable for Toronto as well as other school districts.
Urban Ecology and Ecosystem Services

The growing body of research on schoolyard greening is beginning to paint a picture of benefits for students, teachers and broader communities, yet significant holes remain. In particular, little attention has focused on the ecological impacts of renovated urban schoolyards. Exploring the contributions of schoolyard renovations to environmental health requires an understanding of how ecology functions within urban environments. Urban ecology is a relatively new field that strives to understand the natural systems of urban areas, the services they provide for humans and the threats that face them (Urban Ecology Institute, 2010). This field grew in part out of a body of literature pointing to negative environmental and public health conditions within cities.

Perhaps the most infamous of these conditions is heat island effect, the phenomenon of urban and suburban areas experiencing elevated temperatures compared with their out-lying rural surroundings. Heat islands occur because the dark, paved and metallic surfaces associated with cities capture and re-radiate heat from the sun more than vegetated and moist environments (EPA, 2008). Cities with a population greater than 1 million people have been found to have an annual mean air temperature 1.8 to 5.4 degrees Fahrenheit warmer than their surroundings (Oke, 1997), and this difference can be as large as 22 degrees Fahrenheit on a clear calm summer night (Oke, 1987). These warmer temperatures increase cooling load and related energy use (Akbari, 2005) which in turn leads to higher air pollution rates and greenhouse gas emissions (EPA, 2008). Increased air pollution is known to be connected with increased asthma rates and other respiratory diseases (Levy, 2003). In addition, heat island effect exacerbates the effects of heat waves resulting in general discomfort, increased respiratory ailments and above average rates of mortality in sensitive populations (CDC, 2006). Finally, hot pavement and
rooftop surfaces can heat stormwater runoff, elevating temperatures in streams, rivers, ponds and lakes which affects aquatic health (EPA, 2008).

In response to the myriad negative effects of heat islands on urban environmental and public health, the U.S. Environmental Protection Agency recommends mitigation through adding trees and vegetation, green roofs and cool roofing/paving materials (EPA, 2008). A review of several hundred studies of urban greening found that greened urban areas, such as urban parks, are an average of 1° C cooler than non-green sites (Bowler et al., 2010). This is because daytime air temperatures beneath both individual trees (Georgi and Zafiriadis, 2006; Golden et al., 2006) and clusters of trees (Taha et al., 2007; Souch and Souch, 1993; Sashua-Bar and Hoffman, 2000; Streiling and Matsarakis, 2003) are lower than temperatures in surrounding urban open areas. Surfaces shaded by trees or other vegetation are 20 to 45 degrees Farenheit cooler than unshaded surfaces (Akbari et al., 1997) and evapotranspiration by vegetation can reduce peak summer air temperatures by 2 to 9 degrees Farenheit (Huang, Akbari and Taha, 1990). Besides mitigating heat island effects, other benefits of canopy cover in urban areas include reducing emissions of hydrocarbons involved in ozone formation (Scott et al. 1999), control of stormwater runoff (Xiao et al. 1998), and increasing pavement longevity (McPherson et al. 1999).

A second major ecological condition within urban environments concerns stormwater runoff due to high levels of impervious surfacing. Impervious surfaces have long been associated with the intensity of an urban environment (Brabec, Shulte and Richards, 2002), and the associated loss of forested lands, wetlands and other open spaces that normally absorb and clean stormwater in the natural system changes both the quality and quantity of stormwater runoff (Brabec, Shulte and Richards, 2002). In urban environments high levels of paved, impervious surfacing mean that a majority of precipitation from rain and snowmelt events
cannot percolate into the ground. Instead, runoff accumulates debris and pollutants as it flows over paved surfaces, and then overwhelms and contaminates natural waterways at discharge sites (EPA, 2010). The resulting increased pollutant load and sedimentation of streams causes adverse conditions for fish as well as plants and other naturally-occurring aquatic life, exacerbates flooding and creates unsafe public health conditions for humans interacting with the water (EPA, 2010).

Arnold and Gibbons (1996) identify impervious surfaces as an important indicator of environmental quality because, although the impervious surface does not itself directly generate pollution, it prevents the natural cleansing of water through percolation and instead conveys pollutants directly to waterways. Scientists differ in their opinions about how much impervious surface in a watershed affects stream quality. May et al (1997) contend that the “physical, chemical and biological characteristics of streams change with urbanization in a continuous rather than threshold fashion” (p.491), while Scheuler (1994) reviewed eleven studies of imperviousness and water quality and determined that stream quality declines significantly at a threshold of 10-15% imperviousness. As most cities and even suburban areas are significantly more impervious than this threshold, ecologists, landscape architects and planners are beginning to consider a variety of new stormwater management techniques. These include replacing traditional pavement with pervious paving options such as block pavers and porous asphalt as well as installing rain gardens that help to impound and clean stormwater flowing off paved urban areas.

Recognition that planting shade trees, rain gardens and other vegetation provides valuable ecosystem services such as decreasing heat island effect and stormwater runoff, has brought political attention to urban greening efforts. In 2007 Boston’s Mayor Menino announced an initiative called Grow Boston Greener (GBG), which involved a goal of planting
100,000 trees by the year 2020 to increase the city’s tree canopy to 35% by 2030. The program installed 4,000 trees within the first two years, but unfortunately lost funding in early 2009. Continued work is happening in Boston at the grassroots level through organizations such as the Urban Ecology Institute (UEI) Cityroots program, Earthworks and the Boston Natural Areas Network (BNAN). As these organizations work mostly to green and “tree up” vacant lots and public spaces, the Boston Schoolyards Initiative (BSI) is leading the charge to address the public school sites. However, because the goals of the BSI aren’t explicitly about urban greening, little attention has been paid to how the renovated spaces function ecologically or what ecosystem services they provide. We don’t know much about how school communities and designers have chosen to balance play equipment and ball courts with “outdoor classroom” features, how they have integrated ecosystem services into new plans. We need this information to understand what impacts BSI renovations have had on the ecological health of the surrounding city and its residents. As municipal and school budgets tighten, the advocates for schoolyard reform will need sound and diverse arguments for the ways in which transforming schoolyards can positively impact larger urban communities. This thesis will attempt to fill these gaps by answering the following questions.

**Research Questions**

1. How has the Boston Schoolyard Initiative contributed to urban greening efforts and environmental quality in Boston?

   - What gains in vegetation and tree canopy result from BSI renovations?
   - What gains in pervious surfaces result from BSI renovations?
• What impact do these gains have on neighborhood and city-wide canopy cover, open space and hydrology?

2. How are the traditional play structures, vegetation and outdoor classroom features configured in BSI schoolyards?

• What patterns emerge across many schools and many designers?

• What proportions of BSI renovations are devoted to traditional play areas/structures versus “outdoor classrooms”?

3. How can an understanding of BSI configurations and contributions to urban greening inform future schoolyard renovations in Boston and other urban areas?
CHAPTER III

METHODOLOGY

Overview of Boston Public Schools and the Boston Schoolyard Initiative

The Boston public school (BPS) system proudly proclaims that it is the birthplace of public education in America (BPS, 2011), a distinction that comes from the founding of the Boston Latin School in 1635 and the Mather Elementary School in 1639. From these historic roots BPS has grown into a large educational network of 135 schools that serve 56,340 students from pre-kindergarten to grade twelve (BPS, 2010). Overall, the student body is diverse, with a population that is 39% Hispanic, 37% Black, 13% White, 9% Asian and 2% other or multiracial (BPS, 2010). Seventy-four percent of students qualify for free or reduced price lunch and 38% are English language learners (BPS, 2010). Because Boston has a school-choice and busing program, brought about by a desegregation lawsuit in 1974, the student body is relatively well-mixed and integrated throughout the school system.

Perhaps partially because of its historic nature, the Boston Public School system operates within an ageing building stock. Limited maintenance funding has generally gone to necessary repairs and renovations of the buildings themselves, leaving the surrounding school grounds sorely forsaken. By the early 1990’s decades of neglect had left Boston’s public schoolyards in a dire state: paved, overgrown and unused for anything besides parking. Grass-roots groups around the city were working to improve their local schoolyards but projects suffered significantly from lack of capital investment and generally took 5-8 years to complete (BSI, 2011). In 1994, the Boston Greenspace Alliance and the Urban Land Use Task Force worked
with Mayor Thomas Menino to convene a Schoolyard Task Force to help consolidate disparate efforts and streamline funding. The task force recommended a public/private partnership between the city of Boston and a new non-profit entity, the Boston Schoolyard Initiative.

Since its inception in 1995, the Boston Schoolyards Initiative (BSI) has led the renovation of 78 public schoolyards in the city of Boston (BSI, 2011). The vast majority of these schools are elementary schools, but a few renovations have occurred at the city’s middle and high schools. The schoolyard projects are scattered throughout every one of Boston’s 16 neighborhoods.

