Evaluating the Impacts of Small-Scale Greenspace: A Case Study of Harlem Place in Downtown Los Angeles

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The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. It is a four-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

Christina Tague

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Abstract

The ecological, economic, and social impacts of greenspace have been studied extensively. Currently, however, no comprehensive model exists that provides both a conceptual framework for how to approach greenspace projects on a small-scale, and demonstrates how to assess the impacts of small parcels of urban greenspace on relevant ecosystem services. We used Harlem Place, an alley in Downtown Los Angeles, as a case study to assess the ecological and social impacts of integrating small-scale greenspace into an urban setting where open space is severely limited. Using literature reviews, expert opinion, and modeling, we developed conceptual models for five urban environmental issues that communicate key design considerations and important constraints and tradeoffs to consider when attempting to maximize ecosystem services on local and regional scales. We designed six greenspace scenarios to illustrate the application of our conceptual models to evaluate impacts of interstitial greenspace on urban ecosystems. Permeable pavement and bioswales had the greatest impact on mitigating stormwater issues on a regional level. Benefits of greenspace affecting the immediate neighborhood were related to microclimate and livability. Our results serve to build a foundation for a long-term greening strategy and outreach tool for our client, the Downtown LA Neighborhood Council's Sustainability Committee.

Executive Summary

I. Project Background and Significance

Currently, more humans live in urban environments than any other land use type, and this trend is accelerating. Urban greenspace was historically planned to exist as large parks in distinct settings within a city to provide respite for city residents. With increasing human-dominated land use, there is a decline in available undeveloped land to provide natural amenities and environmental services. A new trend in urban planning is to consider integrating greenspace into the already existing fabric of our city layouts. Instead of serving only as a recreational destination, greenspace can be designed and planned to increase walkability and aesthetic appeal throughout a city. Many cities, including Los Angeles, are facing problems associated with lack of open space and lack of ecosystem services that are provided by greenspace. Specifically, Downtown L.A. has a high proportion of commuters, resulting in problems of increased commuter miles, vehicular air pollution, and little sense of community ownership. However, as shown by a 20% increase in the residential population since 2007, the area is experiencing a shift whereby the demand for mixed-use living within the Downtown core is increasing. With only 30% of Los Angeles residents living within walking distance of a nearby park (Sherer, 2003), there is a clear need for more open spaces and natural amenities in the Downtown.

In addition to providing aesthetic appeal, urban greenspaces have the potential to provide ecosystem services, which can mitigate urban environmental and human health problems. Generally, there is little debate that greenspace provides ecosystem services. However, it is challenging to pinpoint the specific impacts of a greenspace design for a particular location, climate, and group of stakeholders. Furthermore, while much research has been conducted to quantify the impacts of larger scale greenspace areas, there is a lack of information on the effects of redeveloping smaller, interstitial areas. Currently, no comprehensive model exists that provides both a conceptual framework for how to best approach small-scale greenspace projects, and an assessment of the impacts of small parcels of urban greenspace on relevant ecosystem services. Our work in these areas will assist our client, the Sustainability Committee for the Downtown Los Angeles Neighborhood Council, in creating a long-term greening strategy for Downtown L.A.

The Sustainability Committee works with local stakeholders to understand and articulate the needs of the community, but lacks information on the potential value of small-scale greenspace in order to convey its importance and mobilize support. Based on input from our client and Downtown L.A. residents, we chose to use Harlem Place, an alleyway in Downtown L.A., as a case study to demonstrate how to quantify the ecosystem services impacts of small-scale greenspace on a site-specific basis.

To improve knowledge of small-scale greenspace, our project completed the following goals:

- Developed conceptual models for five urban environmental issues to communicate key design considerations and important constraints and tradeoffs to consider when trying to maximize ecosystem services on local and regional scales.
- Created six greenspace design scenarios for Harlem Place in order to illustrate the application of conceptual models and to evaluate the impacts of interstitial greenspace on ecosystem services.

Our conceptual models play a critical role in providing local communities and municipalities with tools to rethink how greenspace can be utilized on the small-scale. This is done first by recognizing an issue that needs to be addressed, such as stormwater management. Second, the conceptual models highlight an ecosystem service, such as flood control, to mitigate the issue. Third, the models illustrate how implementing various design features, such as permeable pavers or vegetation, will allow for the desired ecosystem service. Finally, the models provide constraints associated with each issue and design feature, to reveal possible limitations, and maintenance needs to ensure a greenspace design operates as intended.

II. Harlem Place as a Case Study: Approach & Assessment

Design Scenarios

We created six different greenspace design scenarios for Harlem Place and measured the impacts on five ecosystem services: air quality, stormwater runoff and water quality, urban heat island mitigation, carbon dioxide mitigation, and livability.

Quantitative Models

Currently, no single model or software exists to measure the impacts of ecosystem services on a small-scale. Therefore, we used a combination of iTree Streets and L-THIA, coupled with our own calculations and a literature review to fill knowledge gaps. To quantify air particulate capture, building energy loads, and carbon sequestration, we used the iTree Streets model developed by the US Forest Service to measure the effects of urban street trees. iTree quantifies the deposition of air pollutants onto tree leaves for each tree species built into the model. To quantify stormwater runoff in Harlem Place, we used L-THIA, a long-term hydrologic impact assessment model, created by Purdue University, the U.S. EPA, and the Indian Creek Watershed Alliance. We calculated the effects of variations in permeable pavers, vegetation, and greenwalls on stormwater runoff in each of our six design scenarios. After running iTree and L-THIA, information gaps still existed when measuring impacts of interstitial greenspace. Therefore, we used literature review to fill these knowledge gaps and cross-reference our findings.

III. Results and Conceptual Models

Local vs. Regional Impacts

Ecosystem services can be both social and biophysical in nature, and impacts will differ between local and regional scales. At a regional scale, the impact of greening a single alley is negligible. However, the aggregate effects of interstitial greenspace can be significant. In Los Angeles, stormwater management and air quality are issues of regional concern. For example, urban runoff and water quality affect the Santa Monica Bay and the watersheds of L.A., but can be addressed via smaller, local projects if many redevelopments occur throughout the region. Small-scale greenspace can also have impacts on air quality. Again, however, it is the cumulative effects of many interstitial greenspace projects that will result in measurable improvements in air quality. Harlem Place is in compliance with three major air pollutants, SO_2, NO_2, and PM_{10}, but does not meet EPA standards for ozone, despite greening the alleyway. Therefore, addressing air quality in L.A. via small-scale greenspace may not be the most effective use of resources.

At a local scale, we used our client's survey to determine that Harlem Place residents are primarily concerned with livability (i.e., 20% of residents are concerned with appearance and trash/litter) in the immediate vicinity of their neighborhood. However, when asked to rate their level of concern from low to high for issues such as reduction in stormwater runoff and pollutions, air quality, and microclimate, more residents rated air quality(73%) and access to recreational park space (77%) as a high concern. Although residents rated ecological functions (e.g., air quality) as a high concern, the reality is that residents are more concerned with the aesthetics when considering the impacts of greenspace specific to Harlem Place. Additionally, livability is much more difficult to quantify than reductions in stormwater and air pollution. Affording people the opportunity to relax and walk within an aesthetically pleasing space can increase use, thereby increasing safety and community interaction, and perhaps build support for more projects to achieve biophysical results on a larger regional scale. Generally, we found that stormwater and air quality were the most easily quantifiable ecosystem services in Harlem Place, but residents expressed more concern about air quality than stormwater.

Community or regional concerns, in addition to community input and political support will dictate which ecosystem services are valued by stakeholders. Designs for small-scale greenspace can be optimized to improve specific ecosystem services; however, there are tradeoffs in meeting the priorities of both the local and regional stakeholders. Thus, greenspace design needs to be tailored to the constraints of the site and the needs of the stakeholders.

Role of Design Choices

When discussing interstitial greenspace, variations in design features result in different impacts on ecosystem services. A comparison of our scenarios in Harlem

Place revealed that permeable pavers and bioswales have a greater effect on reducing stormwater runoff and increasing pollutant removal than do trees and shrubs. This greater impact is due to the constrained amount of land available for vegetation planting in alleyways. Design scenarios that incorporated greater amounts and distribution of permeable pavements and bioswales can capture close to all stormwater runoff in Harlem Place. Air pollution and microclimate was improved most in designs that included various tree species, due to increased shading and evapotranspiration. The urban heat island effect was the most difficult to model and to quantify. Microclimate improvements by mitigating the urban heat island effect is primarily a local impact that pedestrians will notice walking through the alleyway as they experience cooler, more pleasant temperatures. From literature review, a pedestrian walking under the immediate shade canopy of a tree can experience a range of 4˚C to a 20˚C decrease in temperature during prime daylight hours. Greenwalls can add an additional 2˚C cooling effect to the proximate area.

Spatial and regulatory constraints largely determine what types of small-scale greenspace designs are feasible. Greenspace projects, such as Harlem Place, require significant creativity in design to maximize impacts. Regulations in L.A. required our project to maintain vehicle access to Harlem Place, which significantly reduced available space for vegetation. Our physical site surveys and in-depth investigation of regulatory constraints were critical to being creative and identifying underused areas, such as nodes, that could be transformed into functional greenspace.

IV. Discussion & Concluding Thoughts

We used Harlem Place as a case study to create a tangible prototype that demonstrates the potential impacts of greenspace integration in underutilized urban spaces. We identified how to think about small-scale greenspace, how to quantify impacts that are both measurable and intangible, and how to design a small-scale greenspace when regulatory and spatial constraints are imposed. The conceptual models produced through our work serve as a design framework to guide future greenspace projects that require a tailored approach. While many of the impacts we modeled were local, interstitial greenspace could have provide substantial regional improvements to ecosystem services if similar projects were replicated throughout an entire region. As urbanization continues to increase, small-scale greenspace will play a pivotal role in providing healthy, livable urban environments. Quantification of the ecological impacts will help build political and community support to create and maintain sustainable urban greenspace projects. We recommend that in designing small-scale greenspace projects, planning should consider both local and regional perspectives and include community, policy, and professional stakeholders. Our project reveals the approach necessary to rethink what urban greenspace can be and how to effectively integrate the natural environment into the built environment.

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INTRODUCTION AND PROJECT GOALS

Is There Value in Small-Scale Greenspace Development?

The broad ecological, economic, and social impacts of urban greenspace have been studied extensively. However, information regarding the impacts of small-scale, or interstitial, greenspace in urban environments is limited. No comprehensive model currently exists that provides both a conceptual framework for how to best approach small-scale greenspace redevelopment projects and demonstrates how to assess the relevant ecosystem service impacts of small parcels of urban greenspace. Our project fills this gap in information by assessing the value of small parcels of greenspace on both a local and regional scale.

Using Harlem Place, an alley in Downtown Los Angeles, as a case study, we demonstrate how to create a tailored approach to quantify biophysical and social impacts of small-scale greenspace. This conceptual framework serves to encourage local communities and municipalities to rethink how greenspace can be integrated into urban environments. Smaller localized impacts have the potential to create significant effects in the immediate vicinity of a neighborhood in addition to cumulative effects when implemented on a broader regional scale.

Project Goals

To improve knowledge of small-scale greenspace, our project seeks to:

- Develop conceptual models for five urban environmental issues to communicate key design considerations and important constraints and tradeoffs to consider when trying to maximize ecosystem services on local and regional scales.
- Create six greenspace design scenarios for Harlem Place in order to illustrate the application of conceptual models and to evaluate the impacts of interstitial greenspace on ecosystem services.

1 Greenspace and Ecosystem Services

1.1 Historical Role and Definition of Urban Greenspace

Urban centers have been planned without significant focus on integrating the natural world into the built environment. Urban environments typically suffer from water pollution, air pollution, and increased temperatures. Greenspace in urban areas can provide basic environmental and social services that greatly impact the quality of life of city residents. These services, defined as "ecosystem services" provide management of stormwater runoff, air quality, carbon sequestration, and temperature regulation, in addition to human health, well-being, and aesthetically pleasing surroundings. Traditionally, greenspace is defined as large, distinct open spaces. This type of destination park land provides places for people to visit, but does not incorporate ecological functioning into the immediate environment that people use on a daily basis. A classic example of traditional greenspace is Central Park in New York City, where numerous residents and visitors go to for nature in the city.

Greenspace provides places for social interaction, physical activity, and freedom of expression. Research supports the evidence that greenspace not only provides ecological function in cities, but also adds to the economic and livability aspects of cities (Bolund & Hunhammar, 1999; Li et al., 2005; Matsuoka et al., 2008; Ridder et al., 2004). Improving the environmental health and appeal of cities may reduce suburban sprawl, promote greenspace development, reduce per capita natural resource use in terms of transportation and building energy demands, and increase community interaction.

Locations designated as greenspace tend to have large amounts of open space, ample vegetation, and frequently have some type of recreation opportunity, such as a playground or basketball court. Today, most cities are fully developed, with limited space available to add new large parks or greenways. The use of interstitial, or small-scale, greenspace has often been overlooked as a viable option for providing greenspace and its respective ecosystem services. As a result, a new challenge for urban planning is reincorporating smaller patches of greenspace into existing built infrastructure.

1.2 General Ecosystem Services Provided by Greenspace

Ecosystem services are the benefits people derive from nature and are classified into four general categories: provisioning (food, freshwater), regulating (climate regulation, erosion, control), supporting (seed dispersal, primary production), and cultural (cultural inspiration, recreational experience) services (Millennium Ecosystem Assessment, 2005). Ecosystem functions include biotic, bio-chemical and abiotic processes, all of which occur within and between ecosystems (Turner et al., 2005; Brussard et al., 1998). Multiple ecosystem services can be provided from each of these functions; de Groot et al. (2002) identifies a non-exhaustive list, identifying approximately 32 ecosystem services, including biological, physical, aesthetic, recreational and cultural. Cultural, psychological and other non-material benefits that humans derive from contact with ecosystems contribute to human health and well-being in urban settings (Butler & Oluoch-Kosura, 2006).

People rely on ecosystem services, both directly and indirectly, to enhance their quality of life and provide the basic necessities of life—food, fiber, climate regulation, and protection from contaminants However, humans have changed ecosystems more rapidly and to a greater extent in the last 50 years than in any other period in history (Rodriguez et al., 2006). This ecological degradation has resulted from meeting the demands of human population growth for food, fresh water, timber, fiber, and fuel. In the past, urban areas depended on surrounding rural land to provide many of these ecosystem services. The growth of urban centers and subsequent changes in the surrounding open space, however, makes it increasingly important for cities to provide natural environments within their boundaries to supply residents with basic ecosystem services. These services have a significant impact on the quality of urban living, and should be considered in land-use planning and major development plans (Bolund & Hunhammar, 1999). "Green Cities" that successfully integrate ecological functioning into the urban fabric provide clean air and water, pleasant streets and parks, and minimize their ecological footprint. They are also resilient to occurrences of natural disasters and encourage green behavior such as the use of public transit (Kahn, 2006).

1.3 Current Knowledge Base of Urban Greenspace

Urban greenspace provides various social, economic, and ecological benefits, including social interaction and community development (Balram & Dragi´cevi, 2005). Ecosystem services provided by greenspace, such as flood control, air particulate capture, and climate regulation, have been studied extensively and their general range of impacts are relatively well understood. For example, there is a great deal of literature on street trees in cities. Urban forests absorb air pollution and particulates (as much as 7000 dust particles/liter of air), block incoming solar radiation (up to 95% in some areas), reduce building energy use by up to 50%, and transpire 100 gallons of water each day of the growing season (equivalent to the cooling effect of 5 air conditioners running for 20 hours) (Girling & Kellett, 2005).

Ecosystem services associated with livability and aesthetics have also been studied in depth, but because they are not easily quantifiable and are highly dependent on stakeholder interests, these services are usually discussed in economic or qualitative terms. The availability of natural open space has been shown to promote social interaction and increase sense of community (Kim & Kaplan, 2004). Stewart et al. (2004) found that the presence of public or semi-public outdoor gathering places promotes community identity. This study also found that by designing the space in a manner that connects people with each other and to places of interest in their local landscape, the desirable end-state of planning is more complete and opportunities for community building are increased.

Urban planners increasingly recognize how spending time in urban green spaces has the potential to reduce stress, alleviate headaches, and increase an overall sense of balance (Hansmann et al., 2007). Open space encourages exercise, which increases health and lowers the risk of disease, as well as alleviating anxiety and depression (Sherer, 2003). A review of 16 years of *Landscape and Urban Planning* (LUP) contributions analyzed studies addressing the issue of contact with nature in urban settings and various ways that contact with nature contributes to improved quality of life, "even if the encounter is only a brief opportunity"(Matsuoka & Kaplan, 2008 p.9). These studies illustrate the consistent message that urban residents greatly value nearby natural environments in their community (Matsuoka & Kaplan, 2008). A study by Schell (1999) suggests that urban planners, landscape architects, and citizen groups should recognize these desires as they attempt to mitigate the loss of natural landscape due to growing urbanization and sprawl.

Recently, governments, communities, and environmental organizations in many developed nations have begun to recognize the importance of incorporating greenspace into sustainability management plans. Ecologists also recognize the role that complex urban ecosystems play in mitigating urban environmental problems and improving quality of life in densely populated cities. Examples of greening projects include New York's PlaNYC2030, developed to increase the quality of life for New Yorkers and reduce GHG emissions by 30% (Schell, 1999). The plan ensures that all residents live within a 10-minute walk of a park, brownfields are remediated, and 90% of waterways are open for recreational use. It also plans for 1800 miles of bicycle lanes, one million tree plantings, and improved pedestrian movement (Schell, 1999). According to the PlaNYC2030 Progress Report, New York's sustainability plan is on track and over two-thirds of the plan's initiatives are complete or on time (2009).

Other examples reveal how green space can be tailored to meet specific local needs. After widespread damage from El Nino mudslides in Bahia de Craquez, Ecuador, the city declared itself an "Ecological City." With the help of the Planet Drum Foundation, the city raised awareness of urban environmental issues and replanted the barrio with native trees, using vegetation to reduce mudslide risk. The City of Bogota implemented a 45-km greenway, as well as a network of integrated bicycle paths, and citywide closures of selected roads during non-peak hours. In an arid, warm climate similar to that of Los Angeles, the city of Melbourne removed pavement and designed building facades to accommodate and engage pedestrians. As a result, the city experienced a 40% increase in pedestrian traffic and witnessed increased jobs and property values (Newman & Jennings, 2008).

1.4 Value of Interstitial Greenspace

The ecological, economic, and social services provided by greenspaces, such as large parks, trees, and Low Impact Development (LID) methods, have been studied extensively in the academic arena. Existing studies, discuss greenspace concepts and issues on a regional scale, yet few studies have looked at what the local impacts of ecosystem services provided by greenspace. For example, the influence of greenspace on biodiversity or stormwater runoff can occur at different spatial scales, both locally and regionally. The impacts of small-scale greenspace are not well understood, but could have a substantial effect if designed according to site specifics and if similar projects were replicated throughout a region. Understanding the local effects of small units of greenspace can lead to a more comprehensive approach to meeting regional planning goals for sustainability.

We find it necessary to question what contribution local environmental impacts have on the regional scale. In other words, how do you determine if there is value in small-scale, interstitial greenspace redevelopment projects in dense, urban areas? Who stands to benefit? With limited space for greenspace development in cities, the environmental and social impacts of small-scale greenspace merit a more in-depth analysis, especially if the cumulative effects of localized greenspaces may be significant to policymakers on a regional scale. Although direct ecological impacts may vary, the aesthetic and social value of nature interspersed in urban areas can reverberate throughout the entire local community. Future planners and community residents will need to reconsider what greenspace can look like in compact cities and begin to integrate more of the natural environment back into the built environment.

1.5 Need for Conceptual Framework

Generally, there is little debate that greenspace provides valuable ecosystem services. However, this issue becomes more challenging when a greenspace design is targeted in a micro scale and specified for a particular location and climate. The effectiveness of a bioswale or tree in one location may vary greatly from the impacts in another city. This can have enormous consequences when attempting to accurately evaluate the impacts of greenspace redevelopment. Literature reviews, theoretical models, and even field data are typically the basis for most greenspace project assessments. Unfortunately, it is difficult to translate this general knowledge about large-scale greenspace into information that is valuable for a particular project site, and even more so when that site only covers only a small parcel of land. Furthermore, even if well-known data exists for a particular component of greenspace, there still exists a great deal of uncertainty in the literature and existing models.

Therefore, determining the optimal design for smaller-scale projects requires a more tailored approach. A conceptual framework is needed to address the challenges involved with applying general knowledge of greenspace impacts to specific small-scale greenspace projects. Creating conceptual frameworks for ecosystem services is one of the main goals of our project. While our conceptual models have been made with Downtown Los Angeles as a template, the ideas behind the models are transferable to any urban setting. Additionally, this framework provides local governments, planners, and community organizations with a roadmap for increasing urban greenspace and enabling goal-driven greenspace designs to achieve maximum benefits.

2 Downtown Los Angeles Overview

2.1 Current Greenspace Issues in Downtown Los Angeles

With only 30% of Los Angeles residents living within a ¼ mile of a park there is clearly a need for more open spaces Downtown (Sherer, 2003). Other cities, such as Boston and New York, provide parks that enable 80-90% of its residents to be within ¼ mile of open space. Having already developed into a dense urban center, it would be difficult for L.A to find space for large parks. Furthermore, "given that Los Angeles also faces an extreme housing shortage, especially of affordable housing, designating land for park development often represents an unacceptable trade-off between scarce housing and park provision" (Pincetl, 2005, p. 368). For this reason, greenspace as a small-scale entity integrated into the building infrastructure of the Downtown could be a workable compromise between the need for housing and the desire for parks.

Downtown Los Angeles is an urban area with many environmental and livability issues. The Downtown is an area with ten times as many workers as residents, resulting in problems of increased commuter miles, little sense of community ownership, and lack of large public greenspace. Since 2007, however, a 20% increase in the Downtown residential population shows that this commuter trend may be reversing and more people are choosing to live in the city (Zarella, 2009). This influx of new residents exacerbates the existing environmental and social issues in the area. Downtown Los Angeles residents do not have much access to traditional greenspace. As seen in Figure 2.1, tree canopy cover in Downtown L.A. (area 52) is less than 10%, demonstrating an overall lack of vegetation. Therefore, utilization of greenspace on a small scale has the potential to provide the ecosystem services in Downtown Los Angeles typically obtained from large urban parks. Integrating multifunctional greenspaces into existing urban infrastructure increases the livability of densely populated urban areas by providing recreational space, ecosystem services, and aesthetic appeal.

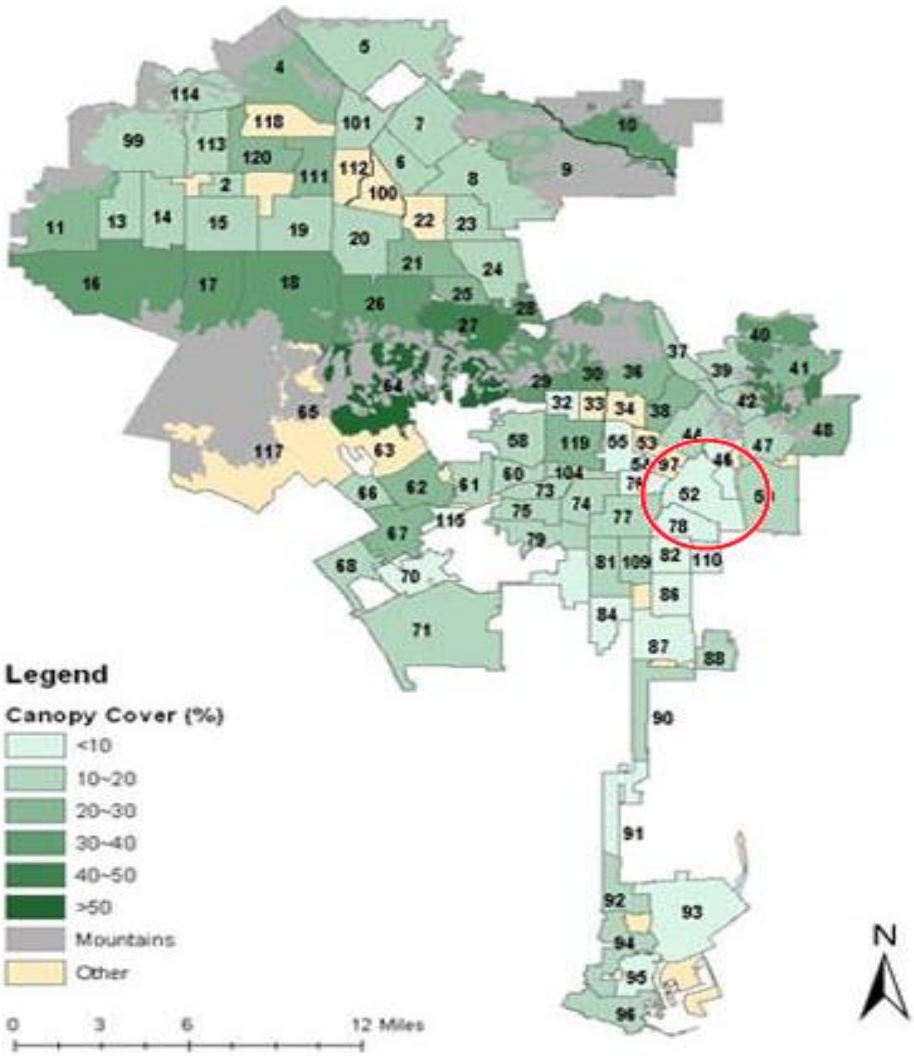

Figure 2.1 Tree cover canopy map of Los Angeles County. Area 52 signifies Downtown L.A. Note that the Downtown is in the lowest bracket of canopy cover percentage, or < 10%. Source: USDA Forest Service, 2006

2.2 Political Climate and Support for Green Infrastructure

The political climate of L.A. is increasingly receptive to open space initiatives, as demonstrated by the recent passage of several progressive city ordinances. L.A.'s long-term *General Plan* developed by the Department of City Planning, includes a chapter on open space and conservation, demonstrating a commitment to reconciling the inherent conflict between development pressure and open space conservation (Envicom Corporation, 1995) Early strides made towards open space conservation include the 1992 passage of Proposition A, which allocated $550 million for parks ($126 million of which designated specifically for L.A. city parks), and the passage of

Proposition K in 1996, a park bond worth $750 million for L.A. county and $25 million annually for the next 25 years ("Proposition 40," 2008).

More advances for open space conservation came in 2002 with the passage of Proposition 40 (the CA Clean Water, Clean Air, Safe Neighborhood Parks, and Coastal Protection Act), which provided $1.186 million to CA State Parks, with $956 million towards local parks. In May 2007, the L.A. Board of Public Works (BPW) adopted its Green Streets Initiative, "to promote, advance and evaluate the implementation and design of streets and parking lots to maximize capture and infiltration of urban runoff and to increase nature services and community beautification benefits" (Daniels, 2008, pg. 7). The Green Streets Initiative sought to proactively handle water quality issues in the city, but also acknowledge the various impacts of green streets, such as decreased urban heat island effect and aesthetic improvements for the city. The Green Streets Initiative Committee is currently identifying pilot projects, sourcing funding options, creating design criteria for green streets, and synthesizing knowledge from experts and academics (Daniels, 2008).

The City Council motioned for the creation of a feasibility report for implementing a Green Alley Program on January 15, 2008. The Green Alleys Program would be similar to an existing program in Chicago, which retrofits alleyways with green design features and permeable pavement to reduce stormwater runoff and create aesthetically appealing neighborhoods. In October 2008, the BPW produced the requested feasibility study, which stated that more than 900 miles of alleyways exist, widely distributed across L.A., which could be utilized for the Green Alley Program. This supplements a March 2008 study which found that "nearly 40% of L.A. County's needs for cleaning polluted runoff could be met by implementing low impact development (LID) projects on existing public lands" (Daniels, 2008, p. 4). L.A. is beginning to recognize the value of ecosystem services, and is becoming increasingly committed to the idea of open space conservation, not just for environmental reasons but for social and aesthetic as well (Daniels, 2008).

Currently, a prominent tree planting initiative in L.A. is the Million Trees L.A. project (Daniels, 2008). This project performed a tree canopy analysis in L.A. to identify areas that are lacking in canopy cover. It also quantified future benefits associated with planting one million trees. A Canopy Cover Assessment Final Report was submitted as an overview of the project and includes an overview of the history of L.A.'s urban development and the Initiative, as well as the cost and benefits of urban forests.

Recent California programs and legislation such as SB375 provide additional context and political force behind the value of urban greenspace. SB375 discourages urban sprawl as part of a larger effort to decrease California's GHG emissions by requiring that the Air Resources Board develop curbing targets for passenger vehicles, largely driven by urban sprawl (Geiselman, 2008). GHG emissions can be mitigated by transit-oriented development, transforming commercial corridors into mixed-use communities, expanded transit opportunities, and urban infill projects. Metropolitan planning organizations, together with their member cities and counties, will create sustainable community strategies that incorporate these greenspace trends.

2.3 Client Need

Our client, the Sustainability Committee for the Downtown Los Angeles Neighborhood Council (DLANC) was recently awarded an American Institute of Architects Sustainable Design Assessment Team grant to create a long-term greening strategy for Downtown L.A. This strategy will address urban livability, equitable development, resource efficiency, and community empowerment. The DLANC works closely with local residents and businesses to understand and articulate the needs of the community, but lacks information on the amount and types of environmental impacts of smaller patches of greenspace in both quantitative and qualitative terms. With this information, the DLANC could better convey the importance of small-scale greenspace and mobilize support. Our project provides this information and assesses the specific impacts of redeveloping the Harlem Place alleyway, one of the many potential greenspace projects that the Sustainability Committee has identified Downtown.

2.4 Overview of Case Study Site: Harlem Place Alley

Using literature reviews, expert opinion, and a combination of existing models, our project evaluates the impact of implementing greenspace on a micro scale. Our study site, known as Harlem Place, is a seven-block service alleyway that runs through historic Downtown Los Angeles. We used Harlem Place as a demonstration project to provide the Downtown community with a visualization of what greening in Harlem Place could look like, in addition to what services it could provide to the community. Figure 2.2 shows a map of Harlem Place in the L.A. Downtown Historic District. Harlem Place runs parallel between S. Spring St. and S. Main St., and is between W. 2nd and W. 7th St. Images of Harlem Place are available in Appendix A.

Figure 2.2 Map of Harlem Place in the Los Angeles Downtown Historic District

3 Methods Justification

3.1 Selecting Relevant Ecosystem Services

An important step in our project was to determine which ecosystem services would be relevant to quantify for small-scale greenspace projects like our case study, Harlem Place. In our initial research, we focused on literature reviews of ecosystem services provided by urban greenspace and focused on those that impact both the local environment and human community, but could possibly be provided with interstitial greenspace. We considered both the climate of L.A., in addition to what issues were of highest concern to stakeholders associated with an interstitial greenspace redevelopment. Using these considerations we addressed the following ecosystem service issues:

1. Stormwater runoff and water pollution
2. Air quality
3. Urban heat island mitigation
4. Mitigation of carbon dioxide emissions
5. Livability

Urban areas typically benefit from the ecosystems services provided by nature outside of city limits, but these urban areas can also greatly benefit when the services are provided internally (Bolund & Hunhammar, 1999). Ecosystem services include stormwater infiltration, groundwater recharge, flood control, lower temperatures in the urban microclimate, reduced building energy demand, and improved air quality. These services can be achieved by implementing design features such as vegetation and permeable pavements. Ecosystem services associated with livability are more difficult to quantify and categorize, but include benefits related to improving livability, such as increased pedestrian activity, improved public health, increased property values, stronger sense of community, and aesthetically pleasing surroundings. These ecosystem services can be provided via effective, creative greenspace designs, such as greenspace connectivity, wide traffic-calming sidewalks, and creation of common open space.

Urban tree plantings and other Low Impact Development (LID) techniques have been studied extensively and are relatively well understood. We focused specifically on existing greenspace studies relevant to Southern California. For example, an NRDC and UCSB analysis found that implementing LID practices, such as rainwater harvesting and capture, and water infiltration into the ground at new and redeveloped residential and commercial properties in urban southern California could increase local water supplies by up to 405,000 acre-feet (af) of water per year by 2030. This volume equals about two-thirds of the amount of water used annually by the entire City of Los Angeles (Garrison et al., 2009).

We also sought out expert opinion on which ecosystem services would be best to assess for our project. We conducted discussions and interviews with highly esteemed professionals, including Dr. Stephanie Pincetl, Director of UCLA's Center on People and the Environment; Dr. Jennifer Wolch, Dean of UC Berkeley's College of Environmental Design and former Director of the Center for Sustainable Cities at the University of Southern California who headed the Green Vision Plan for 21st Century Southern California; Dr. Dave Nowak, Project Leader and Research Forester for the US Forest Service; and Christina Tague and Dr. Robert Wilkinson, professors at the Bren School of Environmental Science and Management, University of California, Santa Barbara. Christina Tague specializes in hydrology and ecosystem processes and Robert Wilkinson specializes in water policy, climate change, and environmental policy issues. Each of these academic and professional experts provided valuable insight regarding the role of greenspace in urban environments, and which ecosystem services would be most relevant to L.A.'s climate and group of stakeholders. We used them as a foundation for determining relevant ecosystem services and the respective models to assess impacts in Harlem Place.

3.2 Methodology for Vegetation Selection

Vegetation is one key component of transforming Harlem Place into a viable greenspace. Our alleyway's primary vegetation design features include trees, shrubs, and greenwalls. Choosing appropriate trees for the alleyway was an important part of maximizing the ecosystem service potential of the greenspace, as well as satisfying City of Los Angeles requirements for urban tree plantings. We narrowed our selection of trees using the iTree model species selector, and various tree selection guides (McPherson 2008; Los Angeles Department of Water and Power, 2005) for California. Table 3.1 outlines questions we considered essential to determine the tradeoffs involved when selecting different tree species.

Questions used to determine tradeoffs in selecting vegetation
1. Will the roots of the species warp the pavement or sidewalk? 2. What amount of maintenance will the species require to thrive in L.A. (e.g., pruning, leaf loss and collection, etc)? 3. What amount of irrigation will the species require to thrive in L.A.? 4. Is the species too tall or have too narrow of a canopy to provide significant shading for pedestrians? 5. Will the species reach a height to provide sufficient shading to building roofs? 6. Is the species prone or sensitive to damage from daily alley usage by people or vehicles that will prevent the vegetation from thriving? 7. Is the species too small to be effectual or aesthetically pleasing? 8. Are the shrubs too tall that they pose a safety hazard for pedestrians walking by them? 9. Will enough space be available in the alleyway to plant the greenwall base into the ground?

Table 3.1 Questions we used to determine tradeoffs in selecting vegetation species to use in iTree to model air quality and stormwater runoff

Using the answers to the above questions, we selected low maintenance trees that have a tolerance for heat and drought, an affinity for sandy loam type A soils, and trees of an appropriate size for a narrow alleyway with substantial shading capacity and habitat potential for birds. From these trees, we chose five tree species that had the highest ecosystem service ratings from iTree's Air Quality parameter (Table 3.2).We also considered iTree's Stormwater parameter – however, as iTree only quantifies interception and not absorption from the soil, this parameter was weighed less than Air Quality.

3.2.1 Five Tree Species Selected

Western Redbud
Cercis occidentalis

California Native: Yes
Water Needs: Moist to Dry Soil. Drought tolerant.
Soil Type: Clay, Loam or Sand
Height: 25 feet
Growth Rate: 24 - 36 Inches per Season
Longevity: Less than 50 to 150 years
Flowers: Showy, Purple. Flowers in Spring.
Fruit: Fruiting in Summer or Fall.
Shading Capacity: Moderate
Litter Issue: Dry Fruit
Root Damage Potential: Low

London Planetree
Platanus acerifolia

California Native: No
Water Needs: Wet to Dry Soil
Soil Type: Clay, Loam or Sand
Height: 65 feet
Growth Rate: 36 Inches per Season
Longevity: Greater than 150 years
Flowers: Inconspicuous. Flowers in Spring.
Fruit: Fruiting in Summer
Shading Capacity: Dense
Litter Issue: Dry Fruit, Twigs and Bark
Root Damage Potential: Moderate

Western Hackberry
Celtis reticulata

California Native: Yes
Water Needs: Moist to Dry Soil. Drought tolerant.
Soil Type: Loam or Sand
Height: 35 feet
Growth Rate: 24 Inches per Season
Longevity: 50 to 150 years
Flowers: Inconspicuous. Flowers in Spring.
Fruit: Fruiting in Summer or Fall.
Shading Capacity: Moderate
Litter Issue: Dry Fruit
Root Damage Potential: Low

California Sycamore
Platanus racemosa

California Native: Yes
Water Needs: Moist to Dry Soil.
Soil Type: Clay, Loam or Sand
Height: Over 65 feet
Growth Rate: 36 Inches per Season
Longevity: Greater than 150 years
Flowers: Inconspicuous. Flowers in Spring.
Fruit: Fruiting in Summer or Fall.
Shading Capacity: Dense
Litter Issue: Dry Fruit, Leaves, Twigs
Root Damage Potential: Moderate

Lacebark (Chinese) Elm
Ulmus parvifolia

California Native: No
Water Needs: Damp Soil.
Soil Type: Clay, Loam or Sand
Height: 65 feet
Growth Rate: Over 36 Inches per Season
Longevity: 50 to 150 years
Flowers: Inconspicuous. Flowers in Spring.
Fruit: Fruiting in Fall.
Shading Capacity: Moderate
Litter Issue: Dry Fruit
Root Damage Potential: Moderate

Table 3.2 Five tree species selected to use in iTree and design scenarios

4 Assessing Small-Scale Greenspace

4.1 Models

Currently, no one model or software exists to measure the impacts of our ecosystem services on a small scale. Therefore, we used a combination of credible available models such as iTree Streets and L-THIA, coupled with our own calculations and a literature review to fill knowledge gaps.

4.1.1 L-THIA

Overview and Background of L-THIA

L-THIA, a long-term hydrologic impact assessment model, is a model used to measure the volume of runoff from different land use types, and was developed by Purdue University, the U.S. EPA, and the Indian Creek Watershed Alliance (Engel et al., 2004). L-THIA is based on computations of daily runoff obtained from climate records including 30 years of precipitation data, soil data, Curve Number values, and land uses. While L-THIA was initially used to assess the impact of land use change on groundwater recharge, as well as the impact of suburbanization on runoff, it has evolved to be applicable for town planning and coastal management as well as analysis of urban sprawl development and their respective impacts for different U.S. climate regions. L-THIA has also been used to determine the apportionment of costs under a fee system for drainage management maintenance costs.

L-THIA is an analysis tool suited to estimate changes in runoff, recharge and nonpoint source pollution due to past or potential land use changes. L-THIA is capable of providing runoff depths and runoff volumes for its built-in land use types. Land uses are categorized into: Commercial, Industrial, Residential, Open Spaces, Parking/Paved Spaces, Water/Wetlands, Grass/Pasture, Agricultural, Forest, and Custom Land Use. If a land use type is not available within the model, the user can custom design a land use type by entering the Curve Number that applies to the land-use.

L-THIA also uses built-in event mean concentration (EMC) values for common non-point source pollutant data (Engel et al., 2004). By multiplying runoff depth for each land use by the area of the site and the appropriate EMC value, one can calculate the net non-point source (NPS) loads (See Appendix B). For each NPS pollutant, the total load divided by runoff volume during a storm event yields the EMC (Baird and Jennings, 1996).

The outputs from L-THIA include long-term average annual runoff for a land use configuration focused on average impact. Thus, a limitation of L-THIA is its inability to measure an extreme year or intense storm event. This is a significant consideration for our project as typical rain events in Los Angeles are sporadic, within a short rainy season (Ackerman & Weisberg, 2003). In addition, L-THIA models use flow averages to determine EMC, which does not correspond to the first flush of pollutants in a storm event; this first flush will have a higher proportion of pollutants than the average. Additional research is needed to improve EMC estimates based on EMC concentrations varying over the duration of a storm event (Engel et al., 2004). Supplementary information regarding how our project tailors L-THIA inputs to Harlem Place, as well as the hydrology and mathematics behind the L-THIA model, can be found in Appendix B: iTree and L-THIA Model Guidance Documents.

4.1.2 iTree Streets

Overview and Background of iTree

iTree Streets is a model used to measure the impacts of urban street trees on ecosystem services that commonly occur in cities. It was developed by a team of researchers at the Center for Urban Forest Research in Davis, CA, run by the US Forest Service's Pacific Southwest (PSW) Research Station. The iTree Streets (iTree) application was conceived and developed by Greg McPherson, Scott Maco, and Jim Simpson. James Ho programmed STRATUM, the Street Tree Resource Analysis Tool for Urban Forests model, an earlier version of the iTree model. The numerical models used by iTree to calculate tree benefit data are based on years of research by Drs. McPherson, Simpson, and Qingfu Xiao of UC Davis (McPherson et al. 2008). References of city data on tree growth and geographic variables were developed under the direction of Paula Peper, Kelaine Vargas, and Shelley Gardner. Revisions for iTree Streets versions were carried out by members of The Davey Institute, including Scott Maco, David Ellingsworth, Michael Kerr, Lianghu Tian and Al Zelaya based on newly available research from PSW and feedback from actual iTree users. The manual was edited and designed by Kelaine Vargas. iTree Streets is available for download online at http://www.itreetools.org/street_trees/introduction_step1.shtm.

iTree's predecessor, STRATUM, uses tree growth and benefit models for predominant urban tree species in 17 national climate zones. Users import data collected in a sample or complete inventory and input community specific information (e.g., program management costs, city population, and price of residential electricity) to customize the benefit-cost data. STRATUM uses this information to calculate:

1. the resource's structure (species composition, extent and diversity)
2. function (the environmental & aesthetic benefits trees afford the community)
3. value (the annual monetary value of the benefits provided and costs accrued)
4. resource management needs (evaluations of diversity, canopy cover, and pruning needs).

The iTree Streets model quantifies air pollution particulate capture as a function of leaf dry-deposition. Trees can uptake gaseous air pollution such as nitrogen dioxide (NO_2), ozone (O_3), and sulfur dioxide (SO_2) through the leaf stomata, where the gases then diffuse into cells or are absorbed by water to form acids (Nowak, 2006). Many airborne particles such as PM_{10} are removed from the ambient air via interception by tree leaf surfaces, where they are temporarily stored until the particles are washed off by rain or dropped to the ground when the leaf falls off the tree. Because of this, while deposition removes particles from the air, it is considered an impermanent capture solution for air pollution. Urban trees have the greatest impact on NO_2, O_3, and SO_2 during the daytime of the in-leaf season when trees are transpiring water. Particulate matter removal occurs both day and night at any time of the year when particles are intercepted by leaf and bark surfaces.

iTree ranks air pollution deposition of tree species based on various leaf and crown characteristics (Nowak, 2008). It is assumed that dense and finely textured crowns with complex, small, and rough leaves will capture and retain more air particles than trees with open crowns and large, smooth leaves. Ultimately, six characteristics were assessed: crown density, crown texture, leaf complexity, leaf size, leaf surface roughness, and leaf margins. Using these characteristics, the iTree team incorporated particle deposition rates and average deposition velocities to rank the tree species in the model, particularly for PM_{10} capture. NO_2, O_3, and SO_2 removal are more related to evapotranspiration. Thus, the transpiration rates of each species and the leaf area index, as well as average pollutant fluxes from various US cities were used to calculate pollutant removal rates for the tree species.

For the Harlem Place case study, our project used iTree to measure air pollution particulate capture, carbon sequestration, and reduction in building energy loads from the selected tree species. For a step-by-step guide on how we programmed iTree for our specific needs for Harlem Place, please see Appendix B: iTree and L-THIA Model Guidance Documents.

4.2 Design Feature Options

Vegetated Swale or Bioswale

A vegetated swale, or bioswale, is an LID feature employed to partially treat water runoff quality, slow and retain runoff flow, and direct runoff water. Swales are essentially ditches, or linear open-channels with a minimum 1-3 feet excavated depth and maximum 5% slope. Bioswales include bioretention media to increase water retention, infiltration and water pollution removal capacity. Benefits of bioswales include increased localized water infiltration, groundwater recharge, and avoided water conveyance infrastructure. Bioswales can also provide multifunctional spaces for biodiversity and aesthetic enhancement. This design option can be used in industrial, commercial, and residential areas; common site areas within these categories include highway medians, roadsides, and parking lots (Florida Field Guide, 2008). In areas where enhanced infiltration is desired, the bioswale can be provided with additional gravel, pervious substrate, or underdrain beneath the swale (Fairfax County Virginia, 2005). For sloped sites or areas receiving intense rainfall, swales can be fitted with check dams or blocks, to slow water flow and increase residence time in the swale. For maintenance, bioswales must be inspected and amended to ensure vegetative cover density and health, prevent erosion, and ensure hydrological functioning of the channel. Specifically, bioswales may require mowing and sediment, debris, or litter removal. It is generally assumed that bioswales have a twenty-five year lifespan before replacement is necessary (Fairfax County Virginia, 2005).

Rain Cisterns

Rain cisterns are large-scale storage tanks designed to capture runoff water from a designated catchment area; the area is often the rooftop of a large commercial or industrial site. Cisterns are most commonly employed to either reduce the stormwater runoff load from a site or to provide a source of non-potable water for landscaping irrigation or other non-potable use. Cistern sizes vary depending upon the local rainfall characteristics and water demand (Florida Field Guide, 2008). Surface pumps are generally needed in larger scale irrigation systems. Cisterns should be cleaned annually and inspected to ensure seals are upholding to prevent insect infestation.

Greenwalls

Greenwalls are wall systems composed of either "cascading groundcovers" or vertical climbing plants growing on and supported by either a freestanding structure, or structural installation on the building façade. The structural support can be a screen, trellis, or cable system. Generally, plants are rooted in the soil space below the structure or in planters affixed to the support structure. Greenwalls are commonly used to reduce the urban heat island effect, buffer buildings from sound, increase aesthetic appeal, and offer cooling via shade and evapotranspiration. These cooling effects can reduce building air conditioning and associated energy demands (Sharp, 2007). Greenwall maintenance follows typical plant care, including watering and pruning.

Permeable Paving

Permeable paving describes a category of paving techniques and materials for surface walkways, roads and parking lots that enables the passage or infiltration of air and water through the paving layer. Types of permeable paving include porous concrete or asphalt, grass pavers, paving bricks, and permeable interlocking concrete pavers (PICPs). Depending upon the intended use of the site, different pavers can offer more support for heavier loads and traffic flow. Permeable paving installations are predominantly used to reduce stormwater runoff flow, recharge groundwater, improve water quality, and improve proximate urban tree planting health by enabling water and air flow to soils (Brattebo & Booth, 2003). The capacity for the system to infiltrate water depends largely on the characteristics of the sub-grade soil, or the aggregate installed (Low Impact Development Center, Inc., 2007).

To function as intended, the surface of permeable paving must kept free of sources of clogging such as leaf litter and trash. Additionally, runoff laden with heavier loads of clay particles commonly leads to clogging of the porous spaces. To increase the pavers' lifespan and effectiveness, periodic vacuuming and low-pressure washing is needed to clear out voids where materials accumulate. Street sweepers with vacuums, brushes, and water ideally should be deployed quarterly over the course of a year. Some studies evaluating performance of permeable pavers recommend that permeably paved parking lots be maintained annually, at a minimum (Hunt & Stevens, 2001). However, this frequency depends on local needs such as pollutant load, use and surrounding vegetation, and sources of street litter.

When installing PICPs, all sites require some excavation. The extent of excavation will depend largely on water table height, rainfall characteristics, intended water volume retention, as well as characteristics of the sub-grade soils and downstream drainage. Substantial aggregate can enable water infiltration for the full overland runoff and temporary water storage load in a storm event. Excavation and aggregate installation also allows improved control over pollutant capture and filtration. Over time the system may require refilling of aggregate fill material following vacuuming (Low Impact Development Center, Inc., 2007).