School communities apply to be part of the BSI program, and depending on funding and other variables, the BSI selects between 3 and 6 projects per year. The whole process generally takes about a year and a half to complete – starting with initial brainstorming and the selection of a consulting landscape architecture firm, moving through project development and the generation of construction documents and finally wrapping up with construction itself. Although the schoolyard renovations are led by and funded through the BSI, the goal is that each project stays local and participatory (BSI, 2011). The BSI strives to create significant public participation from the school community as well as local neighborhood groups in both the design and the stewardship of schoolyard projects (BSI, 2011; Lopez, Campbell and Jennings, 2008).

In terms of programming the renovations, the BSI essentially has two foci. First and foremost, a main goal of the BSI has always been to provide space for active play and recreation. As such, all renovations have included traditional play structures and equipment as well as painted graphics (basketball, track distances, four square and other games) on asphalt areas. The second main goal has been to provide educational space on the schoolyards, and achieving this goal has taken several different forms over the course of the BSI’s history. At first the BSI sought to create simple outdoor amphitheatre spaces where teachers could bring students for classes outside, yet in practice these spaces were rarely used. Over the past 5 years the BSI has
significantly increased its efforts to bring nature and environmental education to schoolyards through the addition of what they call “Outdoor Classrooms”. These Outdoor Classrooms (OC), are small portions of the overall schoolyard that are heavily planted with diverse species of plants to represent sample woodlands and meadows. In addition, they generally include weather monitoring stations, areas for experiments with water or other materials, planting beds and garden tools. In an effort to get teachers using the spaces, the BSI has drafted numerous lesson plans that align with science, math and writing curriculum, and many schools report that their outdoor classrooms are frequently used during the school day. Since 2007, all renovations have included OC features, and the BSI has started going back to previous projects to add outdoor classrooms.

**School Selection Rationale:**

This thesis examines 12 out of the 78 total BSI-renovated schoolyards. For the purposes of comparison, all of the chosen schools are either elementary or K-8 schools; purely middle and high schools were excluded because the play and learning needs of these older student populations are different than younger students. The 12 schools were chosen to represent some balance of containing an OC (8 schools) and not containing one (4 schools). More schools with an OC were chosen because this is the direction the BSI is moving towards. The majority (10 out of 12) of the schools are selected from the most recent completed schoolyard projects. These schools were all renovated between 2006 and 2009. Schoolyards renovated in summer 2010 and those “in the pipeline” for 2011 could not be included due to the lack of availability of aerial photography data. In addition, two schools from the early phases of the program (pre-2000) were selected in order to provide some points of comparison between newer and older design
values. One of these schools (the Trotter) has added an OC since the original renovation, and this addition is included in the analysis. Finally, the schools were selected to represent a general diversity of Boston neighborhoods. Table 1 summarizes the general selection features of each school.

Table 1: General Selection Features of Schools

<table>
<thead>
<tr>
<th>School</th>
<th>Grades</th>
<th>SY Renovation Date</th>
<th>OC Date</th>
<th>Neighborhood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adams</td>
<td>Elementary</td>
<td>2008</td>
<td>2008</td>
<td>East Boston</td>
</tr>
<tr>
<td>Bradley</td>
<td>Elementary</td>
<td>2009</td>
<td>2009</td>
<td>East Boston</td>
</tr>
<tr>
<td>Channing</td>
<td>Elementary</td>
<td>2006</td>
<td>NA</td>
<td>Hyde Park</td>
</tr>
<tr>
<td>Chittick</td>
<td>Elementary</td>
<td>2008</td>
<td>2008</td>
<td>Mattapan</td>
</tr>
<tr>
<td>Curley</td>
<td>K-8</td>
<td>2009</td>
<td>2009</td>
<td>Jamaica Plain</td>
</tr>
<tr>
<td>Everett</td>
<td>Elementary</td>
<td>2003</td>
<td>2008</td>
<td>Dorchester</td>
</tr>
<tr>
<td>Guild</td>
<td>Elementary</td>
<td>2006</td>
<td>NA</td>
<td>East Boston</td>
</tr>
<tr>
<td>Haley</td>
<td>Elementary</td>
<td>1999</td>
<td>NA</td>
<td>Roslindale</td>
</tr>
<tr>
<td>Lyndon</td>
<td>K-8</td>
<td>2009</td>
<td>2009</td>
<td>West Roxbury</td>
</tr>
<tr>
<td>Perkins</td>
<td>Elementary</td>
<td>2008</td>
<td>2008</td>
<td>South Boston</td>
</tr>
<tr>
<td>Philbrick</td>
<td>Elementary</td>
<td>2006</td>
<td>NA</td>
<td>Roslindale</td>
</tr>
<tr>
<td>Trotter</td>
<td>Elementary</td>
<td>1998</td>
<td>2005</td>
<td>Dorchester</td>
</tr>
</tbody>
</table>

**Pervious Surface and Canopy Cover:**

Before and after comparisons of pervious surfacing and canopy cover were generated using a geographic information system (GIS). The twelve school parcels and the school building footprints were selected from the 2010 Boston Parcel and Building Footprints shapefiles, available from the city of Boston (www.cityofboston.gov/maps). Aerial photography from MassGIS (www.mass.gov/mgis) was obtained for the years 1995, 2005 and 2009. Pervious surfacing and canopy cover for before and after each renovation were digitized by hand using the aerial photography as reference. On occasion Google Earth® historic aerial imagery was used to clarify
points of confusion. Total parcel area, building footprints and areas of canopy cover and pervious surface before and after renovations were calculated in GIS in square feet. These data were exported into Microsoft Excel to calculate percent pervious surfacing and canopy cover for each schoolyard and percent increase of both as a result of renovations. All percentages were calculated based on land area (parcel area minus the building footprint area) because it was assumed that landscape architects designing renovations could not alter the building footprint. Percentages rather than raw area numbers are reported to normalize the data for widely variant school campus sizes (see Table 2).

Finally, projected future canopy covers were approximated in GIS by buffering the renovated canopy layers. Based on Watson et al’s (1986) research that newly transplanted urban trees have an average twig growth of 100cm over 5 years, newly planted trees were projected to increase canopy radius by 2 meters over 10 years, and 6 meters over 30 years. Mature trees were projected to increase canopy radius by 1 meter over 10 years and 3 meters over 30 years. This data was also exported into Microsoft Excel to calculate projected canopy cover of the schoolyards 10 and 30 years after renovation.
Table 2: Campus Size

<table>
<thead>
<tr>
<th>School</th>
<th>Parcel Area (sq. ft.)</th>
<th>Building Area (sq. ft.)</th>
<th>Land Area (sq. ft.)</th>
<th>Campus Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adams</td>
<td>39,430</td>
<td>13,334</td>
<td>26,096</td>
<td>Small</td>
</tr>
<tr>
<td>Bradley</td>
<td>69,177</td>
<td>10,176</td>
<td>59,001</td>
<td>Med</td>
</tr>
<tr>
<td>Channing</td>
<td>48,317</td>
<td>10,449</td>
<td>37,868</td>
<td>Small</td>
</tr>
<tr>
<td>Chittick</td>
<td>67,819</td>
<td>15,814</td>
<td>52,005</td>
<td>Med</td>
</tr>
<tr>
<td>Curley</td>
<td>174,914</td>
<td>62,909</td>
<td>112,005</td>
<td>Large</td>
</tr>
<tr>
<td>Everett</td>
<td>66,904</td>
<td>8,949</td>
<td>57,955</td>
<td>Med</td>
</tr>
<tr>
<td>Guild</td>
<td>58,572</td>
<td>21,675</td>
<td>36,897</td>
<td>Small</td>
</tr>
<tr>
<td>Haley</td>
<td>114,509</td>
<td>40,015</td>
<td>74,494</td>
<td>Large</td>
</tr>
<tr>
<td>Lyndon</td>
<td>78,992</td>
<td>34,969</td>
<td>44,023</td>
<td>Med</td>
</tr>
<tr>
<td>Perkins</td>
<td>37,223</td>
<td>9,547</td>
<td>27,676</td>
<td>Small</td>
</tr>
<tr>
<td>Philbrick</td>
<td>32,366</td>
<td>8,957</td>
<td>23,409</td>
<td>Small</td>
</tr>
<tr>
<td>Trotter</td>
<td>142,476</td>
<td>47,508</td>
<td>94,968</td>
<td>Large</td>
</tr>
</tbody>
</table>

**Spatial Proportions and Configurations:**

As-built plans of each renovated schoolyard (obtained from Boston Public Facilities Deptament) were spatially analyzed to determine how much of 5 different categories of space they contained, and what the configuration of those spaces was. The categories of spaces and their definitions are as follows:

1. **Richly Vegetated Space** – Contains a diversity of plant species (although not necessarily native) and shows a variety of plant heights (groundcover, understory/shrubs and canopy). Outdoor classrooms fall into this category, as do minimally maintained “urban wilds” and areas of urban forest. (See Figures 1 and 2) Overlap with Play and Learning Space was allowed.

2. **Lightly Vegetated Space** – Contains very minimal plant species diversity and form variety. Examples include turf grass areas with or without tree canopy as well as
foundation and formal plantings. (See Figure 3) Overlap with Play and Learning Space was allowed.

3. **Play and Learning Space** – Includes all areas of the schoolyard that would be open to students during recess or that could be used for recreational or academic activities. All areas of traditional play equipment and ground paintings fall into this category, as do any naturalized play settings and outdoor classrooms. (See Figures 4 and 5) Generally the limits of these spaces were taken to be fences and walls that prevented students from passing. Overlap with both kinds of vegetated space (rich and light) was allowed.

4. **Entry Space** – Includes any area of the site whose primary purpose is for walking to/from building entrances. The primary types of this space are formal entry stairways and entry courts. (See Figure 6 and 7)

5. **Parking and Service Space** – Consists of any area dedicated to teacher/staff parking, vehicle pick-up/drop-off of students, deliveries or maintenance. In general parking and service space is considered off-limits to students. (See Figure 8 and 9)

Analysis was first completed by hand using trace paper over printed copies of each plan, and then digitized at scale in AutoCAD to obtain exact area measurements of each type of space. Overlap of vegetated space (rich or light) with play and learning space was allowed, but no other kinds of spaces were allowed to overlap. Area data was exported from AutoCAD to Microsoft Excel in order to calculate percentages of each spatial category present on each schoolyard site. Schoolyards were grouped into categories based on their spatial configurations and recommended typologies were created based on these categories.
Figure 1: Typical Outdoor Classroom and Urban Wild

Figure 2: Typical turf grass, canopy tree and foundation plantings
Figure 3: Typical traditional play equipment naturalized play settings

Figure 4: Typical formal entry stairway and entry court
Figure 5: Typical parking area and dumpster and maintenance area
CHAPTER IV
RESULTS AND DISCUSSION

The results and their discussion are divided into three sections: (1) pervious surfaces, (2) canopy cover and (3) spatial proportions and configurations. In each, the raw data is presented, analyzed in the context of the city of Boston and the Boston Schoolyard Initiative and related to relevant literature. Finally, each section contains a set of recommendations stemming from the data and its relationship to literature and current trends.

Pervious Surfaces

Initial conditions on schoolyard sites ranged from entirely or almost entirely paved, like at the Guild, the Perkins and the Philbrick, to more than 50% pervious, as at the Chittick and the Everett (See Table 3 and Figure 10). Before renovation most of the paved areas on campuses were used for staff parking, service and for maintaining required fire access. Most of the pervious areas were foundation/decorative plantings, lawns associated with entry sequences and urban wilds. Interestingly, the largest campuses (the Trotter and the Curley) did not have the largest pervious areas, as proportionally less need for parking might dictate.

For the most part BSI schoolyard designers choose to maintain existing lines between paved and unpaved areas in the new plans. No schoolyard had more than an 11% change (gain or loss) in pervious surface cover (see Table 3). Asphalt parking lots and service areas became paved play areas, often with graphics painted on top of a new bituminous concrete layer. Some asphalt underneath new play structures was replaced with rubberized safety surfacing, which was still impervious. Existing grassy or lightly vegetated areas generally remained as such, and only one school (the Trotter, see below) replaced any asphalt with grass. Two schools, the
Channing and the Everett, added some paved pathways through existing areas of turf resulting in a small loss of pervious surface cover on site.

Table 3: Pervious Surfacing Before and After Renovations

<table>
<thead>
<tr>
<th>School</th>
<th>% Pervious Before</th>
<th>% Pervious After</th>
<th>% Gain or ( % Loss)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adams</td>
<td>33.5</td>
<td>36.1</td>
<td>+2.6</td>
</tr>
<tr>
<td>Bradley</td>
<td>46.0</td>
<td>46.0</td>
<td>0</td>
</tr>
<tr>
<td>Channing</td>
<td>45.5</td>
<td>44.4</td>
<td>-1.1</td>
</tr>
<tr>
<td>Chittick</td>
<td>52.9</td>
<td>52.9</td>
<td>0</td>
</tr>
<tr>
<td>Curley</td>
<td>33.1</td>
<td>37.2</td>
<td>+4.1</td>
</tr>
<tr>
<td>Everett</td>
<td>58.1</td>
<td>53.0</td>
<td>-5.1</td>
</tr>
<tr>
<td>Guild</td>
<td>0.0</td>
<td>2.8</td>
<td>+2.8</td>
</tr>
<tr>
<td>Haley</td>
<td>36.7</td>
<td>46.5</td>
<td>+9.8</td>
</tr>
<tr>
<td>Lyndon</td>
<td>24.0</td>
<td>32.5</td>
<td>+8.5</td>
</tr>
<tr>
<td>Perkins</td>
<td>0.0</td>
<td>9.0</td>
<td>+9.0</td>
</tr>
<tr>
<td>Philbrick</td>
<td>5.1</td>
<td>13.2</td>
<td>+8.1</td>
</tr>
<tr>
<td>Trotter</td>
<td>25.7</td>
<td>36.5</td>
<td>+10.8</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>30.1</td>
<td>34.2</td>
<td>+4.1</td>
</tr>
</tbody>
</table>

Figure 6: Percent Pervious Surfacing Before and After Renovations
When possible, as in the case of the Everett, the Chittick, the Trotter, the Adams and the Bradley, the new outdoor classroom was placed in an already pervious vegetated area. It can be assumed that designers chose to do this because less soil remediation and preparation would be needed in order to support the growth of diverse new plantings. In essence, this choice, when possible, is cheaper and easier than converting paved area to garden, but it does little for the overall porosity of the campus. In the case of the Curley, the Lyndon and the Perkins, no appropriate pre-vegetated area existed, and so the outdoor classroom was carved out of asphalt. Because of this forced choice, these three schools have some of the higher impervious to pervious surface conversion rates.

Although most of the schools in this study group show signs of minimal surface intervention, the Guild stand out as a prime example. Before renovation, the Guild was entirely, 100% paved in asphalt, and used mostly for parking. During renovation more than half the campus was reserved for parking, and the play area remained paved except for a small planted buffer to screen the parking (See Figure 11 and Spatial Category analysis and discussion). Rainwater falling pretty much anywhere on this site flows directly into the city stormwater system, and research would indicate that this mostly paved schoolyard is likely to be several degrees hotter than surrounding pervious and vegetated areas (REF).

In contrast to the Guild, and a notable exception to the minimal surface intervention trend is the Trotter. Of the 12 schools the Trotter had the highest (+10.8%) impervious to pervious surface conversion rate, and none of this change was originally due to the addition of an outdoor classroom (the OC was added later on top of a grassy area). Before renovation, the Trotter was 25.7% pervious, but had a truly huge paved area devoted to staff parking at the back of the school. Because the Trotter is the largest campus in the study group, the designers...
had some extra flexibility around fire codes, parking needs and the space desired for traditional play equipment. With this flexibility significant parts of the old parking lot were removed and replaced with lawn, canopy tree plantings and seating, all of which is accessible from the traditional paved play areas (See Figure 12).

Figure 7: Impervious Surface Diagrams for the Guild School

Figure 8: Impervious Surface Diagrams for the Trotter School
Overall, the BSI renovations of the 12 schools in this study group yielded an average increase of 4.1% pervious surface and school sites ended up between 3% and 55% pervious (see Table 3 and Figure 10). Deciding whether these levels are laudable, appropriate or inadequate requires understanding of how pervious/impervious surface balance affects the environment. Unfortunately, very little scholarly research on pervious surfacing and water quality focuses on the site level. At the watershed level, scientists have differing opinions. May et al (1997) contend that “…physical, chemical and biological characteristics of streams change with urbanization in a continuous rather than threshold fashion.” (p.491). In other words, the more impervious a watershed is, the worse the water quality. Others declare that severe stream degradation occurs at a threshold of 10-30% impervious, or 70-90% pervious (Arnold and Gibbons, 1996; Scheuler, 1994). Clearly none of the schoolyard sites are close to meeting or exceeding 70-90% pervious surface, especially considering that the impervious building footprints have been excluded from the analysis.

However, the schoolyard sites do not make up their own watersheds, they sit within the city of Boston, which is partially within the Charles River watershed and partially within the Neponset River watershed. The city of Boston is currently 57.4% impervious and 42.6% pervious (Extracted from Mass GIS pervious surface dataset, March 26th, 2011). Because the city is already well below the water quality threshold discussed above, at the very least it seems reasonable to expect that schoolyard sites should not worsen the impervious/pervious balance of the city of Boston. In other words, a reasonable goal for pervious surfacing on schoolyard sites should be to meet or exceed the citywide pervious surface rate of 42.6%.