Typically, most designs assume some rate of diminishing infiltration capacity over time due to dirt and debris accumulation, regardless of maintenance. There is some decrease in water infiltration in the permeable paver system over time, in some cases due to compaction or inconsistent paver construction technique. Other common factors that decrease water flow include sub-soils with low permeability, inadequate maintenance, and design flaws (EPA, 1999). A study investigating the relationship between infiltration capacity and age of the permeable paver system for various land uses and maintenance practices found that the most relevant stressors include traffic and contaminant load, heat, and flow variations arising from surrounding impermeable areas (James & von Landgsdorff, 2003).

4.3 Design Scenarios

We designed six greenspace scenarios for Harlem Place in order to measure and compare the impacts of interstitial greenspace. In each design scenario we varied the type and extent of greenspace, such as permeable pavers, trees, greenwalls, and bioswales, in order to isolate the impact of each design option. The extent of coverage for different greenspace design features within the design scenarios are based on area measurements we determined using a physical site surveys and aerial measurements via Google Earth. All scenarios and their respective impacts are based on the following areas:

- total square footage of Harlem place is 46,464 square feet
- total area of 2% of all parking areas is 3,765 square feet
- total area of all nodes is 7,084 square feet.
- total area of our site is considered to be the sum of these areas, 57,313 square feet

As discussed in earlier sections, Harlem Place is a service alley in Downtown Los Angeles and is two vehicle lane widths wide. To the best of our knowledge, access through the alley by service vehicles on at least one side of the alley must remain constant. As a result, options for greenspace redevelopment are limited. In order to consider all opportunities, we considered the possibility that several owners of commercial space and residential buildings along the alley may be willing to participate in some form of greenspace initiative that would provide incentives for converting parking lots or small, unused spaces (defined as "nodes") to vegetated or permeably paved areas. While conducting our site survey, we measured the average size of existing spaces with trees or vegetation in parking lots and along private buildings in the alley; the typical areas currently vegetated in a parking lot was 2% of the total parking area. Due to the small size of unused "nodes" we assumed all nodes have the potential to be converted to vegetated spaces. The use of 2% of parking areas and nodes are incorporated into our design scenarios.

4.3.1 Design Scenario Descriptions

Design 1: Maximum Area Design Scenario

The Maximum Area design represents the design with the most extent of permeable pavement and vegetation, including trees and greenwalls. This design represents potential impacts from maximizing permeable pavement, vegetation, greenwalls and trees in Harlem Place. This scenario assumes that PICPs will be installed in the entire length and width of the Harlem Place alley. In addition to a maximum amount of permeable pavement, this scenario assumes 2% of each parking lot and 100% of identified nodes in the alleyway would be converted to greenspace. Vegetation to be used on 2% of parking lots includes trees and ground cover vegetation, such as shrubs. Due to the small and varying size of each node, only vegetation such as grasses and shrubs would be installed. We assume that greenwall plantings could cover 25% of available wall area on one side of the alley. Assuming the greenwall will be planted to cover 10 feet of the vertical surface of the building, the total greenwall planting area will be 5,808 square feet. As Harlem Place runs northeast, the greenwall will be planted on the northwest side, which receives more sunlight.

Assumptions for Vegetated spaces

For the Maximum Area design we assume 100% private property owner participation in potential greenspace development incentive programs, which results in conversion of 2% of parking areas and 100% of nodes to vegetated areas. Furthermore, per advice from our client, Gunnar Hand, Senior Regional Planner at Los Angeles County Department of Regional Planning, it is highly unlikely that tree planting or tree boxes will be allowed in Harlem Place, due to city planting regulations. Although a business in Harlem Place placed two tree box planters in the alley, the direction of city planting regulations remains uncertain. Therefore, we assume that no vegetation can be planted within the boundaries of the two-lane service alleyway.

The total linear feet available by utilizing 2% of the surface of parking lots in a strip of land contiguous to Harlem Place is 1,126 linear feet. Using Seattle's urban tree planting guide and Los Angeles-based organization TreePeople, which provides standards that urban trees be planted in 5 foot planting strips, we assume each tree planted will require 25 square feet of floor space for our design scenarios. To determine the maximum number of trees which could be planted, granted the required 25 square feet for each tree, we divided the total linear feet available (1,126 linear feet) by the average canopy diameter of trees used. The resulting number of trees able to fit into this area is 45 trees, which would be distributed throughout the 2% of parking areas. The remaining vegetated spaces within the 2% area will be planted with grasses and small plantings. This area is 2,780 square feet [Net vegetated area of 3,906 sq. ft. minus area allocated for trees (45 trees times 25 sq. ft. each)].

Design 2: Only Nodes

The Only Nodes design represents the impact of installing vegetation features only within the privately owned node spaces contiguous to Harlem Place; the entire length of Harlem Place is left as is, paved entirely in impervious concrete. A total area of 7,084 square feet will be vegetated with selected grasses and shrubs. This scenario addresses the issues that some or all parking lot owners may not be willing to convert 2% of parking areas to greenspace. There may be more flexibility for greenspace development in the extra nodes spaces, which have no discernible current rental or significant use value. This design feature quantifies potential impact of redevelopment without the repaving of Harlem Place and thus will indicate how much runoff can be reduced from the baseline conditions with some small pockets of vegetation interspersed along the service alleyway. Design iterations will test the effectiveness of vegetation types including grasses and small plantings, but not trees.

Design 3: Permeable Pavers and Nodes

This third design scenario represents the impacts of installing permeable pavement in half the entire length of Harlem Place, in addition to installing vegetation, such as grasses and shrubs, in 100% of the nodes. The remaining half of the alleyway would remain as impervious concrete. As Harlem Place is a primary service road utilized by small municipal garbage collection trucks which can degrade surfaces, certain types of permeable pavers may not be optimal for the full width of the alleyway. While PICPs may be used in spaces with low vehicle traffic and speeds, such as parking lots, in these applications the blocks must be approximately 80 mm thick and can be more costly. Thus, this design scenario allows for half of the width (equal to one vehicle traffic lane) to be paved with more durable porous concrete or asphalt, and one half be paved with PICPs for the area designated for pedestrian use and some vehicular access.

Design 4: Permeable Pavers Only

The Permeable Pavers Only design assesses the effects of installing PICP in the entire alleyway and quantifies potential impacts of redevelopment by only repaving Harlem Place with permeable pavers. This single design feature will indicate the amount of runoff and pollution that can be reduced from the baseline conditions by utilizing minimal types of greenspace techniques. When compared to other designs, this design will also demonstrate the impact that vegetation has on reducing runoff in Harlem Place.

Design 5: 4% Permeable Pavers

Redeveloping 4% of the alleyway represents the impacts of installing the minimum amount of permeable pavement required to be effective in infiltrating runoff. The functionality of permeable pavement is based on soil infiltration rates, which range from 0.78-1.18 inches/hour (FAO, 2010) in Los Angeles, CA, which has Type A, sandy loam soil. Studies found that if percolation is more than 0.5 inches/hour, but native soil is Hydrologic Soil Group A or B (>0.5 inch/hour), direct infiltration can still be an effective strategy without soil amendments. However, based upon advice from stormwater guideline literature, pervious areas should be at least, if not greater than 4% of the project area (US EPA & Community Design and Architecture, 2005). Thus, while Harlem Place is above this >0.5 inch threshold, to be conservative, we assume that permeable surface area should be at a minimum, 4%. The 4% could be distributed throughout the alleyway. Contiguous permeable pavement would be ideal; however, the feasibility of this in Harlem Place is unknown.

Design 6: Bioswale

The Bioswale design scenario represents the impacts of installing alternative types of vegetation, including a linear bioswale and greenwalls, throughout Harlem Place; pavement will remain impervious concrete. As previously defined, a linear swale functions to improve water quality and reduce peak runoff, which is accomplished by providing a storage area for water and limiting the velocity in the swale. Greenwalls function as a mechanism to improve particulate capture and impact urban heat island effect by increasing local evapotranspiration and shading the building surface on which they are affixed. A linear swale of five feet will be installed down the length of Harlem place; greenwalls will be installed in the northwest side of the alley (to maximize available sunlight) and will run up buildings 10 vertical feet. A width of five feet was selected based upon existing bioswale project design guidelines. This design will quantify and compare the impact of greenwalls and vegetated swales, covering a net area of 11, 616 square feet.[1]

Design 7: Baseline

The Baseline scenario represents current conditions and serves as the control scenario of Harlem Place. The extent of our full site project area and this baseline case includes the Harlem Place two-lane alley, identified nodes, and 2% of parking lots, with 100% of the total area paved, totaling 57,313 square feet. Baseline information for Harlem Place is necessary to accurately assess and compare any greenspace redevelopment.

4.4 General Constraints

4.4.1 Physical limitations to greenspace design

Dense urban development limits availability of expansive open spaces. This was a major reason for focusing our project on the effects of interstitial greenspace, rather than large urban parks. Increasingly, small-scale greenspace may be the only viable option within cities, and potentially represents large areas of land when considered in aggregate.

Not only are there biophysical constraints on space, there are also constraints from existing infrastructure, both above-ground and subsurface. Above-ground infrastructure includes entrances and exits to surrounding buildings and parking garages, which will need to be accounted for in the final greenspace design. Accessibility needs of occupants must be considered. For example, vegetation

[1] Sizing for Linear Swale: Dedicated landscape space must be at least >/=4% of total impervious catchment area, based on percolation rates of 5-10 inches/hour. Ideally, design guideline references suggest that linear swales should be 200-250 ft in length for optimal 9-minute residence time. However, shorter swales are possible as long as they achieve a minimal residence time of 5 minutes.

features such as bioswales should not block entrances unless covered by grates or sections of walkways. Vegetation also requires solar access, which is highly dependent on building shade. Other infrastructural constraints include existing lighting fixtures and drainage pipes from rooftops, which would greatly increase the volume of stormwater entering the greenspace during storm events. In Harlem Place, there are several roof drains into the alleyway, but it was beyond the scope of our project to model runoff from each of these drains. Subsurface infrastructure also ultimately affects the range of design options available, particularly if excavation is required. Underground piping, sewer lines, and building foundations may preclude excavation for planting. Basements either beneath or proximate to the greenspace may become prone to flooding if asphalt is replaced with permeable pavers or soil.

Local climate is another important physical constraint on greenspace redesign. Temperature and rainfall dictate what types of vegetation are appropriate for a site. If considering permeable pavers as a design feature, it is necessary to have a soil type beneath the site that is both porous enough to allow for infiltration, but not so unstable that it will not support the weight of pavers placed above. Furthermore, if existing soil is contaminated it may be necessary to first remediate the site to eliminate potentially hazardous pollutants. The topography of the site should also be considered; sites on steeper inclines or sites that are so uneven as to not allow for adequate drainage will likely require grading before construction begins.

Surrounding uses of the project site will largely impact its effect on the larger community. In terms of increasing connectivity and walkability, the more integrated the site is to other places of interest, the more it will increase foot traffic and benefit local residents and businesses. For example, in Downtown L.A., construction is already underway on the redevelopment of several existing surface parking lots into the upcoming Spring Street Park, which is directly proximate to Harlem Place. If Harlem Place was to be converted to greenspace, it would connect to Spring Street Park, creating a pedestrian corridor through Historic Downtown and potentially linking to more opportunities for small-scale greenspace. Population projections are important for greenspace projects, because they indicate the potential amount of future use of the space. Finally, future maintenance needs over the long-term provide an additional constraint on greenspace redesign. Vegetation will require irrigation, pruning, and possibly additional maintenance if tree roots break through sidewalk. Additionally, permeable paving will require periodic cleaning to maintain infiltration functionality.

Harlem Place

To understand the physical realities of our site, we visited Harlem Place and conducted a physical site survey of the alley. We used the SPACES (Systematic Pedestrian and Cycling Environmental Scan) surveys created by the USC Center for Sustainable Cities, which are predominantly focused on physical site constraints and opportunities of a given site location. The SPACES surveys are designed to provide in-depth information on alley features, where ratings of physical characteristics, locational attributes, aesthetic qualities, and safety related features contribute to detailed composite physical descriptions of each alley (Seymour et al., 2007).

Using Google maps of Harlem Place and the alley auditing forms provided by the SPACES survey, we were able to document walkway connections between the main streets and sidewalks, entrance points from buildings, building heights, and parking lot areas. This survey enabled us to identify constraints to the redevelopment of Harlem Place, and where greenspace implementation was possible beyond the exact boundaries of the primary service alleyway. For example, we were able to identify additional opportunities for vegetation planting in the nodes, which are small, unused spaces created by buildings that do not lie flush with the alley. Figure 4.1 provides an example of what a node looks like.

Figure 4.1 Picture of Harlem Place between 2^{nd} and 3^{rd} Street. On the right is a node space where the building is not flush with the alleyway. This can be an area for vegetation and redevelopment.

We were also able to take note of utilities found in the alley, percentage of impermeable surfaces, amounts of litter and graffiti, noise, visibility, and lighting. This was a crucial first step in creating our design scenarios; by taking inventory of what physical constraints existed in Harlem Place, we were able to envision what its potential future could be.

4.4.2. Regulatory and Economic Constraints

When determining the design and implementation factors to consider for a greenspace project, there are always regulatory and economic constraints specific to the site that affect the range of possible design options. Local policies and zoning ordinances largely dictate what can realistically be implemented in any greenspace project. Cities may have limitations on what can be built on a site and certain sites might be zoned for uses that conflict with the initial vision of the project. Of specific concern for green alley retrofitting is vehicular access regulations. Harlem Place is primarily a service road and alleyway, so although we considered limiting the roadway to one lane, it was not feasible to close it off entirely because business and homes along the alley still need service access in Harlem Place. This is site-specific, however, and needs to be examined thoroughly on a case-by-case basis.

We conducted extensive literature review (Zarella, 2009; "Proposition 40," 2008; Daniels, 2008; Berg, 2008) and worked with the DLANC to determine which regulatory and economic constraints would apply to our design options for Harlem Place. For example, it is not possible to plant trees in Harlem Place since it is a service road, so we looked for opportunities adjacent to the alley where planting would be feasible, which are the parking lots and node spaces mentioned in previous sections. Another regulatory constraint for Harlem Place is gating. In L.A., it is currently illegal to gate an alleyway. Therefore, this was not an option for our project. In 2004, the California Supreme Court ruled that the Nuisance Alley Closure Program, which aimed to prevent crime in alleyways by allowing residents to gate off their alleyways, was in fact illegal and now the practice of alley gating is banned in L.A. (Berg, 2008). However, other communities have worked to change local policies to make them more favorable to greenspace projects. In 2007, Baltimore passed the Alley Gating and Greening Ordinance, which allows residents to gate their alleyways and implement beautification projects if 80% of the property owners abutting the alley consent (Community Greens, 2009).

Zoning of proximate area designations are just as important as zoning regulations for the site itself. Citizens interested in a greenspace project should contact their local planning departments to acquire zoning maps of the site area to better understand what kind of development can legally occur in the area. Other proximate zoning considerations include right-of-ways and setback requirements. The majority of the buildings along Harlem Place are currently zoned mixed use/residential, which means that any redevelopment in Harlem Place will have significance to both residents and business owners. There is even one restaurant that has primary frontage into Harlem Place, suggesting that greening and increasing pedestrian activity through the alley will have a significant impact on their customer base. Zoning also dictates other allowable changes, such as vegetation, surface types, and width of each surface type for the site. Harlem Place must maintain vehicular access, so at least half of the site will likely remain a drivable surface. Other sites may have more or less stringent use requirements that stakeholders need to consider in the creation of design scenarios.

An important question is whether the proposed greenspace location allows for public or private access. Major access points where vehicles enter the alleyway need to be included in the final design of a greenspace project. In Harlem Place, privately owned buildings use the alley for service truck access, mainly for waste hauling and vehicular access to adjacent parking structures. There are also intersections with main roads and pedestrian walkways at the end of each block. Connections to roads and public right of ways need to be included in the final design of a greenspace project. Another critical consideration for implementation is ownership; is the space publicly or privately owned? This will play an important role in what can actually be done on the site, making owners particularly important stakeholders in the design process. Cost of implementation is another especially pressing issue, and funding sources need to be identified early on. Often, there are available public funds and grants that can be applied to sustainable redevelopment projects. Other times, however, projects require private investment. Identifying currently available funding sources for Harlem Place is beyond the scope of our project, but is something that our client, the DLANC, is actively working on. The DLANC will use the end results of our analysis to apply for funding.

4.5 Cost Considerations for Small-Scale Greenspace

There are carbon, water, and economic cost considerations to any redevelopment project. Understanding these costs is critical, as future "hidden" costs have the potential to present serious trade-offs when evaluating the net impacts of greenspace design. To provide a range of possible costs of key design features for our client, we conducted a rough estimate of project costs for Harlem Place in terms of carbon, economics, and water. While many of these costs stem from upfront construction and material procurement, other costs will occur over the life of the project. For example, removing any existing paving requires fossil fuel powered machinery and labor, and thus incurs upfront energy and carbon costs. All new design feature materials, such as permeable pavers, benches, vegetation and lighting, have embedded energy, water and thus greenhouse gas emissions associated with the material harvesting, cultivation, production, shipping and installation. Maintenance and repair costs occur over the life of the project, as well as water costs for irrigation, if needed.

While there is a great deal of uncertainty associated with total upfront and life-cycle costs, they should be considered as part of the net impact of a greenspace project. While it was not within the scope of our project to assess the full life-cycle costs of our greenspace prototypes, it is imperative to consider the trade-offs in design options and how variations in design can affect overall cost of the project.

4.5.1 Carbon Costs

The carbon cost of a greenspace redevelopment project can be substantial. Sources of carbon emissions include machinery and labor for removing existing paving and the preparation and regrading of the site. Additionally, the harvesting, production, installation, construction, and maintenance of the pavers, as well as installation of other LID features such as vegetated swales and greenwalls, have associated carbon emissions. While iTree factors carbon costs in terms of maintenance and decomposition rates of trees into the net carbon impact of each tree, the model does not account for carbon costs associated with other types of vegetation (e.g., shrubs, greenwalls).

Estimating the carbon implications of specific design elements in the absence of complete life cycle assessment information is possible and extremely valuable when designing a greenspace. For example, research indicates that PICPs are superior to asphalt in terms of carbon emissions. As PICPs are modular units, individual blocks can be removed for maintenance of below-street infrastructure or for PICP repair more easily than a uniform asphalt paving. This reduces material use and labor, thereby reducing financial and carbon costs. Additionally, PICPS are made of concrete materials, which do not employ oil-based products for binders as does porous asphalt. The composition of the PICP concrete can include cement substitutes of such recycled waste material as silica fume, fly-ash, and slag which are also recyclable at end-of-life (ICPI, 2008). Furthermore, since PICPS can be designed to be more reflective than the surfaces they replace, and achieve a high Solar-Reflectance Index, they can increase reflectivity of a site if they replace a darker paver, and thereby reduce the urban heat island effect (Rose Paving, 2010). If implemented on a large enough scale, this increased reflectivity in surface areas around buildings can decrease air conditioning demand, thereby decreasing carbon emissions. Carbon costs of design feature can be rated according to many variables, such as material content, shipping distance, color, and end-of-life.

4.5.2 Economic Costs

Low Impact Development (LID)

Any greenspace redevelopment project will involve financial investment. Possible costs include permitting, of existing pavement, installation and purchase of design features, maintenance of the site, and hiring labor such as consultants, engineers, and architects. Depending on the scope of the project, additional amenities, such as bike racks, benches, tree grates, rain cisterns, and informational displays will add cost. Contrary to general belief, often the construction of a site using low-impact, sustainable design features results in lower costs to the community than if traditional, higher impact designs had been used. A frequently cited EPA report shows 17 case studies of LID projects, in which all but one resulted in cost savings when compared to conventional development costs (EPA, 2007). The following is a brief discussion regarding the primary design options that can be varied depending on an organization's financial budget. A summary of cost estimates can be seen in Table 4.1.

Cost Estimates for Design Features				
Estimate Range	**Paver Type**	**Vegetation Type**	**Greenwall**	**Total ($)**
Maximum Area Design Scenario				
	PICP	trees, shrubs	w/ screen	
low	$185,800	$428,800	$278,700	$893,300
high	$371,700	$497,200	$371,700	$1,240,600
	porous concrete	trees, shrubs	w/ screen	
low	$92,900	$428,800	$278,800	$800,500
high	$302,000	$497,200	$371,700	$1,170,900
Bioswale Design Scenario				
	asphalt	bioswale	w/ screen	
low		$23,200	$278,800	$302,000
high		$46,400	$371,700	$418,100

Table 4.1 Range of costs for Maximum Area and Bioswale design scenarios for purchase and installation of permeable pavement, vegetation, greenwalls, and bioswales.

Pavers

Varying the type, amount, and distribution of permeable pavement in greenspace designs can have dramatic effects on the total cost of the project. Assuming typical pricing for installation of different pavers, we estimated the cost ranges for this aspect of our project for our Maximum Area design scenario, as this scenario required the greatest amount of permeable paver to be installed. Therefore, it is not surprising that this scenario represents the most expensive design. The EPA estimates that the price per square foot for PICPs, jointing, and bedding materials ranges from $4-$8 (EPA, 2009), which we based our estimate for the range of costs for permeable pavers in Harlem Place. Using this cost estimate, the paving for the Maximum Area design scenario with PICPs covering the 46,464 square feet of Harlem Place ranges in cost from $185,850 - $371,710. A less expensive alternative, porous concrete, for the Maximum Area scenario lowers the costs of pavers to a range of $92,920 -$302,010.

Vegetation

We estimated the cost of the vegetation for the Maximum Area design scenario using figures from local nurseries in Los Angeles. Our low estimates for trees assumed prices for a 48" tree box, while high estimate figures were obtained from average pricing for 60" tree boxes. For context, a 48" tree box generally provides a "fairly mature tree" that is 3-7 years old and between 10-30 feet tall (O'Connell, 2006). The Maximum Area design calls for 45 trees and 180 shrubs to be installed along the alley, which results in a cost ranging from $428,800 - $497,200.

Greenwalls

Using cost estimates provided by, Greenscreen, a popular greenwall infrastructure company, our project estimated a high and low cost ranging from $20 - $12/square foot for material and labor to install the metal grid on the building facades (2010). Assuming 23,232 square feet of greenwall within our design, the greenwall could cost between $278,700-371,700.

Bioswale

Based on figures found in literature review that bioswales cost $4.50-$8.40 per linear foot for swales when vegetated for seed, and $15-$20 when vegetated for sod, we selected a high and low estimate cost of $10 and $20 per linear foot (Azerbegi, 2009). For the 5 foot wide and 2,232 foot long bioswale specified in the Bioswale design scenario we estimate a cost range of $23,200 - $46,460

Case Study

To compare our cost findings and provide context to the financial cost of redeveloping Harlem Place, we compared our Maximum Area design scenario to a case study of a greyfield project with a similar scope. Clinton Beach Park is a greyfield project redevelopment near Seattle, WA, which followed the Sustainable Sites Initiative. This initiative is a collaboration effort to create performance benchmarks for sustainable land design, construction and maintenance practices. This case study and its documentation provide analysis data on permeable paver cost and paving surface areas, as well as planting and maintenance costs per area. By transferring this cost data per surface type and area to the corresponding type and area specifications of the Maximum Area scenario in Harlem Place, we estimated that grading and repaving could cost $192,000, while planting may cost $138,000. Additional maintenance costs could reach $12,000 annually, resulting in a potential total cost of approximately $340,500. For a closer comparison to Harlem Place, adding the cost of the greenwall would yield an estimate of $714,210 (Henry, 2006).

4.5.3 Water Costs

Although much of our project has emphasized the ecosystem services provided by urban greenspace, including the potential to abate stormwater runoff, there are also water costs involved in LID projects. Water costs primarily include irrigation of vegetation, although this can be minimized through the use of vegetation suitable for the localized climate. One of the constraints in designing a potential greenspace in Harlem Place is minimizing water use for irrigation due to water scarcity in southern California. Therefore, drought-tolerant trees were selected to keep water costs low. Another issue that affects water cost is how people use the site. For example, neighbors could overwater vegetation, or water during the day instead of the night, increasing potable water demand in the community. Furthermore, water consumption may be influenced indirectly as a result of alley users cleaning the alley with hoses or sprayers.