If we apply this goal to the 12 schools in this study group (see Figure 13), we see that five out of the 12 schools (the Everett, the Chittick, the Haley, the Bradley and the Channing) exceed the goal after renovations. However, four out of five of these schools started off
exceeding the goal; only the Haley crossed the threshold as a result of renovations. At the same time, seven out of the twelve schools do not meet the goal at all, with three of these schools (the Philbrick, the Perkins and the Guild) remaining exceedingly far from it. It is abundantly clear that the Boston Schoolyard Initiative could be doing more to ameliorate the impervious/pervious balance in the city of Boston and its watersheds. Future renovations should strive to have all sites meet or exceed the goal of 42% pervious surfacing. Schools that start out above this threshold should strive to increase their pervious surfacing by more than 10% which we have seen is entirely attainable at the Trotter school.

The question of how the BSI and its landscape architects and contractors go about meeting this goal has a relatively simple answer. Essentially there are two options: (1) adding more vegetated space and (2) incorporating permeable paving systems. Although fire code dictates certain paving requirements near buildings, and some areas of play, such as basketball courts and tracks are best when paved, large areas of most schoolyards that do not fall into either of these categories remained covered in asphalt and concrete. The reasons for this may be partially budgetary: it is cheaper and easier to keep existing paving, and even to repave it, than to pull it up and remediate the soil beneath. School communities and the BSI staff also voice maintenance concerns as a reason to keep largely paved schoolyards: school custodians are not trained to care for vegetated areas and do not have the equipment to do so. Yet several schools, including the Haley, the Everett and the Trotter have large grassy play areas that have been enjoyed by school communities and successfully maintained for several years. Networking and equipment sharing among custodial staff may help more school communities accept that vegetated play areas are possible to maintain within urban environments.

For areas that must remain paved due to programmatic needs, fire codes, parking accommodation and maintenance, the BSI and its designers need to start considering the
integration of permeable paving systems. Because of increasing market demand over the past two decades, designers can now choose among a diversity of permeable paving products, from concrete block pavers and structural grass to porous asphalt and concrete. None of the 12 schoolyards in this study used any alternative paving except for gravel, stonedust or mulch on pathways within the outdoor classrooms. Although alternative paving materials are generally more expensive than asphalt or concrete, the cost may become worth it when weighed against the environmental and educational benefits. The conclusion of this thesis contains a detailed discussion of the costs associated with these recommendations.

Figure 9: Percent Pervious Surfacing in the Context of Goal
Table 4: Actual and Projected Percent Canopy Cover Before and After Renovations

<table>
<thead>
<tr>
<th>School</th>
<th>Canopy – No Renovations</th>
<th>Canopy – BSI Renovations</th>
<th>Canopy Gains/Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Canopy Before</td>
<td>% Canopy in 10 yrs</td>
<td>% Canopy in 30 yrs</td>
</tr>
<tr>
<td>Adams</td>
<td>26.8</td>
<td>32.6</td>
<td>45.0</td>
</tr>
<tr>
<td>Bradley</td>
<td>26.2</td>
<td>33.3</td>
<td>47.5</td>
</tr>
<tr>
<td>Channing</td>
<td>38.0</td>
<td>47.2</td>
<td>64.6</td>
</tr>
<tr>
<td>Chittick</td>
<td>15.1</td>
<td>19.8</td>
<td>30.9</td>
</tr>
<tr>
<td>Curley</td>
<td>27.5</td>
<td>34.9</td>
<td>49.8</td>
</tr>
<tr>
<td>Everett</td>
<td>37.0</td>
<td>45.6</td>
<td>62.7</td>
</tr>
<tr>
<td>Guild</td>
<td>0.9</td>
<td>1.6</td>
<td>3.7</td>
</tr>
<tr>
<td>Haley</td>
<td>25.0</td>
<td>36.1</td>
<td>59.5</td>
</tr>
<tr>
<td>Lyndon</td>
<td>15.2</td>
<td>20.5</td>
<td>30.1</td>
</tr>
<tr>
<td>Perkins</td>
<td>2.4</td>
<td>3.7</td>
<td>7.1</td>
</tr>
<tr>
<td>Philbrick</td>
<td>22.9</td>
<td>30.7</td>
<td>48.4</td>
</tr>
<tr>
<td>Trotter</td>
<td>12.6</td>
<td>15.2</td>
<td>20.5</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>20.8</td>
<td>26.8</td>
<td>39.1</td>
</tr>
</tbody>
</table>

**Canopy Cover**

As with pervious surfacing, initial canopy conditions on the 12 school sites are extremely varied, ranging from very little coverage (the Guild and the Perkins) to highs in the upper 30% coverage range (the Channing and the Everett) (see Table 4). This large variation raises the question of “inherited” canopy: some schools, like the Philbrick and the Channing, are blessed with one or several gorgeous mature tree specimens, while other schools, like the Adams, the Everett and the Bradley, have the advantage of significant areas of dense, unmaintained but lush urban forest. These features represent considerable assets on a school site, and schools that start without such features are at some disadvantage because newly transplanted trees, especially those in urban conditions, can take decades to establish themselves and mature (Nowak, McBride and Beatty, 1990). At the same time these inherited trees represent some maintenance challenge. This thesis did not attempt to evaluate the health of any mature trees.
on school sites, but did notice that some mature trees were not living in optimal conditions. The best example of this is a gorgeous 3’ diameter oak tree in the parking lot of the Philbrick where asphalt covers up to the tree trunk itself. This tree’s roots are unlikely to be getting enough air and water, which will ultimately result in a decline of the tree’s health and perhaps death (Gilbertson and Bradshaw, 1985). If existing trees are to remain assets for school sites into the future, the BSI may wish to require landscape architects to consider remediation of adverse conditions and the inclusion of existing trees into maintenance plans.

![Figure 10: Percent Canopy Cover on School Campuses](image)

*Individual school lines show BSI-renovation canopy levels. Schools with no difference between BSI-renovation projected canopies and non-intervention projected canopies are shown in RED. Schools with great gains in projected BSI canopy over the projected non-intervention canopy are shown in BLUE. Schools with small gains are shown in BLACK. The thick black trendline represents average canopy for BSI renovations. The dotted RED trendline represents average canopy in the case that the schools had not had BSI-intervention.*
Beyond inherited trees, most schools (8 out of 12) added some new trees during renovations. Immediately after installation, these schools had little to no change in canopy cover (see Table 4 and Figure 14) due to the small size of new transplants. One school, the Adams, even lost significant canopy (-7.8%) due to selective cutting of trees to make room for the outdoor classroom, and another (the Haley) lost some canopy (-0.3%) due to removal of small trees in concrete planters. Yet after 30 years of growth BSI renovations provide on average 5.1% more tree canopy than the pre-existing conditions would have. Excluding the four schools that didn’t add any shade tree plantings (the Chittick, the Everett, the Lyndon, and the Perkins) as well as the Adams which lost tree canopy, the average canopy gain after 30 years would be 9.3%. The schoolyard with by far the most canopy increase after 30 years is the Trotter (+24.9%). This renovation added a whopping 32 trees, most of which were specified at 4” caliper or greater. In addition, the spacing of the tree plantings (generally 15’ on center) allowed for the trees to grow into themselves and maximize the canopy created at maturity. Finally, most of the Trotter trees were planted in open lawn area rather than containers or tree pits, allowing for healthy root expansion as the trees mature.

Although important for the health of the Trotter trees, this final point highlights a limitation in the canopy projection modeling method used in this thesis. Because of the data available, this thesis modeled all new plantings the same way, not accounting for growth differences between species, planting conditions, pruning/maintenance or possible tree mortality. As noted in the case of the Trotter, open grown trees with non-constricted roots will establish themselves faster and grow more quickly than trees planted in small tree pits or in containers (Nowak, McBride and Beatty, 1990). This modeling limitation is highlighted by the fact that a school which only planted trees in small, raised concrete containers, the Guild, has the second highest rate of canopy increase after 30 years (+16.9%). Moreover, because tree
species planting data was not available for all schools, it is possible that some small flowering trees were mistakenly modeled to grow at the same rate as shade trees. Finally, maintenance plays a large role in the health of new tree plantings. This modeling method had no way to account for how well and how often trees were pruned, watered and fertilized, and all of these actions have the potential to impact tree growth rate and mortality.

Despite the limitations of the tree canopy projection model used, it is useful for painting a rough picture. It becomes clear that the schoolyard renovations that added tree plantings are contributing in a positive way to the canopy cover on their campuses. Ultimately these additions of canopy will support bird and other fauna habitat (Hostetler, 1998) as well as promote a more temperate play environment on hot days (Bowler et al, 2010; Akbari et al, 1997; Georgi and Zafiriadis, 2006; Golden et al., 2006; Taha et al., 2007; Souch and Souch, 1993; Sashua-Bar and Hoffman, 2000; Streiling and Matsarakis, 2003; Huang, Akbari and Taha, 1990). Yet although this bounty of research indicates that additional trees are beneficial for the urban environment, none of it attempts to set a threshold of ideal canopy cover. In fact, Maco and McPhearson (2002) note that although “generally more canopy cover is presumed better”, “defining the ideal canopy cover in any given community has proven a difficult task because of differences in resource structure, land-use patterns, climate, management practices and community attitudes.” (p. 270)

However, American Forests (2002) has identified canopy cover targets by land-use: 15% in downtown and industrial areas, 25% in urban residential and light commercial areas, and 50% in suburban residential areas. Most of the schoolyards renovated by the BSI are in urban residential and light commercial areas, and by this logic should aim for a canopy cover of 25%. Although this provides a general benchmark, the city of Boston has actually set a higher goal. In 2007, in response to the Urban Ecology Institute’s State of the Urban Forest, Boston’s Mayor
Menino established Grow Boston Greener and announced its intention to increase Boston’s canopy cover from 29% to 35% by the year 2030 with the planting of 100,000 trees. Although the program has lost funding, the goal remains, and should serve as a guiding force for all urban greening initiatives including the Boston Schoolyard Initiative.

Measuring the 12 schools in this study against the goal of 35% tree canopy (see Figure 15) shows that eight out of 12 schools are meeting or exceeding this goal after 30 years of growth. In fact, six out of the 12 schools will meet the goal after just 10 years of growth. In addition, both the average trendline for renovations and the trendline for non-intervention meet the goal of 35% canopy. The BSI deserves commendation for its tremendous work in helping Boston meeting its canopy goals. However, four schools in this study group will not meet the target at all, and two (the Guild and the Perkins) are falling significantly short. In addition, when we consider that Boston’s goal is to increase its canopy cover by 6% (29% to 35%), only three schools are meeting or exceeding this metric (See Table 4), indicating that significantly more work could be done. The solution is simple: plant more trees!

Most schools in the study group had open grassy areas that would easily support more tree plantings. In addition, all schools had significant holes in their tree canopy over paved areas. With the exception of the Guild, none of the schoolyards that added trees did so within paved areas – in other words, the vast majority of traditionally paved play areas remained un-shaded. During informal conversations with the BSI staff, an explanation appeared for this phenomenon. It seems that some of the initial schoolyard renovations (in the late 1990s) attempted to integrate trees into paved play areas by using tree grates and protective fences. These trees generally had very high mortality rates because they were isolated in such high-traffic zones, had minimal root space and were often forgotten by custodians during routine maintenance activities. As a result, for the past decade the BSI has steered designers away from
planting trees in traditional play areas. There are however, other ways to think about including trees and plantings within paved areas of the schoolyard. For example large planter boxes with integrated seatwalls could provide enough non-compactable soil area for tree root growth as well as a comfortable, shady spot within the playground to sit. In addition, islands of pervious surfacing within paved areas could support trees and other vegetation as well as providing a welcome play alternative. If BSI renovations are to increase tree canopy beyond a minimum, designers and BSI staff will have to start thinking creatively about incorporating shade trees within areas that must stay paved.

Finally, it is worth nothing that the current and projected canopy cover at many schools benefited significantly from “borrowed” trees. These are trees planted on adjacent properties whose canopy leans over the property line to shade some of the schoolyard. All of the twelve schools had at least a little borrowed canopy, and it played a significant role at the Lyndon, the Curley, the Haley and the Perkins. A future study should examine the canopy characteristics of the properties and neighborhoods surrounding schoolyards to determine the extent of impact of borrowed trees and to explore connectivity among patches of tree canopy as it relates to habitat.


**Spatial Proportions and Configurations**

Spatial priorities and configurations varied considerably among the twelve schoolyard sites. Table 5 summarizes what proportion of each site is made up of each spatial category. Overlap categories are broken out so that the total of each school row adds to 100%. Table 6 shows sums of the overlapping categories to clarify how much of each site is made up of vegetation and play space. The rows in this table do not add to 100%. Despite the immense variation among schoolyards, two factors immediately pop out. First, all schools except the Bradley had some need for onsite staff parking and building services. This need ranged from very little at the Chittick (3.3%) and the Channing (7.2%) to extremely high at the Guild (62.9%) and the Philbrick (41.9%). On average schools devoted a staggering 22.5% of their campus space
to parking and service. Second, as might be expected given the goals of the BSI, all schools had a considerable portion of space devoted to play and learning. Schools ranged from highs above 70% (the Perkins and the Everett) to a low of 26.8% at the Guild. The average proportion of play and learning space was 52.2%.

Table 5: Schoolyard Category Percentages

<table>
<thead>
<tr>
<th>School</th>
<th>% Just Rich Veg</th>
<th>% Rich Veg and Play/Learn Overlap*</th>
<th>% Just Play/Learn</th>
<th>% Some Veg and Play/Learn Overlap*</th>
<th>% Just Some Veg</th>
<th>% Entry</th>
<th>% Parking and Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adams</td>
<td>14.5</td>
<td>7.9</td>
<td>30.2</td>
<td>0.0</td>
<td>13.4</td>
<td>2.4</td>
<td>31.6</td>
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<tr>
<td>Bradley</td>
<td>18.7</td>
<td>7.7</td>
<td>33.3</td>
<td>0.3</td>
<td>20.9</td>
<td>19.1</td>
<td>0.0</td>
</tr>
<tr>
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<td>7.0</td>
<td>7.2</td>
</tr>
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<td>19.9</td>
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<td>3.8</td>
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<tr>
<td>Curley</td>
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<td>6.7</td>
<td>23.2</td>
<td>7.1</td>
<td>32.2</td>
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<tr>
<td>Everett</td>
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<td>29.2</td>
<td>6.6</td>
<td>7.1</td>
<td>16.0</td>
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<td>0.0</td>
<td>10.3</td>
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<td>7.9</td>
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<td>4.6</td>
<td>41.9</td>
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<td>Trotter</td>
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<td>9.8</td>
<td>18.7</td>
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<td>35.3</td>
<td>12.1</td>
<td>14.2</td>
<td>8.1</td>
<td>22.5</td>
</tr>
</tbody>
</table>

* Note, overlap categories are divided out so that each school (row) adds to 100%.
Table 6: Schoolyard Category Percentage Sums

<table>
<thead>
<tr>
<th>School</th>
<th>Total % Rich Vegetation*</th>
<th>Total % Light Vegetation*</th>
<th>Total % Vegetated*</th>
<th>Total % Play and Learning *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adams</td>
<td>22.4</td>
<td>13.4</td>
<td>35.8</td>
<td>38.1</td>
</tr>
<tr>
<td>Bradley</td>
<td>26.4</td>
<td>21.2</td>
<td>47.6</td>
<td>41.3</td>
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<tr>
<td>Channing</td>
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<td>50.6</td>
<td>50.6</td>
<td>63.2</td>
</tr>
<tr>
<td>Chittick</td>
<td>5.4</td>
<td>49.7</td>
<td>55.1</td>
<td>63.1</td>
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<tr>
<td>Curley</td>
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<td>Everett</td>
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<td>70.3</td>
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<tr>
<td>Haley</td>
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<td>56.3</td>
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<td>Perkins</td>
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<td>Philbrick</td>
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<td>11.2</td>
<td>50.1</td>
</tr>
<tr>
<td>Trotter</td>
<td>1.9</td>
<td>31.4</td>
<td>33.3</td>
<td>54.2</td>
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<tr>
<td><strong>AVERAGE:</strong></td>
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<td><strong>26.4</strong></td>
<td><strong>34.1</strong></td>
<td><strong>52.2</strong></td>
</tr>
</tbody>
</table>

* These percentages represent sums of the categories in Table 2. Because of the overlap categories, these percentages will not add to 100%.

In terms of quantities and configurations of spatial categories, this thesis is most interested in where areas of vegetation (either rich vegetation or light vegetation) overlap with areas of play and learning. Although students do benefit from the sight of any vegetation on their school campus (Matsuoka, 2008; Wells and Evans, 2003; Wells, 2000), the areas of overlap are places where students can actually interact with vegetation, which is known to be intellectually, emotionally, spiritually, socially and physically beneficial (Kellert, 2005). Figure 12 presents a matrix charting percent rich vegetation and play/learning overlap versus percent light vegetation and play/learning overlap. Schools that appear towards the top right have the most of both kinds of overlap, and schools that appear towards the bottom left have little of either kind of overlap. This matrix was used to divide the 12 schoolyards into 5 general category types.
Type 1, characterized by the Everett, has a high level of both kinds of overlap. Type 2, characterized by the Chittick, the Trotter and the Curley, has some of each kind of overlap. Type 3, characterized by the Perkins, the Lyndon, the Adams and the Bradley, has plenty of rich vegetation overlap but no light vegetation overlap, while Type 4, characterized by the Haley and the Channing, represents the opposite situation. Finally, Type 5, characterized by the Philbrick and the Guild, has little of either kind of overlap. These 5 schoolyard types are discussed in detail in the sections below, beginning with Type 5.

Figure 12: Matrix of Vegetation Type and Play/Learning Overlap

Schools are grouped into five categories based on their placement in this matrix.
Schoolyard Type 5: Little/No Overlap

The Philbrick and the Guild characterize school sites with little to no overlap between vegetated spaces and areas of play and learning. Looking at aerial photographs of their designs as well as their spatial diagrams and pie charts (see Figure 14), it is immediately apparent that there is little vegetation of any kind on either of these school sites. Very clearly the priorities on both of these campuses were (1) maintaining significant areas of staff parking and (2) creating areas of traditional play. Both of these sites were initially more than 90% paved, and stayed significantly paved for parking and play use after renovations. Neither school chose to or had the opportunity to add an outdoor classroom during renovations.