Our project specified trees which only require watering during their establishment. For newly planted trees, the City of Los Angeles Bureau of Street Services' Urban Forestry Division specifies irrigation needs of L.A. street trees by season, as follows:

- Winter: 7.5 gallons/wk
- Spring: 10 gallons/wk
- Summer: 30 gallons/wk
- Fall: 20 gallons/wk

Based on these assumptions, each tree requires approximately 810 gallons of irrigated water annually (Urban Forestry Division). For the Maximum Area design, Harlem Place's 45 trees would require 36,450 gallons of water annually for maintenance during their first year of establishment. Drought-tolerant shrubs can be provided with mulch to decrease water demand while plants are being established (Pittenger, 2009). Based upon the Urban Forestry Division's estimates for trees, we assume that each shrub will require an average of 1 gallon/wk over the course of the one year. Thus, the 180 shrubs specified in Harlem Place could require an additional 9,360 gallons annually (Urban Forestry Division). As a result, total irrigation demand for the Maximum Area design scenario, with trees and shrubs, is estimated to be 45,810 gallons annually for the first 2-3 years following planting. This number may vary depending on annual variations in rainfall received. However, this water cost can be compared to the overall stormwater reduction of the Maximum Area design scenario, which amounts to 346,422 gallons annually. If this stormwater was captured using greenspace designs, the annual water demand for the site would be more than offset.

4.5.4 Burden of Cost and Allocation of Benefit

An important consideration when evaluating upfront and long-term costs of a redevelopment project is identifying where the burden of the various costs fall, and where the economic benefits are realized. Depending on the scale of impact of ecosystem services, the entity paying for the project may not be the same entity benefiting, which can reduce incentives or create obstacles for implementing projects. The energy savings and other positive environmental impacts provided by urban trees ensure that their benefits outweigh the initial economic costs of planting, irrigation, and maintenance (McPherson, 1995). If tree planting is funded by the public sector, some tangible benefits will be achieved for the city in terms of stormwater reduction, resulting in a reduced burden on water treatment plants, as well as air pollution mitigation. Furthermore, a study by the Forest Service found that one urban tree (over the duration of a 50-year life) can control $31,250 worth of soil erosion, provide over $30,000 worth of oxygen, recycle $37,500 worth of water and yield more than $60,000 worth of air pollution control (Colorado Tree Coalition, 2009). A study of the city of Chicago estimated that the ecological services provided by its urban trees had a present value of long-term benefits, which was double that of the present value of any costs associated with the trees (McPherson, 1997). Another study conducted by the USDA Forest Service and UC Davis found that by increasing tree canopy by 1.3 million trees over L.A., the city would receive $1.64-1.95 billion in benefits over the next 35 years (Greenstreets LA).

The energy savings and aesthetic appeal that trees provide will benefit private building owners. According to Dixon & Wolf (2007, p.7), the existence of trees proximate to property increased the selling price of a residential unit between 1.9 - 9%, and that neighborhoods which include a well-vegetated streetscape “are correlated with a 23% net rise in home value within ¼ mile of the corridor, and an 11% net rise for those within ½ mile”. Thus, it is possible to utilize previous hedonic pricing analysis as a means to conduct cost benefit analysis of greenspace on real estate values; “hedonic analyses of residential housing prices consistently reveal an inverse relationship between housing prices and distance to urban environmental amenities” (Wu & Planting, 2003, p.288). One study estimates that redevelopment of the brownfields into greenspaces would increase property values for the 890 neighborhood residences between $2.40 and $7.01 million (Kaufman & Cloutier, 2006). In terms of air quality and health amenity afforded by greenspace, a Chay and Greenstone study found that 10% reduction in total suspended particulates increased home prices by 3% (Kahn, 2006).

As discussed above, most economic benefits of greenspace are quantified in terms of overall human health within proximity of the greenspace area, specific ecological services to public goods and resources, and in property values. Urban trees and greenspaces, even if on private property, can benefit the public sphere in terms of aesthetic appeal, and their impact on environmental health.

5 Results and Conceptual Models

Overview of Conceptual Models

In order to address selected ecosystem services on the local level in Harlem Place, we transformed our thought processes into a conceptual model framework. Our approach will help decision-makers understand key design considerations and important constraints and tradeoffs to consider when attempting to maximize ecosystem services on local and regional scales. These conceptual models were created to demonstrate how to determine optimal designs for greenspace in order to improve air quality, reduce stormwater runoff, mitigate urban heat island effect, sequester carbon for greenhouse gas mitigation, and improve livability of a community.

5.1 Stormwater

What is the Issue?

Stormwater is a problem in urban environments in terms of both quantity and quality. Stormwater quantity refers to the volume of runoff that flows from storm events; stormwater quality describes the pollutant loads in water runoff, both in composition and amount. These two issues are inherently linked. Urbanization changes the drainage patterns of watersheds with subsequent effects on local water bodies. Hydrological impacts of urbanization include incorporating new areas into the flood plain, increased flooding, increased extent and occurrence of storm events, and increased effluent flows. Impervious surfaces dominant in urban environments promote rapid overland sheet flow of stormwater runoff, precluding infiltration and groundwater recharge (O'Reilly & Novotny, 1999). A residential street in L.A. running for 500 feet has the ability to generate 140,000 gallons of runoff during a storm event (City of Los Angeles Bureau of Sanitation Stormwater Program, 2008). This overland flow, particularly the storm's first flush, carries pollutants into local water bodies, degrading the health of surrounding aquatic ecosystems (O'Reilly & Novotny, 1999; Ahn et al., 2005; Bay et al, 2003). Beyond storm events, there are also anthropogenic sources of street runoff which degrade water quality. In L.A., approximately 300,000 gallons of dry runoff flows daily into the Santa Monica Bay because of overwatering of lawns and sidewalk cleaning (Shapiro, 2003). Greenspace has the potential to address stormwater issues as a result of the ecosystem services of flood control and improved water quality provided by vegetation and permeable pavement.

How Can a Redesign Reduce Stormwater Quantity?

Design techniques that allow more stormwater to infiltrate into the soil help reduce dependence on other flood control engineering, and can prevent damage to built infrastructure following large storm events (Elmqvist, 2008; Brattebo & Booth, 2003). During heavy storm events, runoff into the Santa Monica Bay can be over 1 billion gallons per day (Chau, 2009). Specific to Los Angeles, a March 2008 study found that approximately 40% of L.A. County's requirements for mitigating stormwater pollution could be achieved through LID projects implemented on existing public land (Daniels, 2008). Greenspace can control flooding by increasing infiltration, water storage, and evapotranspiration (USDA Forest Service, 2002). Similarly, greenspace reduces pollution in runoff through increasing water storage, increasing infiltration, and plant uptake (Elmqvist, 2008).

Vegetation decreases the amount of stormwater runoff by uptake through the roots and leaf interception, thereby reducing the volume of captured runoff through evapotranspiration. Design techniques that incorporate vegetation to reduce stormwater runoff include bio-retention basins, swales, tree boxes, and rain gardens. Trees intercept rainfall, and unpaved areas absorb water, slowing the rate at which it reaches stormwater facilities (Elmqvist, 2008). Trees are a cost-effective way to control flooding during storm events. It is estimated that trees in the U.S. metropolitan areas can save $400 billion in the cost of building stormwater retention facilities (Scherer 2003). If one million trees were planted in the city of L.A., they would be able to capture 1.9 billion gallons of stormwater annually (City of Los Angeles Bureau of Sanitation Stormwater Program, 2008). Vegetation also intercepts and absorbs stormwater runoff and decreases peak loads during storm events (Xiao et al., 1998). In areas with combined sewers, the ability of vegetation to capture runoff and slow flow can preclude the occurrences of combined sewer overflows and degraded water quality in proximate water bodies.

The more porous the groundcover, the more stormwater is allowed to infiltrate into the soil. Porous concrete and PICPs are currently existing design techniques that allow for increased infiltration (Brattebo & Booth, 2003). Other LID design features, such as rain barrels and cisterns, allow for stormwater capture instead of infiltration, but the captured water can be used directly for on-site irrigation needs. Increasing water storage, either through vegetation (e.g., rain gardens and swales) or man-made retention bins (e.g., cisterns and rain barrels) captures rainfall, preventing the water from running into drainage systems.

How Can a Redesign Improve Stormwater Quality?

Runoff is the greatest single source of water pollution in Southern California, particularly in the Santa Monica Bay (Shapiro, 2003; Chau, 2009). Increased infiltration of stormwater allows for a portion of pollutants in runoff to break down in soils (Garrison et al., 2009). Pollutants like nitrogen and phosphorus are essential plant nutrients that can be taken up, while heavy metals like copper, lead, and zinc are more persistent. Bioremediation using vegetation is possible, but may expose wildlife to contamination (Pepper et al., 2006).

Permeable pavers, such as PICPs, can reduce loads of water pollutants including nitrogen, phosphorus, heavy metals, and ammonium (James, 1996). A study by Pratt et al. (1999), found that permeable pavement does have the capacity to retain both suspended solids, as well as mineral oil; overall pollutant removal capacity has been found to be similar to that of natural soil (Pratt et al., 1999). Studies have found that the capacity for porous pavers to breakdown petroleum pollution, such as hydrocarbons released from parked vehicles, depends heavily on the capacity of in situ microbes. Heavy metals such as lead, copper, cadmium and zinc generally accumulated at the surface drainage cells and the paver's surface layer, and tend not to migrate beyond 15 cm beyond the system into the subgrade (Legret et al., 1996).

Permeable paver systems can be viable for decreasing petroleum contamination due to their ability to foster microbial aerobic breakdown of hydrocarbons (Pratt et al., 1999). When hydrocarbon levels are notably higher than average, it is possible to seed the area with nutrients and microbes to facilitate degradation, as nutrient supply is a limiting factor in microbial ability to degrade oil derivatives. To reduce the threat of eutrophication, some systems apply low-level nutrient supply of slow-release fertilizers. Evidence suggests that permeable paver systems could be used on a large scale to ameliorate petroleum-based hydrocarbon pollution originating from highways, parking lots, and oil-handling facilities into urban water bodies (Pratt et al., 1999). In general, while soils below pavers are generally effective in retaining pollutants from infiltrated water, in cases with concern for high pollutant loads, an impermeable barrier combined with a collection pipe can be installed. This pipe can transport drained water for additional treatment or disposal.

Vegetated areas can also intercept and filter some of the common pollutants that stormwater runoff otherwise carries into water bodies. A 5-year study in Los Angeles determining the effects of six bioretention areas accepting runoff from parking lots and streets found that after being filtered through plants and soil, none of the monitored stormwater pollutants (e.g., heavy metals, fecal matter, oil) had a negative effect on groundwater. Thus, bioretention can be an effective means to filter out pollutants before water is released into the Santa Monica Bay, known for its water quality issues and beach closures (Carpenter, 2009). Infiltration design features, such as bioswales, can typically retain 70-98% of water contaminants (Garrison et al, 2009).

Design and Planning Considerations

As mentioned, issues regarding stormwater runoff and quality include the peak flow and first flush of pollutants of an event, as well as the total runoff from typical storm events. Thus, to maximize the benefits of a design, different features must be included which can address mitigating water pollution carried in the first flush, slow or retain water to reduce the peak flow, and also retain or infiltrate enough water to reduce total runoff overall. As mentioned, vegetation decreases water runoff and improves water quality. However, the specific size and species of vegetation is a key factor in the level of impact as vegetation types vary in their capacity for uptake and runoff retention (Xiao et al., 1998). Additionally, the net extent of vegetated surface cover, as well as site grading to direct surface flow, will determine how much water from a site the vegetation will absorb. It is also important to consider the local climate of the site as there may be tradeoffs in providing enough vegetation to impact stormwater, but also creating a potable water demand for irrigation of vegetation during dry periods. This is an issue in L.A. considering the brief wet season in which stormwater is an issue, and lengthy dry season, in which irrigation demands can be a burden on water supply.

For permeable pavers, a primary design consideration is dedicating enough site area to the pavers to have an impact. At least 4% of the site should be covered in permeable pavers in order for infiltration to occur, without pavers being overwhelmed by water ponding (US EPA, 2005). Additionally, sites considered for permeable pavement installation must have underlying soil types porous enough to allow for percolation. Generally, site soils should have infiltration rates of at least 0.5 inches/hour (US EPA, 2005). If the subsurface soils have too low of an infiltration rate, additional excavation to allow space for aggregate fill material is required. However, with respect to retrofits in the L.A. basin and southern California, soils are generally porous enough to be suitable for permeable pavers.

Application to Harlem Place

In order to evaluate impacts of greenspace design features on stormwater in Harlem Place, we applied our conceptual model to Harlem Place and tailored it to the needs and constraints of the alley (Figure 5.1).

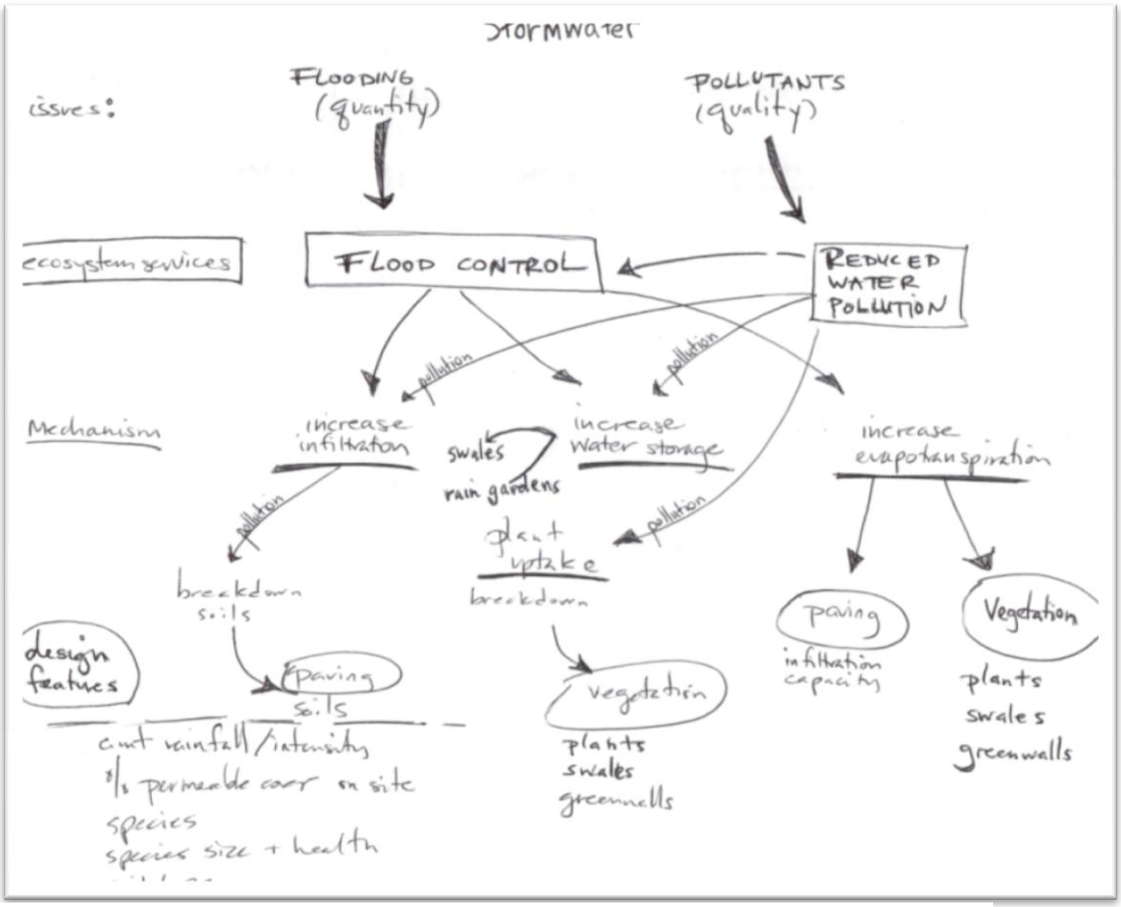

Figure 5.1 Conceptual model of stormwater and the corresponding ecosystem services that provide stormwater runoff mitigation and pollution control.

Our physical site survey of Harlem Place revealed important physical constraints. The alley is currently graded towards the center to channel stormwater out of the site. Retrofits with permeable pavers would likely require grading to level the alley slope or direct water properly towards the bioswale or vegetated areas. Additionally, there are several roof drains that outfall into Harlem Place, which will increase the intensity of water flowing into the alley during a storm and drastically increase runoff peak flow and net amount. Our physical surveys of Harlem Place also revealed that the alley is used throughout the day for service vehicle use, meaning that some of the pollutant loading will include oil and hydrocarbons both from these vehicles and the parking lots that abut Harlem Place.

Design techniques that address stormwater and would be feasible in Harlem Place include a bioswale and permeable pavement. The Bioswale scenario had a range of pollutant removal efficiencies using both vegetation strips and bioretention area capabilities. “Vegetated Strips” are defined as “gently sloped vegetated areas similar to grassed swales” while “bioretention areas” are conditioned soil layers containing a mixture of detritus, humus, and mineral and biological complexes in shallow depressed areas (Sayre et al. 2006). The significant differences between the “vegetated strips” and the “bioretention area” pollutant removal capacities were regarding fecal coliform, copper, and phosphorous. In order to model pollutant load reductions, we used LA County’s Department of Public Works and the Southern California Coastal Water Research Project’s data for ambient pollutant loads for LA Retail/Commercial areas, which is a land-use designation that assumes an average of 88% impervious ground cover (Los Angeles Department of Public Works, 2009).

Discussion of Results

Stormwater Pollution

Pollutants of concern in L.A. are likely zinc, total suspended solids (TSS), copper, and lead, since ambient concentrations for commercial and retail areas of L.A. are higher than nitrogen or phosphorus. Particularly noteworthy is the high concentration of ambient zinc in L.A. runoff, 238.53 mg/l. Although zinc concentrations in L.A. runoff are higher than other pollutants, these numbers are supported by other studies. Hwang et al. (2006) found that zinc was the most abundant trace metal in coastal California tidal marsh sediment study sites, as high as 744 μg/g, followed by lead at (26.6–273 μg/g). Storm events in San Diego have historically led to zinc concentrations in runoff orders of magnitude larger than copper and lead concentrations. For example, one 1994 storm led to copper concentrations in runoff of 0.044 Mg/L, lead concentrations of 0.07Mg/L, but zinc concentrations of 0.32 Mg/L. One possible explanation of these high zinc levels are anthropogenic sources such as motor vehicles, industrial emissions, and construction waste (Winiarz, 2005).

Based on our models the Maximum Area design scenario has the potential to remove the greatest percent of total suspended solids (TSS), phosphorus (P_2), lead, and zinc. The Bioswale scenario, however, has the capacity to remove the largest percentage of nitrogen and copper (Table 5.1).

Pollutant Removal Capacity (mg/L)						
	TSS2	**NO3-N2**	**P2**	**Total Copper**	**Total Lead**	**Total Zinc**
Ambient Concentrations	**67.40**	**4.09**	**0.41**	**34.77**	**11.53**	**238.53**
Maximum Area	58.53 (87%)	1.20 (29%)	0.23 (56%)	17.76 (51%)	8.07 (70%)	184.63 (77%)
Only Nodes	5.75 (9%)	0.20 (5%)	0.02 (5%)	3.87 (11%)	0.76 (7%)	18.28 (8%)
Permeable Pavers and Nodes	55.47 (82%)	1.09 (27%)	0.22 (54%)	15.71 (45%)	7.67(67%)	174.92 (73%)
Permeable Pavers Only	49.72 (74%)	0.90 (22%)	0.20 (50%)	11.84 (34%)	6.92 (60%)	156.64 (66%)
4% Permeable Pavers	1.99 (3%)	0.04 (1%)	0.01 (2%)	0.47 (14%)	0.28 (2%)	6.27 (2%)
Bioswale	46.51 (69%)	1.60 (39%)	0.15 (37%)	31.30 (90%)	6.11 (53%)	147.89 (62%)
Baseline	0	0	0	0	0	0

Table 5.1 Pollutant Removal Capacity (mg/L) for each design scenario based on ambient L.A. commercial/retail concentrations. Percentages represent percent of pollutant removed from current conditions

Stormwater pollution uptake and removal will have significant local and regional impacts, particularly for zinc and suspended solids. Also important to note is the percentage pollutant removal capability for each pollutant, since ambient concentrations can change over time and will vary on a site-by-site basis. The Maximum Area design scenario is able to remove pollution by the percentages shown in Figure 5.2.

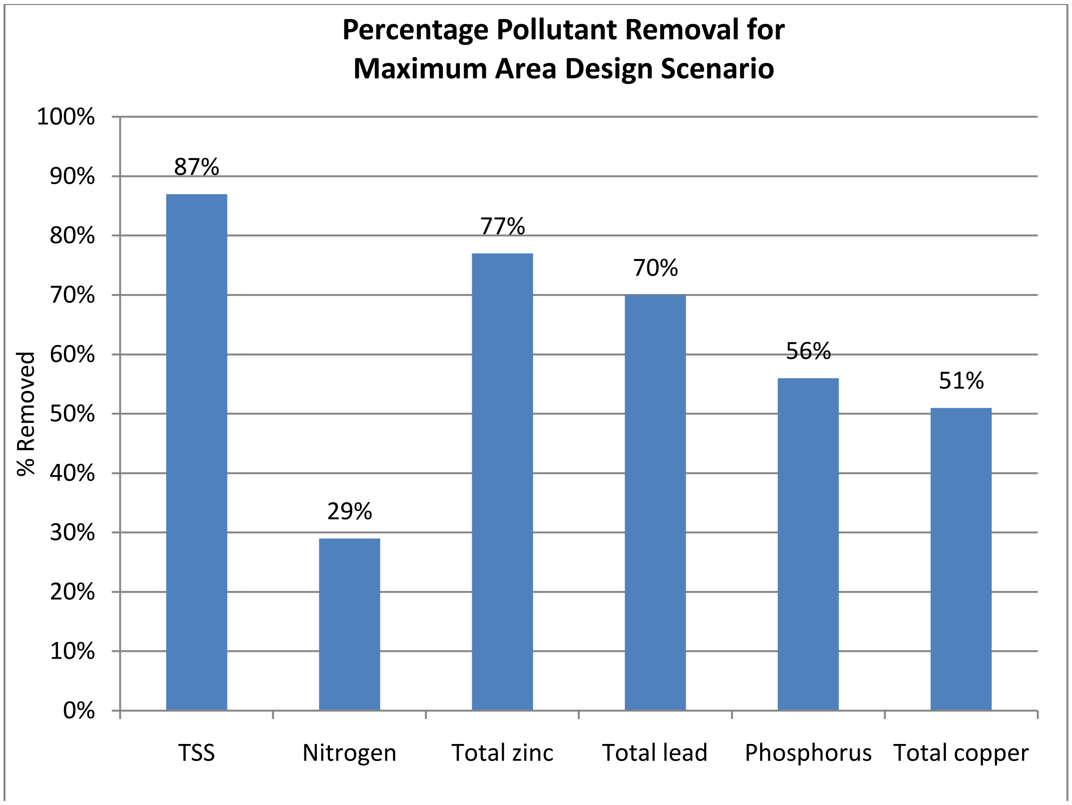

Figure 5.2 Percentage pollutant removal for Maximum Area design scenario, which includes permeable pavers and vegetation.

Additionally, the bioswale can capture 90% of copper in runoff. The difference in pollutant removal capacity between the Permeable Pavers and Nodes Scenario, and the Permeable Pavers Only scenario is minimal. The only change in design between these two scenarios is vegetated nodes in the Permeable Pavers and Nodes Scenario. Additionally, the Only Nodes Scenario has vegetated nodes, but does not incorporate permeable pavers, and the subsequent effect on pollutant removal is much less effective (Figure 5.3).