There is no doubt that these renovated schoolyards are a vast improvement on the paved parking areas that pre-dated the BSI-intervention. Both schoolyards have devoted more than 40% of their campus to play and learning space, and these are definitely vibrant, engaging and active places. However, the lack of opportunities for students at these two schools to interact with vegetation is notable, and could certainly be improved upon.

Figure 13: Key to Spatial Diagrams and Pie Chart Categories
Figure 14: Spatial diagrams for the Philbrick and the Guild, Type 5 Schoolyards
Schoolyard Type 4: Light Vegetation Overlap

Both the Haley and the Channing have significant areas where light vegetation and play and learning space overlap. Unlike the Type 5 schools, both the Haley and the Channing had areas of light vegetation that pre-dated the renovation, and these areas were subsumed to one degree or another by the new play areas. As the aerial photographs in Figure 15 illustrate, the lightly vegetated areas at the Haley consists primarily of a large open turf playing field, and the Channing has a large, open grassy and treed entry area at the front of the school. Although most of the Channing’s entry area would not be accessible to children during recess, a small amphitheatre was added in the corner of this space during renovations, and is occasionally for outdoor instruction.

Overall, the priorities of Type 4 sites are clearly (1) active recreation and (2) maintaining open space. Approximately 50% of each site remains lightly vegetated open space, although more of this is accessible to children on the Haley campus. Similar to the type 5 schoolyards, neither the Haley nor the Channing chose or had the opportunity to install an outdoor classroom at renovation. Although the Haley does have a small area of richly vegetated urban wild, it is not accessible to children. Again, these two schools are providing vibrant active play space, but are missing opportunities to interact with richly vegetated areas.
Figure 15: Spatial Diagrams for the Haley and the Channing, Type 4 Schoolyards
Schoolyard Type 3: Rich Vegetation Overlap

This group is made up of schools that have opportunities for students to interact with rich vegetation but little to no overlap with lightly vegetated areas. Looking carefully, there are really two sub-types among the four schools in this category. Type 3A, characterized by the Lyndon and the Perkins, each contain an outdoor classroom which is the only rich vegetation on site (see Figure 16). Although the outdoor classroom is a tremendous and valuable resource on both of these sites, it remains an island, an isolated patch of rich vegetation that is enclosed and solitary. Looking at the aerial photograph of the Lyndon (Figure 16), it becomes clear that the main play areas are tucked within the wings of the school, and the outdoor classroom is separated from the nearest of these by a large expanse of barren paving. In short, the asset of the outdoor classroom is not well integrated into the fabric of the schoolyard.

Type 3B schools, characterized by the Adams and the Bradley, are similar in that they have an outdoor classroom where students can interact with rich vegetation, but they also have significant areas of urban wilds that are inaccessible to children (see Figure 17). Both of these areas of urban wild pre-dated the renovations but were not integrated into the new design of playspace. The reason for this exclusion probably has to do with accessibility issues – both urban wilds are on steep slopes falling away from the school and are currently separated from areas of play by retaining walls and fences. Although students derive some educational and psychological benefit from seeing this rich vegetation from their classroom windows and play areas (Matsuoka, 2008; Wels and Evans, 2003; Wells, 2000), there is a lost opportunity for them to touch it and interact with it.
Figure 16: Spatial Diagrams for the Lyndon and the Perkins, Type 3A Schoolyards
Figure 17: Spatial Diagrams for the Adams and the Bradley, Type #B Schoolyards
**Schoolyard Type 2: Both Vegetation Overlap**

Schoolyards of type 2, like the Curley, the Chittick and the Trotter, have some balance between interaction opportunities with rich vegetation and interaction opportunities with light vegetation (see Figure 18). All three of these schools have outdoor classrooms, which accounts for all of the rich vegetation on site. Interestingly all three of these outdoor classrooms are at the exterior of the school parcels and accessible to the neighborhood. In other words, although they remain a somewhat isolated patch of the school campus, they are more integrated into the fabric of the community. This is particularly evident at the Curley, where the outdoor classroom is separated from the play areas by the school building and parking areas, but open to the side street. All three campuses have significant grassy areas of play which enable vegetative interaction when the outdoor classroom isn’t open or accessible. In general, type 2 campuses are starting to provide some options for students in terms of choosing what level of vegetative interaction they would like.
Figure 18: Spatial Diagrams for the Chittick, the Curley and the Trotter, Type 2 Schoolyards
Schoolyard Type 1: High Overlap of Both Vegetation Types

The Everett has the only schoolyard among the 12 schools in the study group that exemplifies this type, and several unique features account for its stand-alone status. First, although other schoolyards contain urban wilds, the Everett is the only schoolyard that allows children to access rather than just look at the wild area. The entire southwest portion of the site is comprised of wooded hillside that existed before the renovation. Although designers added some foreground shrubs and seating boulders at the forest edge, the wild area is not fenced or walled off, allowing children to enter it during times of free play. The outdoor classroom, which was added several years after the initial renovation, is contiguous to the urban wild, but did not impinge upon any of the wild area; instead, it added even more rich vegetation to the site (see Figure 19).

Second, the Everett stands out for its use of a vegetated gradient (see Figure 20). Students exiting the building at recess first encounter a traditionally paved play area with painted graphics and climbing structures. Moving outward (and southwest) from the school building they come to a terraced and planted retaining wall with steps that lead to a lightly vegetated lawn area. Walking across this lawn area they enter the richly vegetated zone of the urban wild. What this gradient creates is a gentle transition between the structured building and the wildest nature. It satisfies fire code and other building constraints because the area closest to the building remains paved, but creates a richly layered experience for children at play.

This thesis unabashedly puts schoolyard type 1, characterized by the Everett, forth as a recommended typology upon which to model future schoolyard renovations. The reasoning for this recommendation has its roots in literature, which in a variety of ways proves that kids like nature and nature is good for kids. First and foremost, children have a preference for nature (Simmons, 1994; Nabhan and Trimble, 1994) and form attachments to natural places (Hart,
In addition, spending time with nature has restorative benefits for children, including improved cognition (Kaplan, Ryan and Kaplan, 1998; Wells, 2000), reduced stress (Wells and Evans, 2003; Hartig et al, 1991; Tenneson and Cimprich, 1995) and improved focus (Hartig et al, 1991; Tenneson and Cimprich, 1995). Finally, exposure to natural settings has been shown to cultivate environmental ethic and build future environmental stewards (Tanner, 1980; Nahan and Trimble, 1994; Harvey, 1989). Among the 12 schoolyards in this study, the Everett stands out as the schoolyard type that has the most intense and varied opportunities for children to have these kinds of interactions with nature that are known to be good for them. Because the BSI serves urban children who may have a particularly high prevalence of nature deficit disorder (Louv, 2005), including quality opportunities to interact with vegetation on school grounds should be a priority of the BSI, and the Everett provides a successful model for doing so.

In some ways the Everett is lucky to have had such vegetated resources on site before renovation - many of the schools in this study group did not have that kind of advantage. However, it is also important to note that the designers and school community chose to capitalize on the existing features, and incorporate them into the new design. In other scenarios (like the Adams and the Bradley) the urban wild would have been fenced or walled off to prevent daily access or cleared entirely. Future research work should examine what specifically about the Everett school culture and community relationship with the landscape architects allowed for this flexibility.
Figure 19: Spatial Diagrams for the Everett, Type 1 Schoolyard
Figure 20: Section of the Everett Schoolyard
Alternative View of Spatial Proportions Analysis

Although opportunity to interact with vegetation was a clear priority in setting up the schoolyard typologies discussed above, it’s also important to note that some research has found value in visible (not necessarily accessible) vegetation. Among high school students views of natural settings (trees, shrubs, etc) from classroom windows improves academic performance and graduation rates (Matsuoka, 2008). Similarly views of and proximity to natural settings has been shown to improve cognitive functioning and reduce stress among elementary school children (Wells and Evans, 2003). The matrix in Figure 21 explores how schools have prioritized play space versus vegetative space on the campus. Schools with more visible vegetation on campus appear higher on the chart, and schools with more play opportunities appear towards the right. Although three schools (the Guild, the Philbrick and the Perkins) still have minimal vegetation on site, in general schools are much more tightly grouped than in Figure 12, and four schools have a campus that is more than 50% vegetated which represents a significant amount of visual impact. However, it is important to remember that visual connection to nature is only part of the picture, and that more research connects between benefits to actual interaction. Figure 22 adds percent overlap with vegetation (either rich or light) to Figure 21, to show that the Everett, and to a lesser extent the Haley, is the only school that is providing both significant visual and physical access to vegetation.
Figure 21: Total percent vegetation vs. Total percent play/learning

Figure 22: Total percent vegetation and total vegetation and play/learning overlap vs. Total percent play/learning
CHAPTER V

CONCLUSIONS

The Future of the Boston Schoolyard Initiative

The stated mission/vision of the Boston Schoolyard Initiative is to “transform Boston’s schoolyards from barren asphalt lots into dynamic centers for recreation, learning and community life” (BSI, 2011), and no one would argue that the BSI has truly excelled in this mission for the past 16 years. Thousands of children as well as school staff and community members at 78 schools have benefitted from schoolyard renewal. The happy clamor of children at play can be heard from schoolyards at recess during the school year as well as evenings and weekends year-round, and many teachers are bringing classes outside to learn from outdoor classroom features.