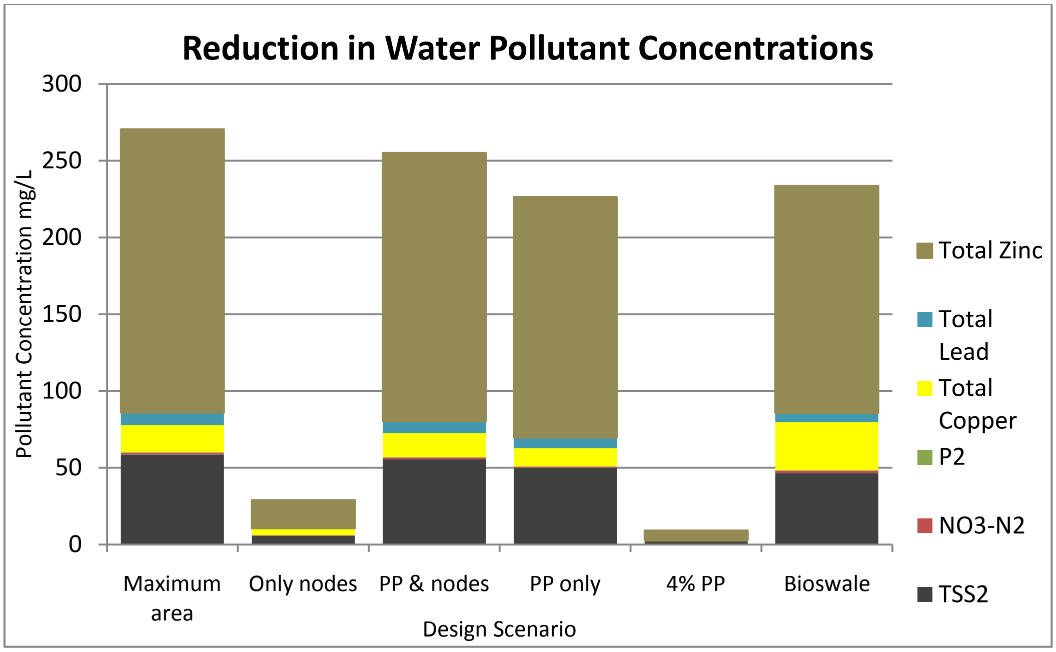

Figure 5.3 Reduction in water pollutant loading for each design scenario, based on ambient concentrations.

The minimal difference in pollutant removal with the added node space demonstrates that the vegetation in the node space has lower pollutant removal capabilities than permeable pavers, and thus does not significantly change stormwater quality. However, this does not mean that permeable pavers are uniformly more effective at improving water quality. The Bioswale scenario was nearly as effective as the Maximum Area design scenario at removing water pollutants. The Maximum Area design scenario has potential to uptake the most zinc, lead, phosphorus, and TSS, while the Bioswale scenario had the greatest capacity to uptake nitrogen and copper (Figure 5.4).

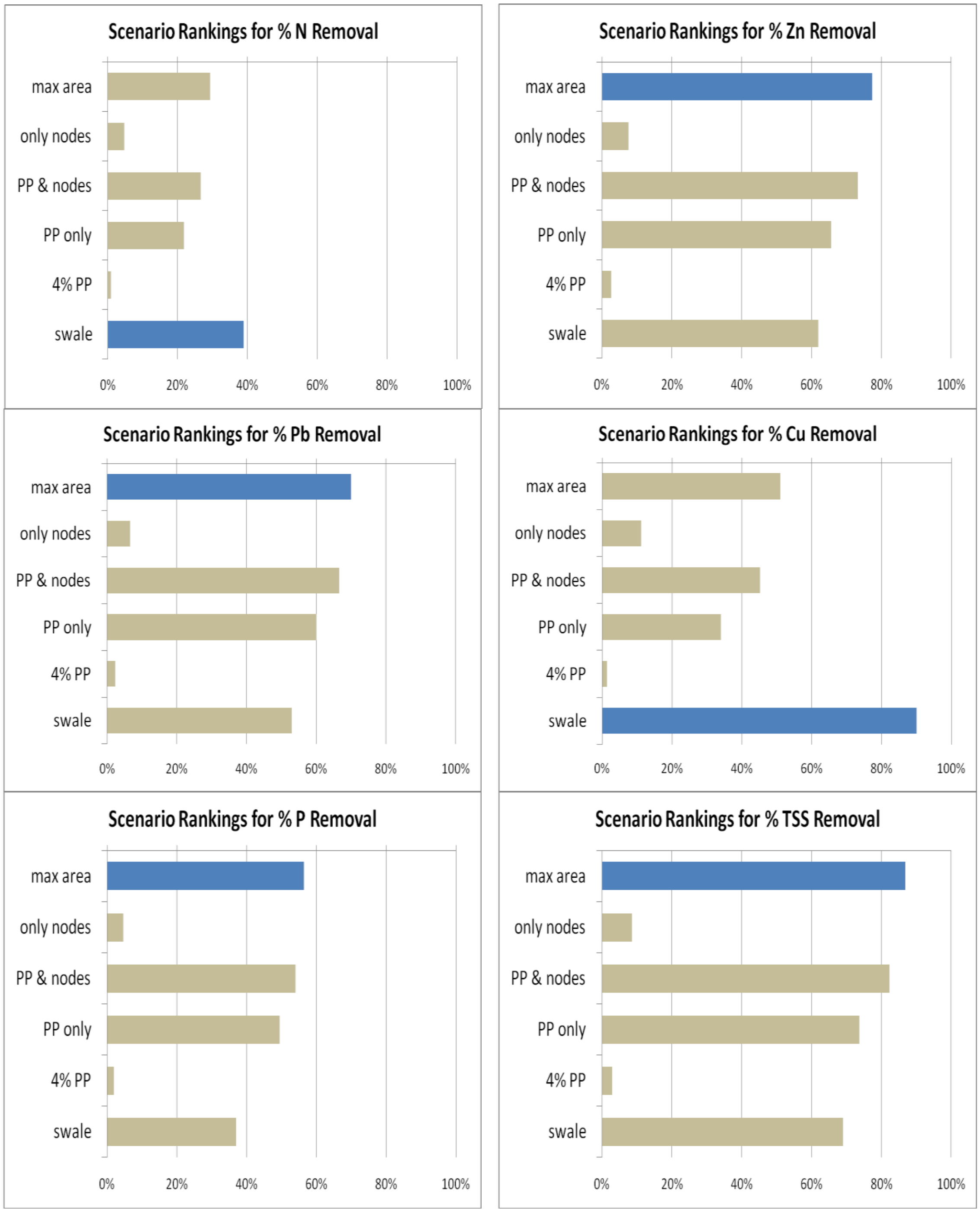

Figure 5.4 Percent removal of nitrogen, zinc, lead, copper, phosphorus, and total suspended solids for each design scenario in Harlem Place

Stormwater Runoff Reduction

We used L-THIA to calculate the reduction in runoff provided by each of our design scenarios, based on the percentage of site area retrofitted with permeable pavers and vegetation. By using many years of climate data in the analysis, L-THIA focuses on the average storm impact, rather than an extreme year or storm event. L-THIA calculates baseline runoff volume based on averaged annual precipitation for our site location; we estimate that Harlem Place receives 412,266 gallons of stormwater annually. The Bioswale Scenario enables Harlem Place to potentially capture all stormwater runoff hitting the alleyway, nodes, and 2% of the parking lot area. This is based on the assumption that our bioswale of 11,616 sq ft., can service a paved area of 290,400 sq. ft. (US EPA, 2005), which is much larger than the 57,313 sq ft. of our Harlem Place case study. However, this is a conservative estimate. The decrease in runoff from our six design scenarios is shown below in Table 5.2.

Runoff Leaving Harlem Place						
Design Scenario	**Permeable Surface**	**Vegetation**	**Trees**	**Paved**	**Total Runoff from site**	**Runoff Reduction from Baseline**
Maximum Area	63,428	2,303	112	0	65,843	346,422 **(84%)**
Only Nodes	0	1,678	0	36,1308	362,986	49,279 **(12%)**
Permeable Pavers and Nodes	63,428	,678	0	27,080	92,186	320,079 **(78%)**
Permeable Pavers Only	63,428	0	0	78,038	141,466	270,800 **(66%)**
4% Permeable Pavers	2,537	0	0	398,896	401,434	10,832 **(2.6%)**
Bioswale	0	0	0	0	0	412,266 **(100%)**
Baseline	0	0	0	412,266	412,266	0 **(0%)**

Table 5.2 Amount of runoff (in gallons) escaping from Harlem Place per each design scenario. Note the 100% reduction in runoff from the Bioswale Design, and the 84% reduction in runoff from the Maximum Area design.

The runoff reductions from greening Harlem Place can be compared to current baseline conditions. Currently, the alleyway, nodes, and 2% parking lot spaces are entirely impervious. The total runoff from the site is 412,266 gallons. We summarize the reduction in runoff from this baseline number for the six design scenarios in Figure 5.5.

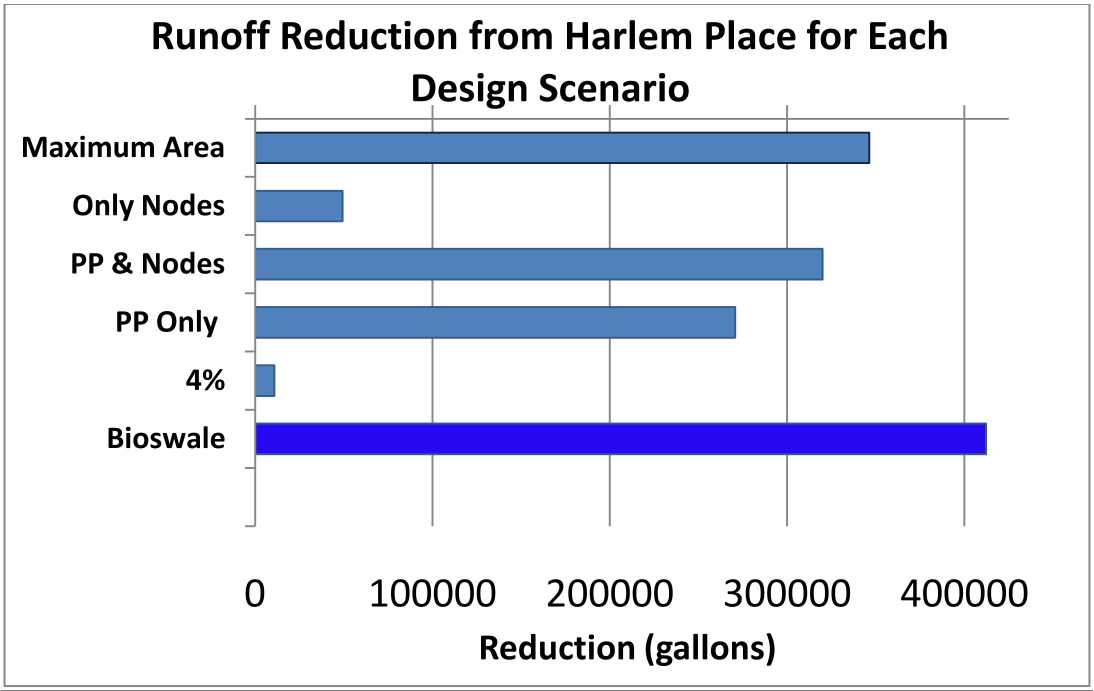

Figure 5.5 Reduction in runoff volume (in gal) for each design scenario in Harlem Place.

Our site survey revealed that roof drains outfall into the alley. Therefore, we also estimated the water quantity that would be produced from the buildings' rooftops lining both sides of Harlem Place. Using runoff coefficients for rooftops and estimating the net roof surface area with Google Earth, we estimated the impact of our Bioswale design on reducing the net runoff assuming all roofs drain to the alley. Based on the size of the bioswale used, we estimate that the Bioswale design could capture 54% of the roof drainage from buildings, in addition to the runoff from the site itself. However, these impacts are relevant on both a local and regional level if replicated throughout the city. For example, our Maximum Area design scenario can reduce stormwater runoff by 346,422 gallons. If redevelopment of our Maximum Area design was extrapolated out to the 900 miles of alleys currently in LA (assuming average alley width of 15 feet), cumulatively, these redeveloped alleys could capture 75,543,600 gallons of runoff from a 1-year storm event, 155,530,971 gallons from a 5-year storm event and 235,518,328 gallons from a 25-year storm event (Table 5.3). This amount of runoff reduction is equivalent to 0.5% of the net runoff in L.A. Based on these results we can conclude that permeable pavers and bioswales have the capacity to capture more stormwater than vegetated nodes and trees in Harlem Place.

Stormwater Capture Potential of Green Alley Redevelopment (gal)			
Storm Event	Volume of LA Rainfall	Harlem Place Potential (including roof drainage)	Cumulative LA Alley Potential
1 Year	14,722,771,800	646,851	75,543,615
5 Year	30,311,589,000	895,236	155,530,971
25 Year	45,900,406,200	1,143,620	235,518,328

Table 5.3 Volume of runoff generated by 1-Year, 5-Year, and 25-Year storm events in Los Angeles and capabilities of runoff capture from the Max Area design scenario for Harlem Place compared to potential if all LA alleys were redeveloped according to the Max Area scenario.

Conclusions

For Harlem Place, our modeling suggests that greenspace redesign has the potential to capture close to all stormwater runoff falling onto the study site (over 400,000 gallons annually). Additionally, a bioswale would be able to capture over half of the runoff drainage from roofs abutting Harlem Place. Even converting only 4% of Harlem Place to permeable pavement would result in an annual reduction in stormwater runoff of more than 10,000 gallons. Additionally, each design scenario has the capacity to absorb common runoff pollutants. To provide context Table 5.4 below, shows ambient concentrations of copper, lead, and zinc in Harlem Place Runoff in comparison to EPA drinking water standards.

Pollutant Reduction in Maximum Area Design Scenario			
	Baseline Loads for L.A.	Loads Reduced To	EPA Drinking Water Standards
NO3	4.09 mg/L	2.89 mg/L	10 mg/L
COPPER	34.77 mg/L	17.01 mg/L	1.3 mg/L
LEAD	11.53 mg/L	3.46 mg/L	0.015 mg/L
ZINC	238.53 mg/L	53.9 mg/L	5 mg/L
TSS	67.4 mg/L	8.87 mg/L	500 mg/L

Table 5.4 Water pollutant reduction from Maximum Area Scenario, compared to EPA drinking water quality standards
Source: US EPA, 2009b

Although stormwater runoff does not need to be cleaned to such stringent standards, it serves as a basis of comparison in terms of human health. The Maximum Area design scenario can reduce 77% of zinc and 70% of lead in stormwater, while the bioswale can effectively absorb 90% of copper in runoff. Other redesign scenarios, particularly the Only Nodes and 4% Permeable Pavers scenarios, can take up only minor amounts of all pollutants measured. However, reducing water pollution by as much as 90% in the alley can have significant ecological and human health effects on a local level and regionally if more greenspace projects occur throughout the watershed.

Overall, each design scenario has a measurable impact on stormwater runoff quantity and quality. Although certain impacts are minor, the Bioswale and Maximum Area redesign had significant local impacts. There is potential for all of these effects to be aggregated with other potential greenspace projects and extrapolated to a regional scale.

5.2 Urban Heat Island Effect

Figure 5.6 shows our result of a conceptual model for mitigation of the urban heat island effect. The following section refers to the conceptual model below and discusses the results of this model and how we tailored it to Harlem Place.

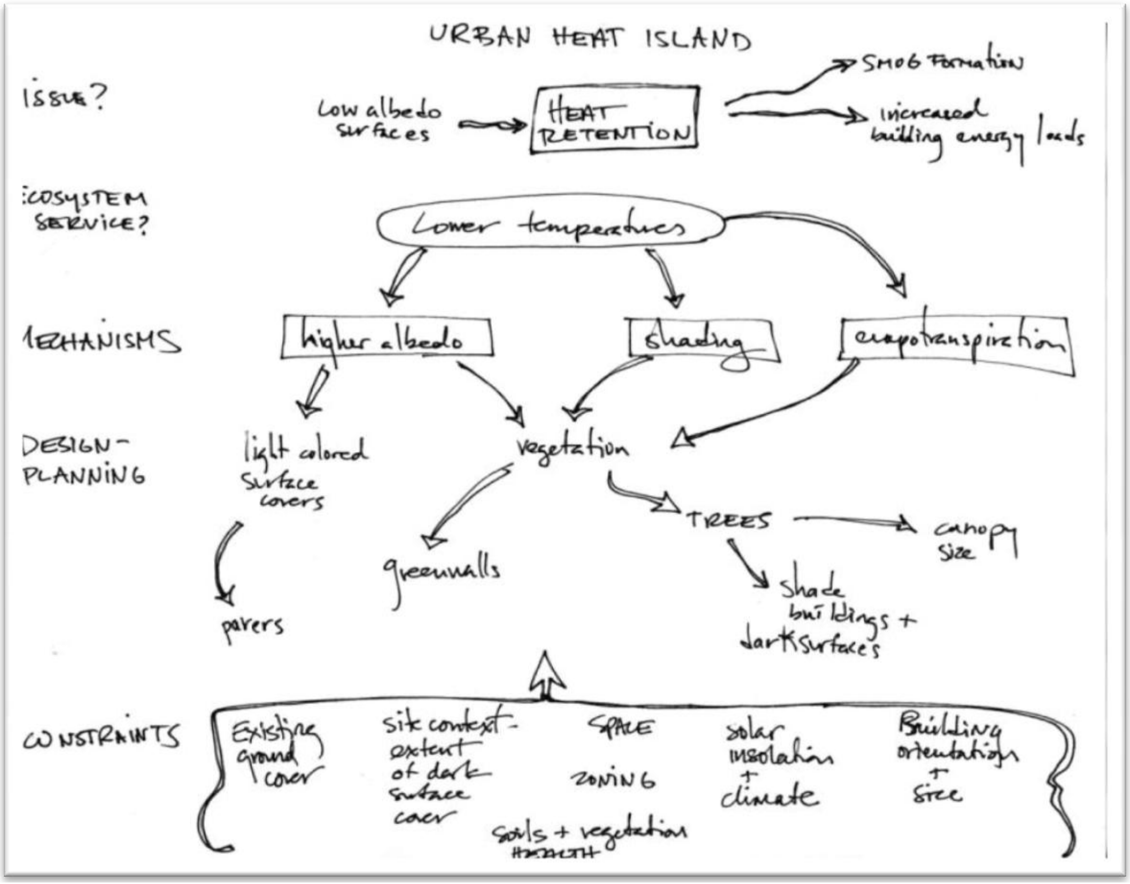

Figure 5.6 Conceptual model of urban heat island mitigation and the corresponding ecosystem services that provide the mitigation capacity.

What is the Issue?

A microclimate is the interaction of the built environment with weather on localized scales; air temperature, solar radiation, humidity, precipitation, topography, vegetation, surface type and building characteristics all affect the microclimate. In cities, a significant problem known as the urban heat island effect causes near-surface air temperature elevation relative to pre-urbanized conditions or rural areas outside the city. Several factors and conditions lead to the heat island effect. Changes in surface cover can result in reduced evapotranspiration and increased heat storage in darker (low-albedo) surface materials; anthropogenic heat release can occur from energy consumption and waste heat rejection, heat stagnation can exist within dense human infrastructure, and greenhouse effects of localized particulate air pollution can raise temperatures (Japan Ministry of the Environment, 2000). When areas are developed, low-albedo surfaces generally increase, causing heat to be stored and released slowly. These changes in surface heat storage both decreases comfort and increases energy demands as buildings require more air conditioning to combat elevated outdoor temperatures (Rosenzweig et al., 2005). While shaded, light-colored, or moist surfaces have comparable temperatures to surrounding air temperatures, on a hot, sunny day, urban surfaces can reach temperatures 50–90°F (27–50°C) hotter than ambient air (Berdahl & Bretz, 1997).

As air temperature is related to the formation of smog, the urban heat island effect can also increase urban smog formation and degrade air quality. This heat island effect will likely be intensified with climate change and can be more drastic during heat waves. This issue is particularly relevant to L.A. in the summertime, when low wind speeds and high temperatures are common (Rosenzweig et al., 2005). Figure 5.7 demonstrates an urban heat island profile for different land uses.

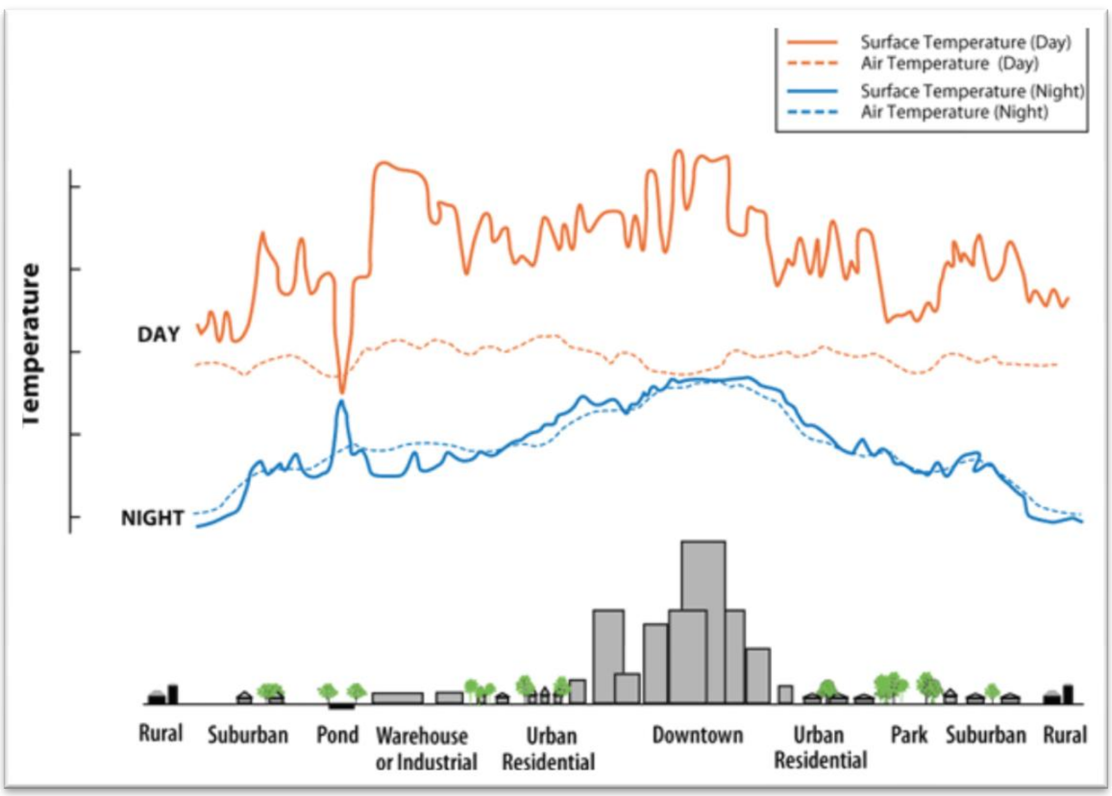

Figure 5.7 Urban Heat Island Profile
Source: U.S. EPA, 2009a.

How Can a Redesign Decrease the Urban Heat Island Effect?

In order to understand the impact of various types of greenspace on urban heat island, our project considered how various design and natural features can address the issue of low-albedo surfaces and subsequent increased outdoor temperatures, smog formation, as well as increased indoor building energy loads. To ameliorate these conditions, our conceptual model focuses on increasing albedo, shading dark surfaces and buildings, and increasing evapotranspiration, which provides a cooling effect on localized microclimates. Replacing or shading low-albedo surfaces with vegetation or higher-albedo surface features can decrease the amount of radiation absorbed (Carver et al., 2004). Additionally, increasing vegetation increases evapotranspiration and its cooling effect, as plants transpire water vapor through open stomata during photosynthesis. However, an important issue to consider is where, or on what scale a design feature's impact on microclimate and the urban heat island effect will be felt.