Yet while we celebrate how far the BSI has brought Boston’s schoolyards, it is important also to look ahead and consider how much further the BSI could go. Doing so requires casting a somewhat critical eye on what the BSI has accomplished, and asking: is this the best that society can do for urban schoolyards? Yet even to ask this question is complicated, because we need to understand what kind of “best” we as a society are striving for. The BSI essentially has four competing priorities/goals for schoolyard renovations. These are: (1) to promote physical activity, (2) to provide educational resources, (3) to improve the urban environment and (4) to accommodate administrative, safety and service needs. Balancing these four priorities is a delicate business, and most schoolyard renovations have favored the first and the fourth.

Promoting physical activity and providing recreational space has long been seen as the most dire need, and accommodating administrative, safety and service needs has often been more of a legal and governmental requirement than a choice. In contrast, this thesis has focused on the
second and the third goals, asking how BSI renovations have affected the environment and exploring how much children can interact with nature as an educational resource on school grounds.

Looking strictly at the third goal, to improve the urban environment, this thesis has found that the BSI has had some positive impact on Boston’s environment. On average BSI renovations provide 4.1% more pervious surfacing and 5.1% more canopy cover after a growth period of 30 years. In general research shows that these improvements will mitigate the effects of urban heat island (REF), improve water quality (REF), contribute to cleaner air (REF), and positively impact human health and well-being (REF). Yet measuring these average gains as well as specific schools against reasonable local environmental benchmarks showed that the BSI could absolutely be doing more in terms of contributing to citywide sustainability. This thesis has recommended that future renovations (1) replace more asphalt with pervious surfacing and (2) plant more trees (See Table 7).

**Table 7: Summary of key recommendations, their integration and cost implications**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Integration</th>
<th>Cost Implications</th>
</tr>
</thead>
</table>
| (1) Replace more asphalt with pervious surfacing | • Permeable paving on traditional play areas, parking areas and entry areas  
• Turf in some active play areas CAN ACCOMPLISH WITH NO REAL CHANGE TO PROGRAMMING | • May be 2-6 times as expensive to install (Stormwater Center, 2010)  
• Long term savings for storm drains, CSO and flood damage  
• Training custodians to maintain porous pavement  
• Annual seeding/mulching and/or vacuum cleaning costs |
| (2) Plant more trees | • Anywhere outside fire lanes  
• On turf, in planter, in areas of permeable paving, in urban wild areas CAN ACCOMPLISH WITH LITTLE CHANGE TO PROGRAMMING | • Trees are inexpensive ($50-$300)  
• Training custodians to care for trees  
• Cost to buy supports, fertilizers, grates, etc |
| (3) Create more opportunities for children to interact with a view a variety of nature | • Preserving and designing access to existing urban wilds and vegetated areas  
• Plant more vegetation throughout CAN ACCOMPLISH WITH LITTLE CHANGE TO PROGRAMMING | • Recycled and natural features are less expensive than traditional play equipment  
• Logs, wood and plantings may need periodic replacement |
| (1) | Recommended typology = Everett School |

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Integrating these recommendations should not be difficult for the BSI because both can be accomplished with little to no change in site programming. Permeable paving can easily be incorporated into traditional play, parking and entry areas, and turf can replace asphalt on some active play areas. Similarly trees can be planted anywhere outside of fire lanes- on turf, in planters, in areas of permeable paving and in urban wild areas. Every one of the 12 schoolyards in this study group had areas that could legally (according to fire codes and Public Facilities Department building requirements) as well as logistically be transformed from paved to pervious surfacing. This is particularly true on school sites that were initially entirely or mostly paved, like the Guild and the Perkins. In addition, numerous ideal locations for new tree plantings could be identified on every school site in this study group. Some schools, like the Lyndon and the Perkins, planted as few as 2 trees during renovations. Although in some ways increasing pervious surfacing and increasing tree plantings will go hand-in-hand, tree plantings can and should be included throughout paved areas as well. The BSI and its landscape architects need to revisit previous attempts at the inclusion of trees in paved play areas and their reasons for discontinuing the practice, because creative solutions do exist, and the benefits could be far reaching.

There is no doubt that integrating these recommendations has some associated costs. In general pervious surfacing might be 2-6 times as expensive to install as traditional asphalt (Stormwater Center, 2011), but the pervious surfacing will translate to eventual savings for the city in terms of storm drain and CSO problems, flood damage and other factors. Because the city is a partial funder of the BSI and should be interested in its own long term maintenance costs, this argument should resonate with them. Trees on the other hand are a low-hanging fruit in terms of cost-effective interventions. The cost of a transplant tree from a nursery generally
ranges from $150-300 depending on size and species, and could be as low as $0.10 if the city wishes to buy bare root trees and nursery them itself. Beyond cost, trees are one of the most frequently donated items – community members love to give and install memorial trees, and it is likely that many of the BSI’s tree needs could be met in this manner. Finally, both pervious surfacing and the installation of additional trees will have some associated maintenance costs. Custodians need to be particularly trained to care for pervious surfacing so that it doesn’t clog and malfunction, and trees will need seasonal watering, pruning, fertilizing and other care. Although it is possible that some of the funding for these recommendations will need to come from the existing programmatic budget, the BSI should also actively seek out specialized grants for installing sustainable features and perhaps create a separate pool of private donors to support environmentally beneficial practices.

Looking to the second main goal, to improve educational resources on school sites, this thesis examined specifically the educational resource of nature and where/how children have access to this resource. The results were pretty widely disparate, with some schools, like the Everett, providing significant access to vegetation and other, like the Guild, providing practically none. Eight out of twelve of the schools had an outdoor classroom, and there is no arguing that these features provide an incredible opportunity for children to interact with a rich variety of flora and fauna. Yet in every case the outdoor classroom was fenced, and generally off-limits during recess, which constrains children to a more formal, classroom-style interaction with nature, particularly because most of the schools with an outdoor classroom did not have other vegetated areas to explore during recess. The Everett was the only schoolyard in this study group that employed an integrated model between play space and variety of vegetated space. The gradient of student experience at the Everett can and should be studied as a standard for future schoolyard renovations (see recommendations in Table 7). Looking ahead to 2011, the
designs by Klopfer Martin Design Group (KMDG) at Young Achievers Academy (the old Lewenberg School) are pursuing a similar integrated approach. Future research should examine how school cultures at the Everett and Young Achievers support the integrated play environment in order to help other schools follow this trend.

Returning to the four main competing priorities of the BSI, this thesis acknowledges the incredible work that the BSI has accomplished, particularly regarding (1) promoting physical activity through quality play equipment and (4) accommodating the administrative, safety and service needs of schools. Yet this thesis also makes the case that more attention can and should be paid to (3) improving the urban environment and (2) providing educational resources, particularly opportunities for children to connect with nature. Balancing these four priorities more equally in the future will be an incredibly delicate act, and it will be different at every single school. The BSI needs to think deliberately about how to educate and train the landscape architects they hire to think holistically and creatively about the school site in relationship to these four priorities.

Accomplishing holistic and creative balance of priorities may require somewhat of a philosophical shift at the Boston Schoolyard Initiative. During informal conversations with the BSI, the Boston Public Facilities Department and some of the landscape architects that they have worked with numerous times, a significant number of challenges and constraints facing urban schoolyard design were continually raised. A list of the factors that came up most frequently appears in Table 8. There is no denying that these challenges have played a significant role in shaping the program of the BSI over its 16 years of operation. In fact, these challenges are often used to explain and justify why certain design choices have been made or are required and why others are not allowed. For example, early renovations included some trees in tree pits on paved traditional play areas. The BSI noticed that many of these trees died within a few years
and attributed the mortality to their placement in a high traffic area and the difficulty for custodians of maintaining isolated vegetation. As a result the BSI emphatically does not recommend planting trees or other vegetation in any largely paved, isolated or high traffic zone within the schoolyard.

Although this represents one way of adapting to challenging circumstances on urban schoolyards, it is a closed-door kind of problem-solving. If the BSI is going to move forward and embrace its role in urban greening, it must adopt a more open-door, open-ended form of problem-solving. Rather than relying entirely on “fail-safe” schemes (Ahern, 2011), we need to cultivate and celebrate a culture of experimentation in urban schoolyard design. This means adopting instead a “safe-to-fail” mentality in which we take a small risk by incorporating part of an unproven idea into built work and then monitor and adapt it as needed (Ahern, 2011). In the event an experiment fails entirely, scientists and designers have an opportunity to question why and how it was unsuccessful and use that information to innovate a new solution. Iteration by iteration, these small experiments have potential to lead us to large new discoveries of what is possible (Kaplan, 1996).

Embracing this “safe-to-fail” model, each new schoolyard design should incorporate at least one experiment in urban greening: a new design for integrating trees in paved areas, a rain garden adjacent to play areas, a patch of concrete block pavers in the parking lot. These experiments could become a valuable part of BSI programming and curricula at schools. With appropriate scaffolding, students, staff and community members would take ownership for monitoring the specific experiment on their campus and for reporting on it to the BSI and its designers. Designers could collaborate with students to innovate improvements which could then be tried at the next school. More than anything else, it is this culture of experimentation
that will enable the BSI to balance goals of sustainability and education with goals of play and requirements of administration.

Along these lines, this thesis strongly recommends that the BSI create a database to manage and organize attempted solutions to the common challenges they face in urban schoolyard design (see Tables 8 and 9). This could be a rich digital database or a simple, old-fashioned file system; regardless, each challenge would be matched to relevant small experiments, successful examples and resources. Landscape architects and school communities could search this database during their design process to open dialogue about the myriad creative ways to address the challenges at their particular school site. In this way, the process of problem-solving becomes solutions-oriented and remains open to new ideas and creativity. Although at first the database could be limited to the scope of the Boston Schoolyard Initiative’s work in Boston, ultimately this database is a tool that ought to move beyond Boston, incorporating the many successes and experiments concerning urban schoolyards in the wider world and providing resources to sister programs of the BSI.
### Table 8: Challenges and Constraints Facing BSI Schoolyard Designers

<table>
<thead>
<tr>
<th>Programmatic</th>
<th>Site and Context</th>
<th>Values, Perceptions and Philosophies</th>
<th>Administrative and Safety</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking needs</td>
<td>Neighborhood character and level of support for school</td>
<td>Perception that urban students don’t “like” nature</td>
<td>Funding limits</td>
<td>Protection from vandalism/crime/misuse</td>
</tr>
<tr>
<td>Vehicle pick-up/drop-off and bus turnaround needs</td>
<td>Surrounding land use (residential, commercial, industrial, park, etc)</td>
<td>Varying school philosophies</td>
<td>Little recess time, testing pressure</td>
<td>Care of vegetation (training custodians, making time)</td>
</tr>
<tr>
<td>Desire for formal entry space</td>
<td>Busy streets adjacent to parcel</td>
<td>Changing school leadership</td>
<td>Fire codes, maintaining fire lanes and emergency access</td>
<td>High turnover of custodial staff</td>
</tr>
<tr>
<td>School focus on themes/curricula like music, art, physical education, environmental education – finding room to express these on the physical campus</td>
<td>Existing topography, vegetation and site conditions</td>
<td>Lack of teacher enthusiasm for using outdoor features in curriculum</td>
<td>Maintaining teacher sightlines as they relate to student safety</td>
<td>Educating children to take care of features</td>
</tr>
<tr>
<td></td>
<td>Placement of school building on parcel</td>
<td>Lack of parent involvement</td>
<td>Physical safety and liability issues</td>
<td>Funding upkeep costs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Boston Public Facilities Department (PFD) requirements for building maintenance</td>
<td></td>
</tr>
</tbody>
</table>

*From conversations with the BSI, Public Facilities Department staff and school landscape architects*

### Table 9: Sample Solutions-Oriented Database Organization

<table>
<thead>
<tr>
<th>Challenge or Constraint</th>
<th>Log of Relevant Small Experiments Conducted</th>
<th>Successful Examples</th>
<th>Lessons and Ideas to Apply Forward</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>From above (Table 8), and constantly added to or sub-divided as more issues come up.</td>
<td>Can be cross-listed (i.e. apply to multiple challenges). Description as well as pictures and details of the experiment.</td>
<td>Schools listed and the features that addressed the challenge described with words, pictures and design drawings. Reports from students and principals concerning experiments included as relevant.</td>
<td>Lists of successful methods that can be replicated and ideas for future experiments that might push the solutions further.</td>
<td>Names and contact info for designers, principals, teachers and other people familiar with the successful examples. Websites, research papers, etc with relevant information.</td>
</tr>
</tbody>
</table>
Ecological Schoolyards Beyond Boston

Urban schoolyard reform projects are on-going in many cities throughout the nation and the world, including New York, Washington DC, San Francisco, Los Angeles, Denver and London. Although these projects are doing amazing and diverse work, for the most part they focus on creating recreational spaces. There is a need for collective realization that urban schoolyard reform can be about more than play. Public schoolyards are by nature publically owned, which means they are some of the low hanging fruit for urban greening programs. These are not properties that need to be acquired to add to the city green-space network, they simply need to be greened in order to become key hubs in the network. In addition, schools are educational spaces by definition and mission, and few things would re-enforce that mission more than letting it spill out into environmental education on the school grounds.

Creating this kind of philosophical shift in the urban schoolyard reform movement requires consolidating scattered efforts. Rather than each city having its own organization working in isolation, we need to build a network that will connect and support these organizations in their efforts to create ecological, urban schoolyards. This network would be a forum for member organizations to share best practices and problem-solve common challenges. It would also provide a clearinghouse for research related to urban schoolyards, connect researchers to schoolyard projects and connect schoolyard projects to funding opportunities outside their cities. Finally, this network would act as an advocate for urban ecological schoolyards in the social and political arena, working to educate the public and decision makers about the benefits of greening urban schoolyards.
As this network expands it would be valuable to create a uniform set of standards for evaluating how green or ecological each schoolyard renovation is. Just as this thesis attempted to set goals for pervious surface cover and canopy cover based on context in the city of Boston, schools nationwide need benchmarks to set goals and evaluate progress. At first these benchmarks might be specific to urban schoolyard reform, yet over time it would make sense to link them into already established national standard systems for evaluating and rewarding sustainability, such as the Sustainable Sites Initiative (SSI) and the Leadership in Energy and Environmental Design (LEED) program. Certification by these programs is becoming a much-sought honor, and participation in these programs by urban schoolyards could bring attention and new funding to the ecological schoolyard movement.

**Future Research**

This thesis has explored what contributions the urban schoolyard reform movement is making to the urban environment and how children have opportunities to interact with nature on renovated urban schoolyards. The possible (and much needed) extensions to this research are numerous. In particular, as this thesis recommends increasing vegetated features on site, there is a need to understand how urban students interact with vegetated features. Most of the studies concerning children and vegetation have been conducted in suburban and rural settings. Urban students are thought to suffer more severely from nature deficit disorder (Louv, 2005), and therefore may respond very differently to aspects of nature within their city environment.

We also need to understand how vegetated, natural and environmentally sustainable play features hold up to the heavy use and traffic they receive on urban schoolyards. Studying tree and shrub mortality and maintenance needs over several seasons on several different types
of renovated urban schoolyards would help designers and decision-makers understand what kinds of plants do best and what kinds of configurations work best. On a related note, the Boston Schoolyards Initiative has made it clear that one of their greatest challenges is educating, training and retaining custodial staff to care for ecological features on schoolyards. There is a need for research into the variety of models employed for public schoolyard maintenance and the ways in which custodial staff, school staff, students and neighborhood coalitions collaborate at successful schools. A detailed understanding of these factors and successful models would help future schools organize maintenance plans that function well and are sustainable.
APPENDIX A

SCHOOLYARD LAYOUT AND MATERIALS PLANS

Organized by school, in alphabetical order:
Adams
Bradley
Channing
Chittick
Curley
Everett
Guild
Haley
Lyndon
Perkins
Philbrick
Trotter

These plans are excerpts from the larger sets of constructions documents provided by the Boston Public Facilities Department for each school in the study group. Construction document sets also generally included existing conditions plans, demolition and site preparation plans, planting plans, grading plans, utilities plans as well as pages of construction details. Where possible, the Boston Public Facilities Department provided “as-built” construction document sets rather than just design construction document sets.
APPENDIX B

PHOTOGRAPHS OF THE EVERETT SCHOOL

Taken March 26th, 2011 by Kate Tooke
NOTE: These pictures were taken in early spring conditions and do not reflect full vegetation.

Vegetable beds with cold frames on the northwest side of the school

Traditional play structure close to the school
Traditional painted asphalt play area directly adjacent to school, looking towards planted retaining wall, steps, lawn and urban wild hillside beyond.

Looking from the lawn area back towards the traditional play structure. Logs for play are in the foreground.
Looking from the lawn area up the hillside at the trails through the urban wild.

Looking from the lawn area toward the outdoor classroom. The gate is not locked.
Looking from the top of the urban wild (southern corner of school parcel) down at the outdoor classroom, lawn area and school beyond

Urban wild path and logs set for play in the Outdoor Classroom