Shading

Many studies find that tree planting is one of the most cost-effective means of mitigating urban heat islands. Trees shade to surrounding pavement surfaces can reduce asphalt temperatures by as much as 36°F within the proximate shaded area (Dixon, 2007). While trees yield the greatest mitigation effects on the heat-island effect, well-sited shrubs, green roofs and walls also provide these benefits to urban microclimates. One study found that greenwalls alone could reduce daytime temperature maximums from 2.6 - 5.1 ˚C, and daytime temperature averages from 1.7 - 3.4 ˚C within the "canyon space" or alley between the buildings affixed with greenwalls. This study concluded that "if applied to the whole city scale, [green walls and green roofs] could mitigate raised urban temperatures, and especially for hot climates, bring temperatures down to more 'human-friendly' levels and achieve energy saving for cooling buildings from 32 - 100%" (Currie & Bass, 2005, p.493). In terms of design and planning, a notable conclusion was the impact of the width of the street "canyon" on the cooling effect. A critical and broadly relevant finding of the study was that the wider the canyon, the less effect the greenwalls would yield in terms of cooling effect (Jones & Alexandri, 2008). Thus greenwalls would yield greater microclimate mitigation on a single-lane alley.

Evapotranspiration

During photosynthesis, plants release water vapor through their stomata, the openings in the leaf surface. This transpiration of vegetation and most significantly, trees, can serve as natural air conditioning, helping to mitigate the effects of dark surfaces and glass that can make cities net heat storing and releasing environments. For example, the transpiration from a single large tree can produce the cooling effect of ten room-size air conditioners operating 24 hours a day (Sherer, 2003). The transpirations from a mature, well-watered tree with a 30-foot crown can be equivalent to on average, 40 gallons water/day. The cooling effect of this process can reduce annual cooling energy within a proximate home by 2%-8%, and reduce peak cooling by 1%-10% per tree (Rosenfeld et al., 1998).

In the same process, permeable pavers lower surface temperature via increased evaporative cooling. When water passes through the paving, some infiltrates into the underlying soil while some water remains in the paver matrix. This water later evaporates when warmed by solar insolation, drawing heat away from the pavement and yielding a cooling effect similar to vegetated land cover (Wong, 2005).

Albedo

Dark surfaces, such as asphalt and buildings, absorb solar insolation and reradiate this heat, increasing localized temperatures. Every 10% increase in solar reflectance can decrease surface temperatures by 7 ˚F (4 ˚C) (Wong, 2005) One study found that a combination of mitigation measures in L.A. including increased trees and vegetation as well as solar reflectance changes could decrease temperature by 1.5 ˚F (0.8 ˚C). The benefits associated with these temperature reductions and indirect benefits (energy savings and smog decrease) in L.A. from pavement albedo improvements would be more than $90 million (1998 dollars) per year (Wong, 2005). Examples of albedo surfaces in a built environment are shown below in Figure 5.8.

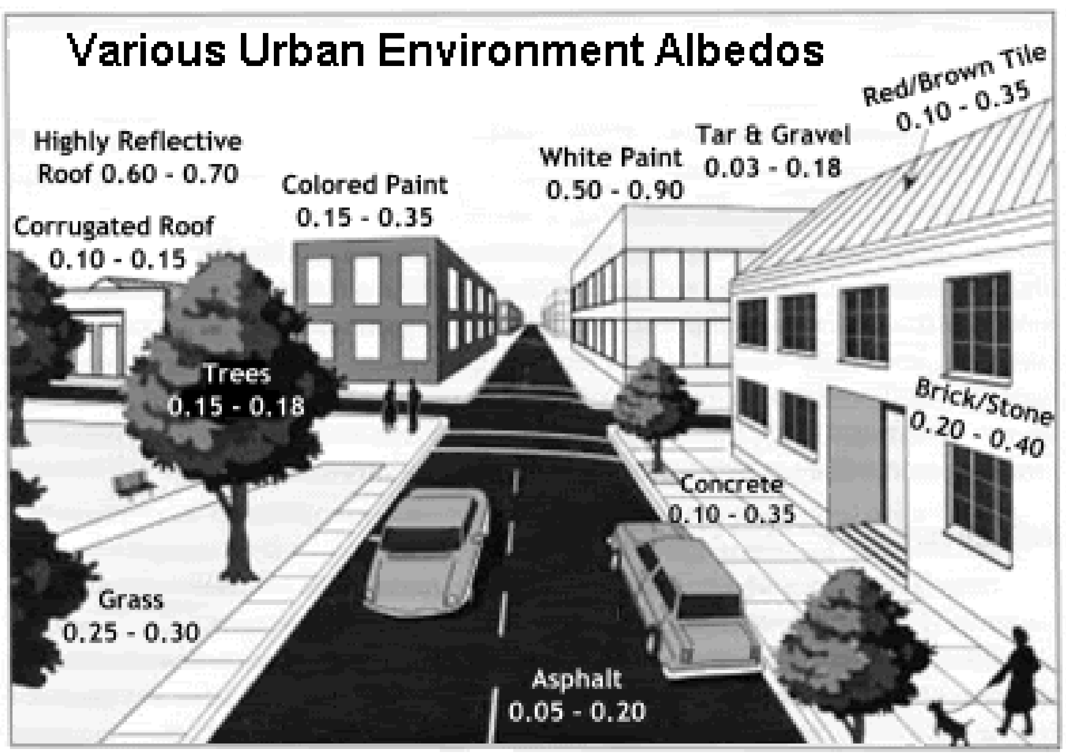

Figure 5.8 Common Urban Surfaces and Albedos.
Source: Goodman, 1999.

Heat Island Reduction Impacts for Reduced Building Load

Depending on tree size and location as well as building energy use and structure, even individual urban trees can yield energy conservation in buildings through their shading and transpiration (Carver et al., 2004). The resulting cooling of ambient temperatures decreases building cooling demands. Using Micropas4, a building energy analysis program, one study estimated cooling loads using hourly shading coefficients on a 1,761 sq. ft building with a tree assumed to block 85% of incoming solar radiation during in-leaf periods. With a 15-year old tree that is 24 ft. tall, energy savings can reach approximately 340kWh annually (McPherson, 1993). In terms of the cost-effectiveness of shade trees on reduced building loads, one study found that despite the time delay before optimal shading benefits while trees grow, small shade trees were second to increased building attic insulation in cost-effectiveness (McPherson, 1993). Within buildings, tree shading of windows and walls can decrease air conditioning use by 25-50%, whereas outdoors, the evaporation from one adult tree can result in a cooling effect comparable to ten room size air conditioners running 20 hours/day (Colorado Tree Coalition, 2009).

Application to Harlem Place

As explained above, greenspace can reduce the urban heat island effect and improve microclimate. To estimate impact, our project first identified design options that can reduce the urban heat island effect. We then applied these design options to Harlem Place factoring in site-specific constraints (Figure 5.6 above).

Shading & Evapotranspiration

During our site survey, we determined that the multistory buildings contiguous to Harlem Place are too tall for tree shade to have a significant impact on reducing internal building energy loads. Thus, the typical percent roof shade calculation for building energy load reduction estimation as used in iTree was not transferable to Harlem Place. However, there are opportunities to shade large glazed surfaces on the ground level floors, several of which are slated for gallery or shop space. Additionally, several restaurants and café entrances exist on Harlem Place, which may leave doors open during business hours and thus receive conditioning benefits from tree shading. In order for tree shade to have any impact on the interior building conditions along Harlem Place, tree shade must be optimized for windows, and particularly, the glass facades of first story shops and gallery spaces. Considering this evidence, we decided to focus on tree shading and greenwalls to impact the pedestrian experience along Harlem Place, as well as tree shading on dark parking lot surfaces.

Albedo

Considering the importance of solar reflectance on heat absorption, any replacement of paving in the Harlem Place design scenarios should increase reflectivity by specifying light-colored blocks or porous asphalt. During our site survey of the current conditions of Harlem Place, we found that the site is dark grey concrete. This concrete color is relatively light-colored compared to asphalt, but new pavers could still yield some increased reflectivity. However, the greatest impact on albedo would come from the Maximum Area design scenario, which includes redeveloping 2% of the parking lots (currently paved in dark asphalt) to vegetated space and using light-colored PICPs to resurface the service road portion of the site. Additionally, the trees planted in the Maximum Area design scenario are specified to shade the edges of the parking lot, thereby increasing reflectivity along the perimeter of the parking area. Considering the small size of Harlem Place in the context of Downtown L.A., any changes in albedo and decreased absorption of heat would only be felt within the microclimate of the alleyway. In order for greenspace to have a significant impact on the heat island of a city as a whole, greenspace projects would need to be distributed on a larger scale.

Reduced Building energy demand – iTree

Many studies of the impact of trees on energy loading by shading deal with the percent of shade covering small single family homes. As mentioned in section 4.1.2, iTree can be used measure the impact of shading. iTree focuses on buildings with elevations short enough for trees to shade the rooftop which receives the most direct and intense insolation. The percent shade over a building surface and roof is a critical factor in reducing building cooling load. As iTree assumes an energy load reduction by the implementation of city trees, this estimate may not be representative for certain sites and conditions. The effects of tree shading of tall multistoried buildings over four floors, such as the case in Harlem Place, is generally much less, as the percent of tree shade over the whole building is minimal and trees cannot shade the roof. Additionally, tree impacts on energy savings in winter rely on estimates of reduced wind infiltration, which are also based on smaller structures. Thus, for shade to have any impact on larger, multistory building conditions, tree shade must be optimized for windows, and particularly, any glass facades of first story shops and gallery spaces. While in many cases, trees may have no impact, trees that shade significant glazing, or open-air cafes on the ground floor could offer significant building load and comfort improvements.

Discussion of Results

Improved Local Microclimate & Aesthetics

Both the Maximum Area and the Bioswale design scenarios include a 10-foot vertical greenwall flanking the buildings. Based upon the Jones and Alexandri (2008) study, which quantified the impact of greenwalls on urban microclimate, our project was only able to provide an approximate estimate of the effects of greenwalls installed in Harlem Place due to time constraints and the level of site-specific calculations required. However, it is important to note the greenwalls would likely improve both air quality and mitigate some of the localized urban heat island effect. It is possible that lining the vertical building surfaces along Harlem Place could decrease the localized temperatures (within the human occupied area of Harlem Place) by 3-4 ˚F (1.7 - 2 ˚C).

To evaluate the impacts of our Maximum Area design scenario on the microclimate of Harlem Place, we first calculated the results of our tree planting using figures provided from Nowak and McPherson (1993), that within the proximity of the tree, a 0.04-0.2 ˚C temperature reduction can be realized per percent tree canopy cover increase. Under our model tree size of a 25-foot canopy, the total canopy cover of 45 trees in the Maximum Area design scenario would be 22,050 square feet. Under this canopy cover, pedestrians could experience a 7.2 ˚F, (4 ˚C) decrease in ambient temperature, a substantially cooler space compared to full sunlight. Considering the impact of both greenwalls and trees within this design, the microclimate within the human occupied space of Harlem Place could be enhanced by a net decrease in daily high temperatures of about 11˚F (6˚C).

Building Energy Demand

iTree also can calculate the energy savings by tree shading in the Maximum Area design scenario. Most urban tree models, as well as iTree, focus on buildings with elevations short enough for trees to shade the rooftop. Shading of roof and the percent shade of roof is a critical factor in reducing building cooling load. Thus, because the buildings lining Harlem Place are multi-story, it is unlikely the trees in Harlem Place will significantly reduce building energy loads. iTree estimates that 45 trees could reduce electricity demand by 2.63 MWh and natural gas by 8.55 therms annually. As discussed, due to issues of building scale and applicability to our site, we did not consider these estimates to be realistic. However, determining which tree species yield the greatest energy savings indicates the density and width of the canopy, and thus, the shade and microclimate benefits the trees could provide to pedestrians. The trees with the greatest impact were the California Sycamore, the Hackberry, and the Western Redbud.

Conclusion

The central impact of decreasing localized temperatures by shading, reflectivity, and evapotranspiration will affect the immediate microclimate within the alley, thereby improving the pedestrian experience of Harlem Place. Specifically, generating shading and increasing vegetation can decrease the localized temperatures for pedestrians utilizing the space, especially when under tree shade canopies. Planting trees to also shade ground level retail and commercial spaces that may have open doors and large glazed surface areas could also provide energy savings for buildings. Though we were unable to quantify the potential building energy savings, other greenspace projects surrounded by smaller buildings may benefit significantly from tree shading. Overall, our results indicate that our Maximum Area design scenario improves shading, albedo, and evapotranspiration, leading to greater human comfort within the alley. The Bioswale design scenario, which includes a greenwall, would reduce heat gain directly on the building wall on which it is affixed. While the greenwall and bioswale would both yield some cooling for the proximate spaces via evapotranspiration, this design scenario has no changes in other paving materials, nor tree shade, resulting in minimal impacts for occupants of the space due to decreasing temperatures. While the heat island effect can be mitigated within a site, the relative size of the design features in relation to surrounding buildings, dark surface area coverage, and the urban environment are critical constraints to the scale of impact on urban environments as a whole.

5.3 Air Quality

Very little data exists for the impact of small-scale greenspace on air quality. Figure 5.9 shows our result of a conceptual model for air quality. The following section refers to the conceptual model below and discusses the results of this model and how we tailored it to Harlem Place.

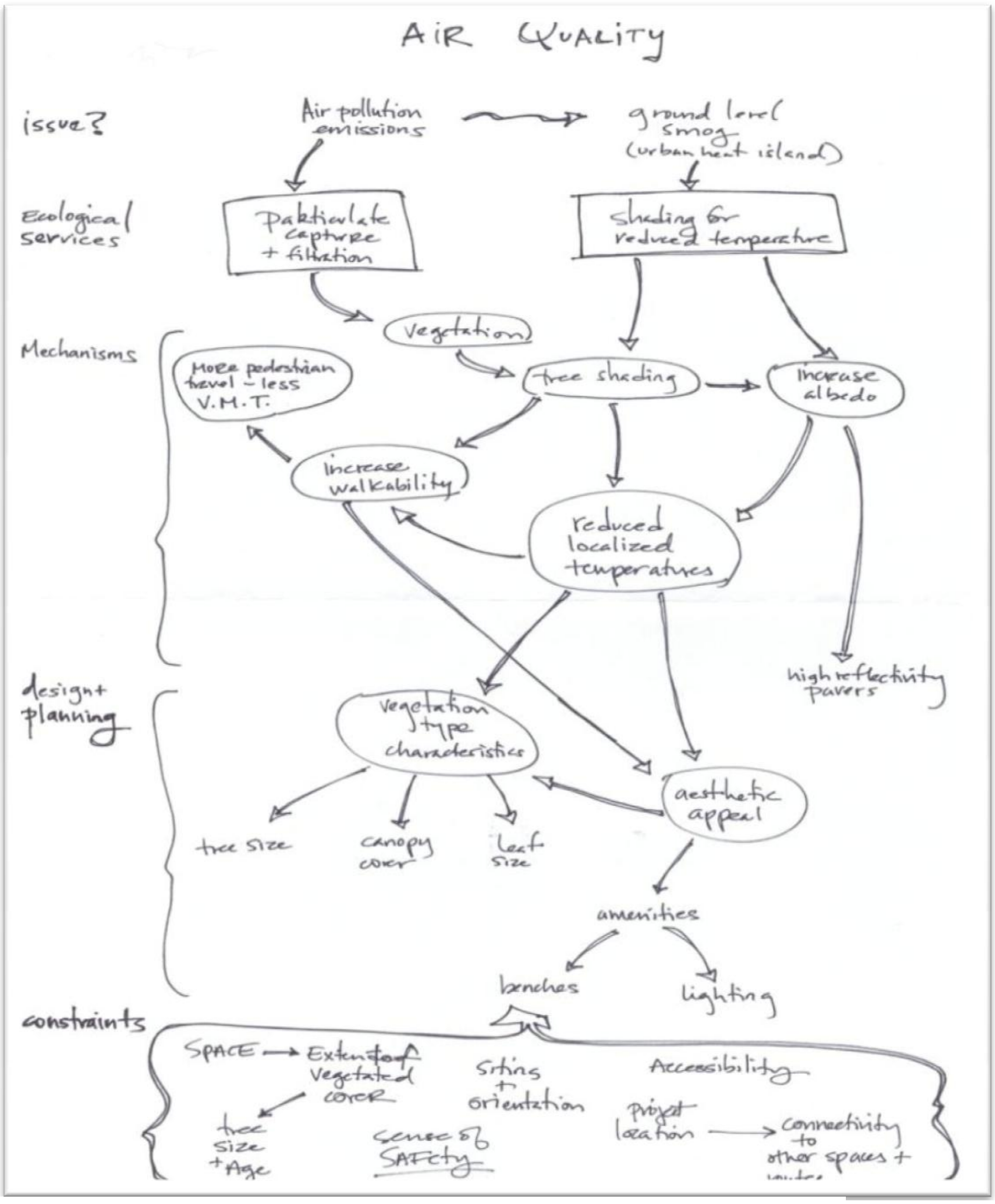

Figure 5.9 Conceptual model of air quality and the corresponding ecosystem services that provide the air quality amenity.

What is the Issue?

Air quality is an important amenity because of the harmful health impacts of airborne pollutants. In California alone, premature deaths linked to particulate matter are now at levels comparable to deaths from traffic accidents and second-hand smoke (California Air Resources Board, 2007). Figure 5.10 shows the health impacts of air pollution each year in California.

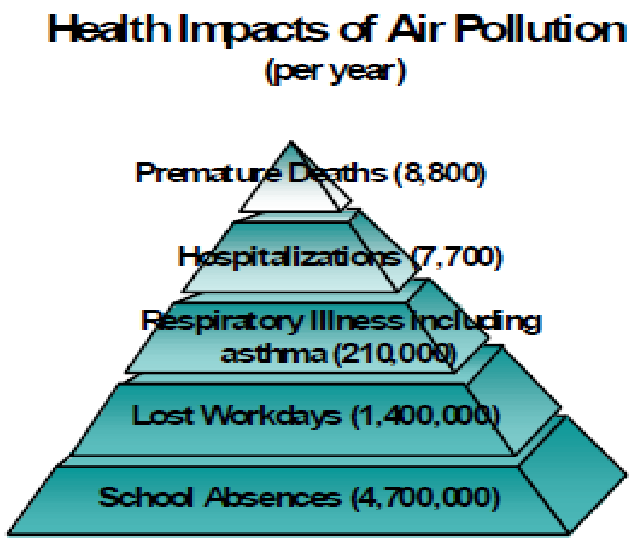

Figure 5.10 Annual health impacts from air pollution in California.
Source: CA Air Resources Board, 2007

Attaining the California particulate matter and ozone standards would annually prevent approximately 6,100 hospital admissions for respiratory disease, 1,500 hospital admissions for cardiovascular disease, 210,000 cases of asthma and lower respiratory symptoms (such as cough), and 17,000 cases of acute bronchitis. Air pollution not only affects city residents, but also aquatic and terrestrial ecosystems. For example, Los Angeles air pollution is a source of toxic metal pollution into the Santa Monica Bay; Air pollution contributes 50% of the chromium and 99% of the lead pollution going into the Bay (Jahagirdar, 2006).

How Can a Redesign Improve Air Quality?

The ecosystem services that provide better air quality include air pollution particulate capture, air pollution filtration, avoided emissions from energy production within buildings, and, on a larger scale, the associated avoided emissions from power plants. Greenspace can improve air quality by incentivizing pedestrian movement; creating engaging streetscapes that buffer street noise and provide shade encourage humancentered movement, thereby decreasing automobile use and the associated vehicular exhaust and smog. Studies show that busy roads can degrade air quality within a 50-100 meter radius and even exposure in short durations can be harmful to human health (Nowak, 1994). By strategically placing trees to block, absorb, and decrease gaseous pollutant concentrations in the air, emissions can be significantly reduced.

The U.S. Forest Service calculated that over a 50-year lifetime, one tree generates $31,250 worth of oxygen, provides $62,000 worth of air pollution control, recycles $37,500 worth of water, and controls $31,250 worth of soil erosion (Sherer, 2003). The effect of planting ten million urban trees annually in the U.S. was modeled for impact on atmospheric CO_2 over a 50 year time period. In the year 2040, these trees would have stored 85 million tons of carbon and prevented the production of another 315 million tons of carbon (Nowak, 1993). One study found that Chicago's urban forest canopy saves the city over $1 million annually in pollution control services, such as reduced CO, SO_2, NO_2, O_3, and particulates (Scheer, 2001). A Sacramento tree-planting initiative in the 1990's reduced city CO_2 levels by 200,000 metric tons annually, subsequently reducing taxpayer burden by $3 million each year (Scheer, 2001). Trees in New York City removed an estimated 1,821 metric tons of air pollution in 1994 (Sherer, 2003).

The air quality "issues" to address in the urban environment are air pollution emissions and the formation of ground-level smog. The ecosystem services provided by greenspace that mitigate these issues are particulate capture, reduced localized temperature to prevent ozone formation, and improved walkability. The "mechanisms" that can provide these ecosystem services are tree plantings and increasing surface albedo. Next, "design considerations" include the types of vegetation, ranging from the kind of tree species, the tree canopy size and shade capacity, and the availability of space for the tree in the urban setting.

Application to Harlem Place

Based on the DLANC survey of Harlem Place residents, air quality is of high importance to the local community. Harlem Place is flanked by numerous parking lots; ground-level ozone from parked cars is a major source of smog pollutants. Parked cars emit hydrocarbons from gasoline evaporating out of leaky fuel tanks and worn hoses; these emissions are a significant component of urban smog, comprising as much as 20% of the total inventory of emissions. Greenspace, particularly tree plantings, can help address this air quality issue. Shaded parking reduces these emissions by lowering air temperatures 1-3 degrees Fahrenheit, gasoline temperatures 4-8 degrees F, and temperatures inside the car by as much as 40 degrees F. Support for shading and other greenspace measures are evidenced by the fact that California currently funds tree planting in parking lots as an air quality improvement measure due to their significant impact on local air quality (McIntyre, 2008).

Urban smog is further exacerbated by the urban heat island effect, discussed in greater detail in Section 5.2. This demonstrates that one design technique, such as tree planting, can have effects on multiple issue areas. Because Harlem Place is lined with numerous parking lots, vegetation can play a significant, measurable role in improving air quality. Our Maximum Area design scenario places trees along the parking lots to help maximize air particulate capture and shade parked cars to mitigate ground level ozone formation.

To quantify air pollution reduction in Harlem Place, we used the iTree Streets model to determine the particulate capture capabilities of our selected tree species. iTree "quantifies the air pollutants (O_3, NO_2, SO_2, PM_{10}) deposited on tree surfaces and reduced emissions from power plants (NO_2, PM_{10}, VOCs, SO_2) due to reduced electricity use (measured in pounds or kilograms)" (McPherson et al., 2005, p. 42). Our project focuses primarily on the deposition results from iTree because reduced building energy load in Harlem Place would be negligible, due to space constraints and building heights. Furthermore, design constraints within Harlem Place dictate that we cannot rely solely on trees to capture air particulates. Thus, we used iTree primarily as the starting point for obtaining data on air quality. Additionally, we used literature review and other sources to supplement our data and estimate the air particulate capture abilities of shrubs and greenwalls. It must be noted, however, that very little scientific inquiry has been made to the air quality impacts of shrubs and greenwalls. There is a general consensus that greenwalls have air quality benefits as well as protect buildings from graffiti and acid rain degradation, but no extensive formal study currently exists.

Air Quality Results

Local Impacts

The Maximum Area scenario is the only design scenario in which we quantified the ecosystem service impacts of trees. Thus, this design will demonstrate Harlem Place's potential for improving air quality. In the Maximum Area scenario, we simulated planting 45 trees, or nine each of these five species: the Western Redbud, London Planetree, Western Hackberry, California Sycamore, and the Lacebark (Chinese) Elm. Using iTree, we found the air particulate capture capabilities of these trees and quantified them for Harlem Place. Overall, the Western Hackberry and the London Planetree had the greatest air pollutant reduction impacts (Table 5.5).

Air Pollutant Reduction for Hackberry & Planetree				
	O_3	NO_2	PM_{10}	SO_2
Western Hackberry	3.96	1.89	2.34	0.18
London Planetree	4.3	1.71	2.16	0.09
Total (all trees)	19.4	9	11.1	0.6

Table 5.5 Annual deposition rates of common air pollutants (in lbs)

We compared the five selected species to two species with inferior air particulate capture capabilities that are commonly planted in Los Angeles in order to demonstrate the increase of particulate capture if species selection is considered more in designing greenspaces (Figure 5.11).

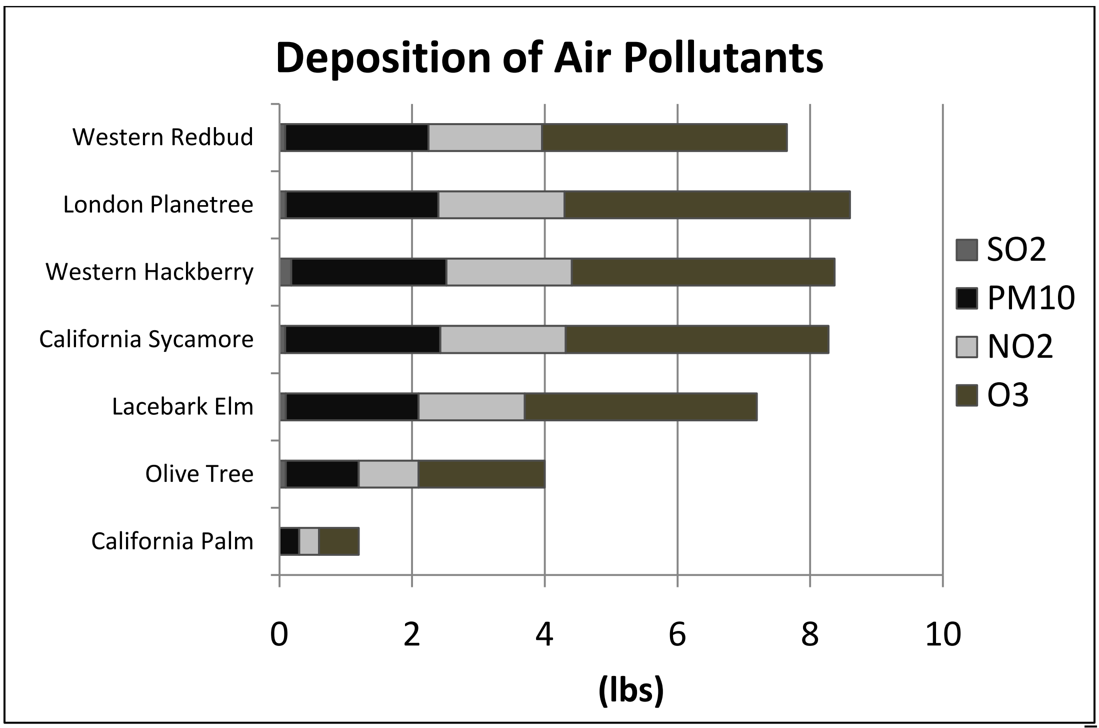

Figure 5.11 Deposition (removal of pollutants) of four primary air pollutants onto the five different tree species (nine trees per species) for Harlem Place, as well astwo additional species to demonstrate the superior air particulate capture capabilities of those species selected for Harlem Place.

To give context and meaning to our results, we compared the pounds of air pollutants removed annually from Harlem Place with EPA secondary standards for ambient air quality (Table 5.6).

EPA Secondary Air Quality Standards				
	O_3	NO_2	PM10	SO_2
EPA secondary standards	0.075 ppm	100 ug/m^3	150 ug/m^3	1300 ug/m^3
Annual LA concentrations	0.073 ppm	0.0275 ppm	30.9 ug/m^3	0.0003 ppm
Pollutants in Harlem Place (lbs)	152.17 lbs	53.88 lbs	68.79 lbs	0.894 lbs
Annually allowable by EPA (lbs)	52.11 lbs	104.22 lbs	156.34 lbs	1354.92 lbs

Table 5.6 Air pollution removed using Harlem Place redesign compared to EPA secondary standards, in concentrations (ppm) or mass (lbs)
Source: US EPA, 2010

We also determined current levels of air pollution in Downtown Los Angeles using the South Coast Air Quality Management District's 2008 report on air pollution levels. We assume a volume of air above Harlem Place to serve as the zone of air from which our pollutants are being removed. Using the width of our alley, 20 ft (6.1 m), the length of the alley, 2323.2 ft (708.1 m), and a typical mixing height of 300 m, this yields a volume of air in Harlem Place of 1,294,994 m^3. Using conversion factors and this volume of air, the South Coast Management District concentrations were converted into annual pounds of pollution in Harlem Place. Next, the EPA secondary standards for ambient air quality were also converted into annual lbs of pollution within the Harlem Place air volume. Finally, by comparing the EPA standards to both the current pollution levels in Harlem Place and the new pollution levels after trees remove pollutants in our Maximum Area scenario, we determined the results shown in Figure 5.12

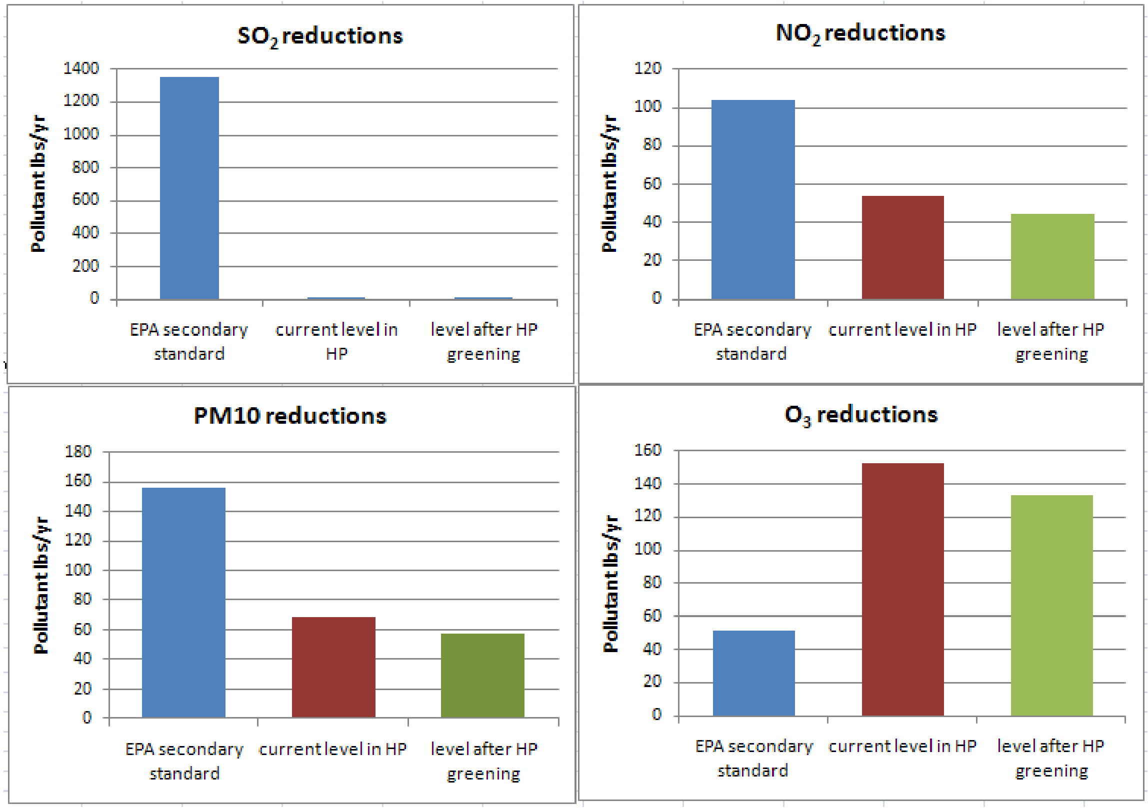

Figure 5.12 Comparison of EPA secondary air quality standards and reductions in air pollutants as a result of trees planted in Harlem Place.
Source: US EPA, 2010

As illustrated in Figure 5.12 the impact of SO_2 in Los Angeles is negligible. There are not coal-fired power plants in California, which is typically the major source of this pollutant. Downtown Los Angeles is currently in compliance with EPA secondary standards for NO_2 and PM_{10}, however, Harlem Place greenspace improves on this standard. In contrast, Downtown Los Angeles is out of compliance with ozone levels. However, adding greenspace to Harlem Place was not substantial enough to improve air quality to meet EPA standards, although the Maximum Area scenario removed approximately 20 lbs of ozone.

In addition to deposition, iTree can also model the impact trees have on reducing power plant emissions. Trees have a shading and cooling effect on surrounding buildings which reduces demand for air conditioning, thus requiring less energy production at power plants. As discussed earlier, there is much uncertainty in this calculation, and while strategically placing trees to shade large windows and door entrances would yield some energy load reductions, the trees' impacts on building energy demand for multi-story buildings, such as the ones lining the Harlem Place alley, are not likely to have an effect. Furthermore, iTree does not calculate $PM_{2.5}$ pollution, which would be useful information, since the Downtown area is out of compliance with the $PM_{2.5}$ federal standards at least 10 days a year.

Regional Impacts

Though air quality improvements in Harlem Place may have negligible impacts on the greater Los Angeles area, it is important to realize that the cumulative effects of numerous alleyway greening projects can play an important role in citywide air quality improvement. From "Air pollution removal by urban trees and shrubs in the United States" by Dave Nowak:

> Through pollution removal and other tree functions (e.g., air temperature reductions), urban trees can help improve air quality for many different air pollutants in cities, and consequently can help improve human health. While the existing percent air quality improvements due to pollution removal by urban trees are modest, they can be improved by increasing urban tree canopy cover. The combined total effects of trees on air pollutants are significant enough that urban tree management could provide a viable means to improve air quality and help meet clean air standards in the United States (2005, pg. 122).

Los Angeles has 900 linear miles of alleyways. Extrapolating from the 40 lbs of total air pollutants removed from the Maximum Area design scenario in Harlem Place, and given that Harlem Place is approximately 0.5 miles in length, we can predict an estimated 72,000 lbs of air pollutants removed from Los Angeles if similar greenspace projects were adopted citywide.

Air pollutants can be highly mobile and affect a much larger area than their source. Although Downtown Los Angeles is in compliance for many major air pollutants, the Downtown receives coastal breezes blowing air pollutants east, towards the mountains over areas such as Riverside and San Bernardino. Therefore, it is still important to reduce air pollution further in Downtown in order to mitigate regional pollution caused by pollutants traveling inland via predominant wind patterns.

Conclusion

Given the desires of the Harlem Place community to improve their local air quality, including design features such as trees and greenwalls in a Harlem Place redevelopment would work towards this goal. Our Maximum Area scenario for air quality in Harlem Place calculates that small-scale greenspace redevelopment has the potential to remove 40 lbs of air pollutants annually, simply by planting trees. Improving air quality in Harlem Place would promote the health of residents and preserve building facades along Harlem Place.

5.4 Mitigation of Carbon Dioxide Emissions

The conceptual model for CO_2 mitigation is shown below in Figure 5.13. The following section refers to the conceptual model below and discusses the results of this model and how we tailored it to Harlem Place.

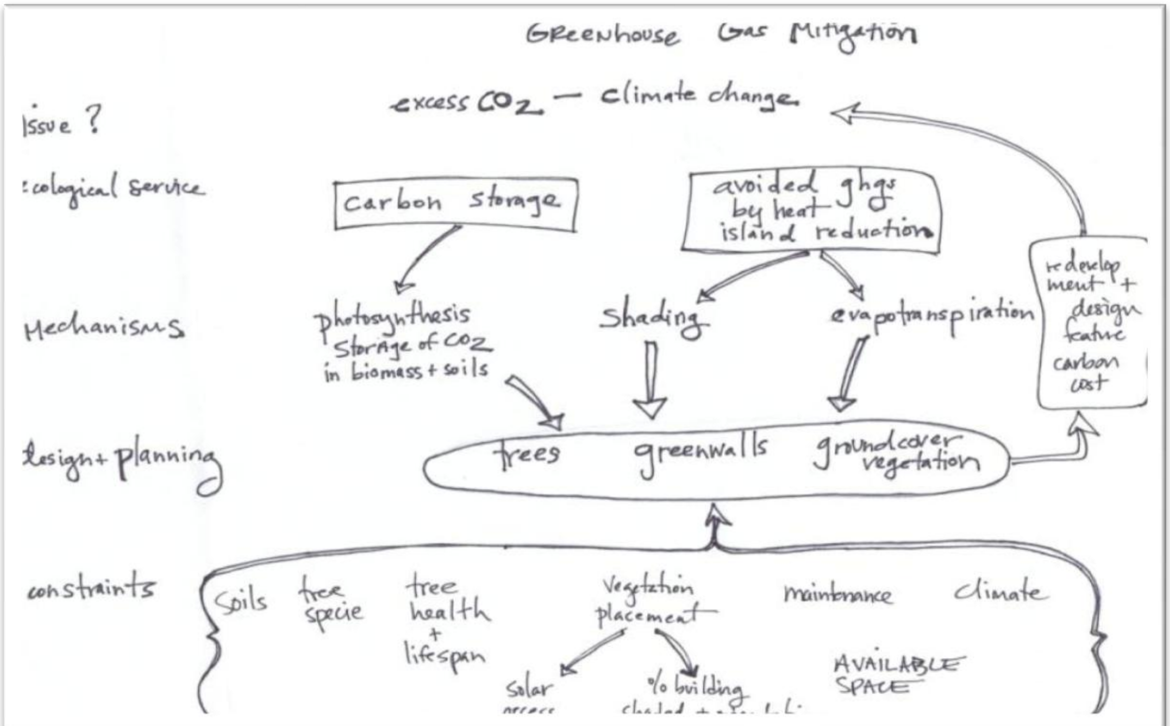

Figure 5.13 Conceptual model of mitigation of CO_2 emissions and the corresponding ecosystem services that provide the mitigation capacity.

What is the Issue?

As global climate change gains prominence and legitimacy on the international political agenda, finding both mitigation and adaptation strategies are of increasing importance. Anthropogenic emissions of carbon dioxide are one of the main contributors to global warming and have been increasing exponentially over the past 100 years. One of the mitigation strategies, along with cutting emissions, is promoting biological sequestration of atmospheric carbon through biomass.

During photosynthesis, vegetation converts sunlight and CO_2 into glucose and O_2; a plant can store that carbon as biomass until it eventually dies and decomposes, releasing the carbon back into the environment. This makes the ecosystem service of carbon storage highly temporal in nature, and subject to a variety of constraints. Constraints from the natural environment that impact carbon storage include species, soil type, climate, and topography. Urban vegetation also contends with the constraints presented by the human built environment, including size of planting site, irrigation requirements, and maintenance.

How Can a Redesign Affect Carbon Sequestration?

Carbon storage in biomass is not the only means by which vegetation reduces greenhouse gas emissions. In fact, there are three separate processes that allow vegetation to reduce CO_2 emissions: direct carbon sequestration; avoided CO_2 generation from reduced building heating and cooling demands resulting from shade and buffering; and reduced building energy heating and cooling demand by mitigating the urban heat island effect. On average, for every kWh of electricity created, about 1.39 pounds of carbon dioxide is released in the air (McPherson, 2007). Urban trees mitigate this effect by saving 3 kg of carbon per year by lowering the city's overall need for air conditioning due to urban heat island effect mitigation. This same tree will save an additional 15 kg of carbon if it directly shades a building (Rosenfeld et al, 1997). Additionally, an urban tree with a 25-foot crown saves 40-300 kWh by reduced air conditioning demand and 0.15-0.5 kW during peak cooling demand (McPherson, 2007).

Application to Harlem Place

Carbon savings from avoided emissions vary widely depending upon siting and building size. Harlem Place is lined primarily with buildings that are four-stories or more, which means that any shading would not have a significant impact on building energy demand. Additionally, planting 45 trees would not have enough of a cooling effect to reduce air conditioning demand in Downtown L.A. Although greenwalls and groundcover also have potential to sequester atmospheric carbon, on the scale of Harlem Place, the effects would be negligible. Therefore, we chose to model carbon sequestration for the Maximum Area design, as it was the only relevant effect for Harlem Place. We used two different methods of modeling carbon sequestration potential of our Maximum Area design scenario: iTree and custom calculations based on literature review.

Carbon Sequestration Results

First, we used iTree to measure the total pounds of carbon sequestered annually from the 45 trees representing five different tree species modeled in the Maximum Area design scenario, resulting in 3,015 lbs/yr. This estimate from iTree measures the amount sequestered per tree, taking into account the amount of carbon released from decomposition at the end of the tree’s life as well as anticipated carbon releases from maintenance.

From literature review, we found that carbon sequestration in shade trees occurs at a rate of 4.5 – 11kg/yr on average (Akbari, 2002). Therefore, we modeled the amount of carbon sequestered by the 45 trees in the Maximum Area design scenario annually based on this range. As seen in Table 5.7, this resulted in a low estimate of 445.5 lbs/yr, a mid-range estimate of 767.25 lbs/yr, and a high estimate of 1089 lbs/yr. While some studies find that a typical tree can reduce atmospheric carbon dioxide by approximately 200 lbs pounds annually over a 40-year period, we used the more conservative estimate of 4.5-11kg/yr (McIntyre, 2008).

Carbon Sequestration Estimates of Literature Review vs. iTree Model (annual)			
Literature Review	Low Estimates (4.5 kg/yr)	Medium Estimate	High Estimate (11 kg/yr)
kg	202.5	348.75	495
lbs	445.5	767.25	1089
iTree Estimates (lbs)	Carbon Sequestered (lbs)	Decomposition & Maintenance (lbs)	Net sequestration (lbs)
Hackberry	810	-58	752
Western Redbud	104	-37	67
London Planetree	810	-58	752
California Sycamore	810	-58	752
Lacebark (Chinese) Elm	737	-45	692
TOTAL			3015

Table 5.7 Carbon sequestration potential of literature review compared to estimates based on project modeling, using the based on Maximum Area design scenario.

For this ecosystem service, it is possible that any benefits of sequestration will be negated by the production, installation, construction, and maintenance of the site. Because of this, the net impact of the redevelopment may be a net positive for carbon sequestration. However, the bulk of these carbon costs are from the initial installation of the greenspace, and so over time the project may compensate for this carbon intensiveness. A potential of greenspace is the possibility that it will increase walkability in a city, and incentivize pedestrian traffic rather than vehicle use. The avoided carbon emissions from reduced vehicle use could help greenspace areas to be carbon sinks.

Conclusion

Although we found a wide range of estimates for carbon sequestration potential for the Maximum Area design scenario, we were able to determine that there would be a measurable impact from planting 45 trees in Harlem Place. Carbon storage is an ecosystem service that is highly dependent on the needs and conditions of the site. For a space with shorter buildings, tree shade would likely have a significant impact on reduced building energy demand. McPherson et al. (2008) found that there is the potential to plant 1 million trees throughout L.A., which would reduce electricity demand by 917,000 MWh and reduce 1.02 million tons of atmospheric carbon. The carbon costs of greenspace projects should be looked at over an extended time period to determine if the upfront costs of installation can be overcome.

5.5 Livability

What is the Issue?

The United Nations defines ecosystem services as the benefits people derive from nature, which can be categorized as provisioning, regulating, supporting, and cultural services (Millennium Ecosystem Assessment, 2005). Using this definition we identify livability as an issue that is reliant upon, and impacted by the ecosystem services provided by nature. Livability refers to the interaction between environmental health, community, and local economies. The level of livability directly relates to how “easy” or comfortable a place is to live; it is a measure of the quality of life in a particular region. Ecosystem services that influence the livability of a location are more social in function and include social interaction, sense of community, sense of safety, health benefits (physical and psychological), and education. In general, an increase in the amount of each of these services contributes to enhanced livability of a community.

A significant body of literature supports the concept that greenspace provides ecosystem services such as sense of community and mental /physical health benefits. A review of 16 years of *Landscape and Urban Planning* (LUP) contributions analyzed studies addressing issues of nature in urban settings and documents various ways that contact with nature contributes to improved quality of life, “even if the encounter is only a brief opportunity” (Matsuoka and Kaplan, 2008, p.9). This review of LUP contributions illustrates that urban residents greatly value natural environments in their community, with nature providing a sense of community identity and cohesiveness (Matsuoka and Kaplan, 2008). Urban greenspace provides amenable spaces or distinct areas where social interaction takes place. This interaction and the setting of the greenspace foster a greater sense of community, and improves the quality of life (Inerfeld & Blom, 2002).

Widespread trends reveal that the ability and value of “natural” urban areas to offer residents spaces to be active and interact with their community is increasingly recognized. Planners understand that citizens value greenspaces more for their non-market characteristics rather than the economic and utilitarian benefits (Hague & Siegel, 2002). However, contrary to other ecosystem services, such as flood control or air pollution reduction, the exact way in which various greenspace designs impact the livability of an area is not as tangible. Therefore, in order to develop a conceptual model for how to think about maximizing social ecosystem services, a broader approach must be used. While it is difficult to identify exact linkages between livability and specific design options, it is possible to identify general design features that should be considered to maximize the benefits that small-scale greenspace can have on livability.

How Can a Redesign Affect Livabilty?

Figure 5.14 illustrates our conceptual model for livability. We identified five primary design options that urban greenspace projects should focus on enhance livability: amount of greenspace developed, the spatial distribution of greenspace, connectivity to other existing greenspaces, community input, and education regarding the ecological function of greenspaces. For our evaluation of Harlem Place, we relied heavily on literature reviews, a community survey of Harlem Place residents, and client input to identify what ecosystem services would be provided by interstitial greenspace and how changing design features under local constraints affects the services provided. Overall, primary constraints for each design scenario in Harlem Place, or any small-scale project, include available space to redevelop, funding, city ordinances, community attitudes and perceptions of greenspace, and socio-economic factors

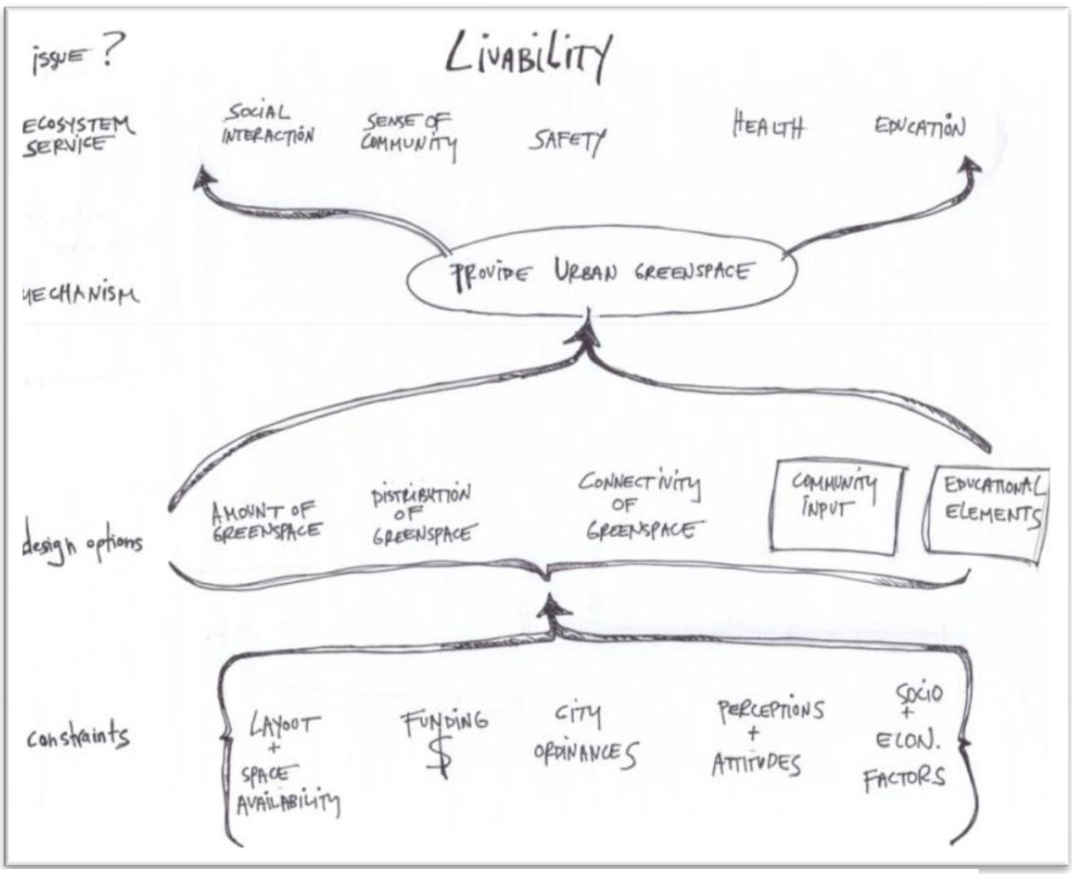

Figure 5.14 Livability conceptual model as it relates to Harlem Place

Design Options &Application to Harlem Place:

Total Amount and Spatial Distribution of Greenspace

When parks are provided in the city at any scale, the space can become woven into occupants' daily life-patterns, and provide aesthetically appealing areas for relaxation, and pedestrian travel, as well as facilitate encounters and sociability. These are important elements to the quality of life. The amount of greenspace desired, or required, by a community varies for each specific project. The amount of greenspace which can potentially be redeveloped is constrained by the amount of open space available in addition to the layout and density of the city or neighborhood. In addition to the total area dedicated to greenspace development, the distribution of greenspace throughout a community plays a critical role in the impact that ecosystem services provide. For example, one portion of a city may be able to support a large area of greenspace redevelopment, while other areas may lack space or capacity to implement greenspace. Thus, the LID features will be concentrated and geographically isolated from the rest of the city, precluding the benefits of ecosystem services, such as sense of community or safety, from certain regions. A greater impact may be realized if greenspace is distributed or interspersed in a manner that invites community members into new greenspace areas increasing the accessibility of the areas, usefulness as a pedestrian route, as well as social interaction between residents of different neighborhoods. Both the amount and distribution of greenspace greatly depend on the layout and density of the community and the available area for redevelopment.

Our physical site survey of Harlem Place revealed how our site was set within a relatively compact area, constrained by city planting ordinances, requirements for vehicle access, adjacent parking lots, and entrances to private buildings. Therefore, small amounts of greenspace and LID designs, creatively applied within our constraints, were considered to achieve a more aesthetically pleasing alleyway. Based on the DLANC survey Downtown residents were most concerned about the appearance of Harlem Place (77%), including the trash and litter (also 77%) in the alleyway. Respondents were also concerned about safety (54%) and odor (69%), and exactly half were concerned about pet waste. Very few residents were concerned about lighting (8%). One resident was concerned about drugs/alcohol/graffiti (not included on the survey), which could be considered an issue of both safety and appearance (Figure 5.14). In terms of safety, 65% of respondents felt safe walking through Harlem Place, although other surveys conducted in L.A. found that safety was a top concern in L.A. alleyways (Wolch, 2009).

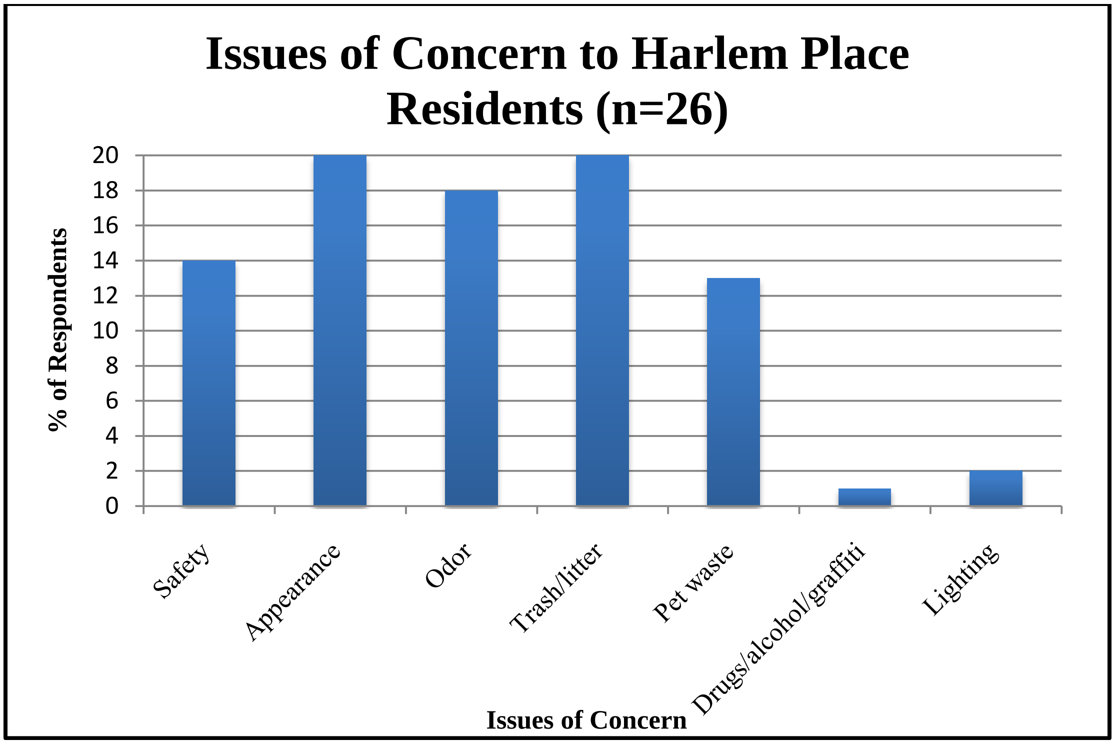

Figure 5.15 Issues of concern to Harlem Place residents

Due to size constraints, large open greenspaces were not possible in Harlem Place, however, interspersed vegetation (trees, shrubs, and greenwalls) and aesthetically pleasing permeable pavers matched community survey desires and evidence found in literature reviews. The results of the DLANC survey, however, were not completely aligned with our results of the impacts of greenspace on ecological ecosystem services. The surveys revealed that Harlem Place residents were much more concerned about the aesthetics of the alley than ecological functioning. Concerns regarding stormwater runoff and the regional impacts that local runoff has on water pollution levels in Santa Monica Bay were ranked second to last. Residents were concerned the least with the lack of shade in the alley, which suggests that a cooler microclimate is not a priority for them or that they did not consider how shade can improve microclimate and aesthetic quality. When modeling the impacts of design scenarios on biophysical processes such as infiltration, installing permeable pavement in the alley significantly reduced stormwater runoff. We estimated that planting 45 trees could lower the temperature directly under the canopy by up to 20° F. Based on these results, there may be tradeoffs associated with design choices regarding what residents are concerned about (aesthetics) and what design(s) may maximize impacts of greenspace on biophysical or biotic services. However, while residents did not express concerns about shading or microclimate, trees have an immense impact on visual aesthetics in addition to the ecological services they provide. While our survey did not capture this distinction, when designing smaller, site-specific greenspace projects, clearly identifying who the stakeholders are and what the specific goals of a redevelopment's design elements is critical to create buy-in from community members and policymaker, in addition to maximizing the tangible benefits for relevant parties.

Connectivity to Existing Greenspace

The level of connectivity between greenspaces is an important design factor in redeveloping urban hardscapes. Urban environments are highly fragmented, with minimal open space. This existing open greenspace is often present in isolated patches, which not only limits the number of people impacted by it, but restricts the cumulative impacts greenspace could have on a regional scale. Just as roads connect city residents to each other, small-scale greenspace can be integrated into the built environment in a manner that connects interstitial greenspaces to each other, thus creating a larger network which can facilitate corridors for residents and wildlife. A network of greenspace would also create greater capacity for stormwater retention and conveyance. With no current greenspace in Harlem Place, and limited access to existing greenspace, each of our design scenarios adds vegetation and LID features to Harlem Place, creating a foundation for a network of greenspace throughout Downtown. Developments for an adjacent neighborhood park, Pershing Park, is underway and will serve as a major corridor for the greenspace designs we proposed.

Community Input

The level at which community input is integrated into greenspace projects can strongly influence the impact of the greenspace on local livability. It is important for local users and residents to have input on the management of their green spaces. This fosters a sense of ownership and responsibility of the resource (Kaplan, 1980). By including citizen input, the public will better understand tradeoffs faced by planners and planners will better understand the needs of the community and the non-monetary values that local residents place on urban green space (Balram and Dragi´cevi, 2005). A study by Nilsson et al. (2007) found that excluding community input could lead to public mistrust in planners' and policymakers' decisions, often hindering the successful development of greenspace projects.

Some of the greatest impacts of small-scale greenspace projects are the aesthetics and community building it provides. Therefore, it is crucial to have ample community input when designing a project of this nature. The results of the DLANC survey provided us with useful information about how to redesign Harlem Place. There was a wide range of responses to what the word "greenspace" meant to community members, although many respondents considered greenspace to mean more traditional or established parklands (Table 5.8). All respondents felt that redesigning Harlem Place into greenspace would increase the value of their properties.

What do you think when you hear the word “greenspace”?
“Land for non commercial, public use”
“..a park, with trees and a water fountain”
“I definitely think of 'park' 'landscaping' 'grass' 'trees' 'benches' 'paths'”
“I think of community space with greenery of some sort (trees, grass, garden), that’s not as large as a park”
“A place with a distinct green identity - somewhere with a true sense of place”
“Good, beautiful, lush, inviting and a place to relax”
“The words "green," "environment," "sustainability," and other similar words are overkill. Must we incorporate such words with everything these days? Sure, it's important, but how about we focus on a drug-free, clean and safe habitat for the community”
“An environmentally-friendly space that incorporates outdoor spaces for the community, incorporates living plants and trees and helps to improve the natural elements such as light, water and air”

Table 5.8 DLANC survey responses from Harlem Place residents when asked “What do you think of when you hear the word “greenspace” See Appendix C for full survey and responses

Current uses of Harlem Place are to access to businesses abutting the alley (50%), access to adjacent parking areas (42%), and as a thoroughfare through Downtown L.A. (27%). Only 8% of respondents used the alleyway for walking pets, although pet waste was listed as a main concern among half of the respondents. Additionally, half of respondents use Harlem Place on a daily basis. When asked to rate their level of concern for a series of issues in the alley (e.g., stormwater runoff and pollution, air quality, amount of shade) from low to high, most residents generally placed a high level of concern on all the issues presented, with the exception of the amount of shade in the alley, which most residents rated at as having a medium level of concern (Figure 5.16). Specifically, more residents rated local air quality (73%), access to recreational space (77%), and amount of vegetation in the alley (62%) as a high concern. Residents placed less of a priority on stormwater runoff and water pollution and shade in the alley.

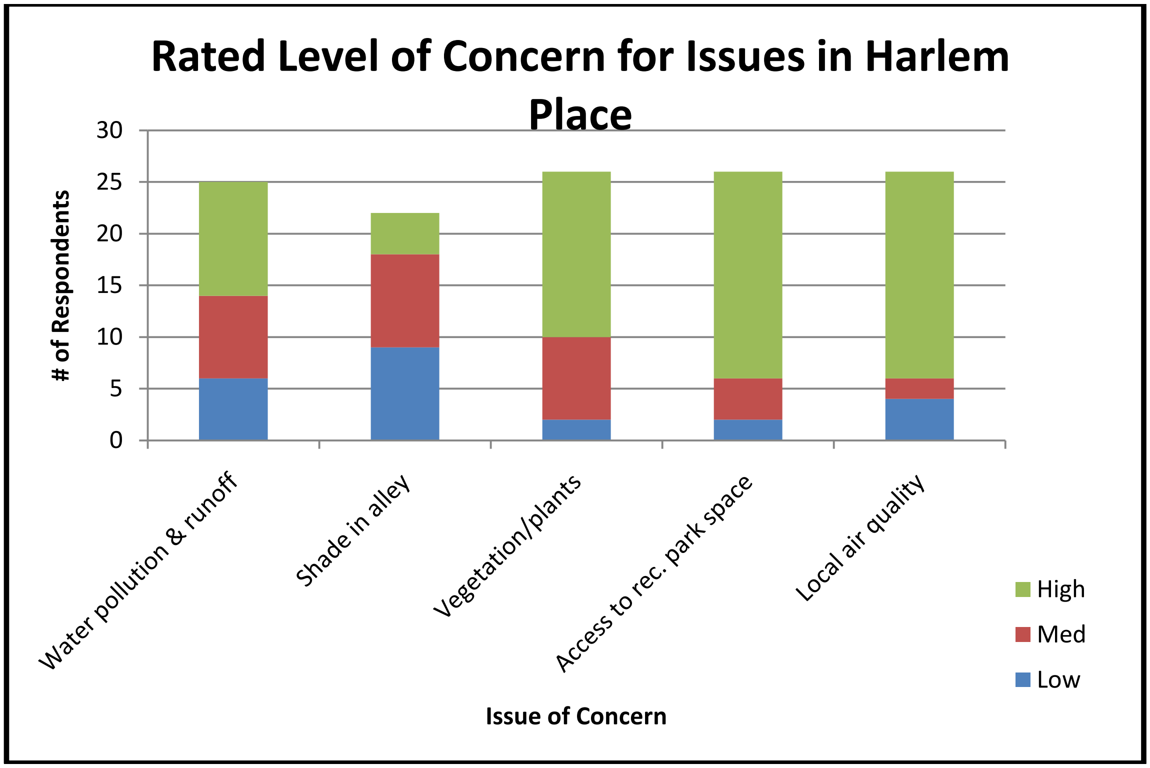

Figure 5.16 Rated level of concern of Harlem Place residents

The residents' highly rated concerns, however, differed when asked specifically what they were concerned with in Harlem Place, as seen above in Figure 5.15. Although residents rated ecological functions, such as air quality, as a high concern, most residents are more concerned with the appearance of Harlem Place.

Perhaps respondents were less concerned about water quality and shading because they are not fully aware of the potential problems associated with issues like stormwater or lack of shading and how greenspace can ameliorate these problems. These disconnects represent tradeoffs associated with what residents desire in a greenspace and what designs will maximize ecosystem services. Designing a greenspace that balances what a community desires in their neighborhood and what designs maximize ecological ecosystem services is a challenge and warrants significant attention in the planning process.

Education

In addition to community input, we identified education as an element to consider incorporating into design options when designing small-scale greenspace projects. Educating community members about how a greenspace functions ecologically creates a positive feedback loop by spurring interest in other services that greenspace may provide. This may lead to support for more community or individual greenspace projects. Using public outreach and education to focus the public's attention on particular ecosystem services aimed at alleviating local environmental problems, as well as aesthetic and recreational values, fosters community support for green space projects (Jim & Chen, 2006).

Education about greenspace also influences the political support and community buy-in necessary for interstitial greenspace development and should be tailored to the specific audiences within the stakeholders of a greenspace project. For example, if an organization is trying to get broad, regional support from policymakers and funding resources, regional impacts, such as reduction in water and pollution mitigation, should be emphasized. In contrast, if political support exists, but there is a lack of buy-in from the local community where a project is proposed, education regarding aesthetics and the cooling effect of trees and vegetation may be more effective. As discussed in earlier sections, the political climate for "greening" projects in Los Angeles is strong, and residents of Harlem Place had shown interest in a greenspace project. The DLANC survey results, however, indicate that the motivations for redeveloping Harlem Place with greenspace are based more on creating an aesthetically pleasing, walkable alley. If the goal of our client and Los Angeles policymakers is to maximize reductions in stormwater runoff into the Santa Monica Bay, we recommend installing the maximum amount of permeable pavers and a bioswale, if feasible. In contrast, if there is greater concern for increasing the Downtown community's involvement with an overall greening strategy, we recommend a greenspace design that focuses more on increased vegetation and aesthetic appeals to draw community members to the area, as well as consider how to provide education regarding how greenspace adds to ecological functioning. Open space implementation is feasible only if the local community values open space (Kline, 2006). For example, in the aftermath of Hurricane Hugo, Charleston, SC residents mourned urban forest damage as the most significant loss for the city, citing environmental, aesthetic, recreational, and personal justifications. This value, however, was not fully recognized until after the open spaces were damaged; this reveals a pressing need for public education about the values of urban green space (Hull, 1992).

Educating local residents on definitive goals and strategies of achieving greener communities will aid in successful greenspace projects (Jensen et al., 2000). The education component of installing greenspace in Harlem Place is critical for our client to achieve their goal of a long-term greening strategy for Downtown Los Angeles. According to our client, and Chair of the Sustainability Committee, despite a growing city-wide emphasis on sustainability and passage of several ordinances and policies that encourage sustainable development, such as the Green Streets Initiative and Proposition O, the Sustainability Committee needs a way to communicate complicated environmental and planning issues to diverse community stakeholders in a relevant and meaningful way (Zarella, 2009). Using education elements as a design option in the Harlem Place project can increase the visibility of the project, not only bringing more residents to the area, but also increasing the community's overall understanding of how greenspace impacts air quality, water quality, and local temperatures in the alley. Potential options to incorporate education into the greening project include informational placards or neighborhood workshops explaining how a specific design (e.g., bioswale) functions ecologically.

Conclusion

Currently, available models only measure social impacts of greenspace in economic terms, but fail to quantify the social services provided by greenspace. Therefore, we used literature review and the DLANC community surveys to investigate the impacts of small-scale greenspace on livability. Greenspace enhances sense of community, social interaction, safety, and health benefits. However, the exact way in which varying greenspace design options changes the level of livability is not easily defined. Specific to Harlem Place, however, we determined that community input and education about greenspace functionality may be key design options that can be varied in order to maximize the impacts of small-scale greenspace on livability. Tradeoffs between what a community desires in a greenspace design and what designs will maximize ecological ecosystem services present challenges to planning a greenspace project and should be acknowledged early in the process. Education regarding the ecological impacts of greenspace could help better align community desires with strategies to maximize environmental impacts. Variations in design should be tailored to the appropriate stakeholders and align with identified goals of the project to ensure sustained support for the new greenspace.

6 Discussion

6.1 Issues of Scale and Extrapolation to Regional Scale

As previously mentioned, effects of a greenspace redevelopment can be differentiated by their local and/or regional impact. Although small greenspace projects will have tangible local effects, such as tree shading and aesthetic appeal, measurable cumulative effects would occur if interstitial greenspace projects were replicated throughout the region.

Although some of our biophysical results were relatively small in Harlem Place, these impacts can be extrapolated to a regional scale. There are over 900 linear miles of alleyways in L.A. (Scott, 2008), meaning that in addition to other interstitial and underutilized spaces, there are many opportunities for greenspace redesign projects to take place throughout the city. The Maximum Area design scenario can capture approximately 40 lbs of air pollutants; if this design was implemented in every L.A. alley it would equate to approximately 72,000 lbs of air pollutants removed from the air every year in the city. Additionally, the Maximum Area design for Harlem Place has the potential to capture 346,000 gallons of runoff. If this design was extrapolated out to the 900 miles of alleys in L.A., they could cumulatively capture 75,543,600 gallons of runoff from a 1-year storm event, or 155,530,971 gallons from a 5-yr storm event and 235,518,328 gallons from a 25-year storm event. iTree estimates that the Harlem Place Maximum Area scenario can sequester 3,015 lbs annually. If all every alley in Los Angeles incorporated trees that could sequester this amount, 5,427,000 lbs of atmospheric carbon would be taken up annually; this is equivalent to removing 450 cars from the road. Similar studies support this notion. McPherson et al. (2008) found that it would be spatially feasible to plant one million trees in the city of L.A. According to their analysis, over the 35-year life span of the project, the one million trees would reduce stormwater runoff by 17.4 billion gal over a 35-year period, reduce electricity demand for air conditioning by 917,000 MWh, sequester 1.02 million tons of CO_2, and reduce PM_{10} by 2,365 tons, O3 by 3,121 tons, and NO2 by 2,494 tons. Although there is uncertainty surrounding our estimated impacts, in addition to feasibility issues associated with converting every alley in L.A., this extrapolation demonstrates that even small, localized impacts can have a large effect when applied to a region or watershed.

Responsible Agencies

Often, the disparity between local and regional benefits of greenspace and the cross-jurisdictional nature of ecosystem services leads to confusion about which agencies and organizations should take charge of greenspace projects. In L.A., for example, ecosystem services provided by greenspace would benefit the Department of Public Works, Department of Water and Power, the Southcoast Air Quality Management District, Municipal Health and Sanitation Departments, and others. The valuation of ecosystem services does not occur under traditional accounting methods. Therefore, there is a need for a new centralized agency to manage urban forests and green spaces, along with a new budgeting system that incorporates the monetary value of ecosystem services (Pincetl, 2007).

6.2 Summary of Results

Our project completed two primary goals:

> 1. Developed conceptual models for five urban environmental issues to communicate key design considerations and important constraints and tradeoffs to consider when trying to maximize ecosystem services on local and regional scales.
>
> 2. Created six greenspace design scenarios for Harlem Place in order to illustrate the application of conceptual models and to evaluate the impacts of interstitial greenspace on ecosystem services.

We evaluated the impact of five relevant ecosystem services through six design scenarios we generated for Harlem Place. We found that permeable pavers and bioswales have a greater effect on stormwater runoff quantity and pollutant removal than vegetation, partly due to the physical and regulatory constraints on alleyways wherein there are more opportunities for permeable paver installation than tree planting. However, trees provide the microclimate mitigation, air pollution reduction, and aesthetic appeal of the alleyway that permeable pavers do not have much impact on. Literature reviews indicated that greenwalls have a measurable impact on air pollution capture and reduced building energy loads, but sufficient data about greenwall impacts on building heat gain and particulate capture is lacking, and therefore beyond the scope of our project.

The five trees species (45 trees total) we modeled, including the Western Hackberry, London Planetree, Lacebark Elm, California Sycamore and Western Redbud will decrease four major air pollutants: ozone, sulfur dioxide, nitrogen dioxide, and PM_{10}. Downtown Los Angeles is out of compliance with EPA ozone standards, and while the trees modeled in Harlem Place can yield a notable decrease, they were not able to reduce ozone levels to the EPA standard. Though Downtown Los Angeles is in compliance with other significant air pollutants like SO_2, NO_2, and PM_{10}, it is important to continue to reduce levels of these pollutants in Downtown, as air pollution follows air currents which travel towards the mountains over other parts of the greater Los Angeles area.

While iTree calculate values for energy load and corresponding carbon dioxide reductions, because the Harlem Place buildings are large multi-story buildings, our trees would not reduce building energy loads significantly. However, trees may have an effect on building energy in other site locations with smaller structures. Urban heat island mitigation was difficult to model, but using data from literature reviews, we concluded that the effects of both trees and greenwalls could potentially cool the alleyway by approximately 6°C (11°F). Carbon sequestration as an ecosystem service will likely be negated by the carbon footprint of implementing new design features. In order to estimate the impact of using small-scale greenspace as a carbon sink, additional data is needed about the carbon intensity of redevelopment and project maintenance, as well as the behavioral changes greenspace can have on decreasing vehicle miles travelled. The greatest impacts of tree planting and other vegetation in Harlem Place are likely improved livability and use of the site. Locally, greenspace can improve livability and sense of community, which can increase support for more greenspace redevelopments, yielding biophysical results on a larger regional scale.

To lend transferability to our project, our conceptual models for ecosystem services provide a framework to guide future planners in determining what design choices, constraints, and tradeoffs are important to consider. These models outline some of the complexities involved in achieving desired ecological and social impacts from a greenspace.

6.3 Key Findings and Implications

Ecosystem services can be both social and biophysical in nature, and impacts will differ between local and regional scales. Therefore, there is no simple way to quantify the effects of greenspace uniformly across all ecosystem services; greenspace design needs to be tailored to the constraints of the site and the needs of the stakeholders. Furthermore, there are ecosystem services that can be quantified and those that cannot.

In Harlem Place, the urban heat island effect is most relevant on a micro-scale, meaning that tree shade provided in a project site will have the most tangible impact on the immediate users proximate to the vegetated area, and under the canopy. The impacts of designs on the urban heat island effect was particularly difficult to quantify, considering the building massing and context of L.A's extensive dark surface cover. Mitigation of carbon dioxide was also challenging to quantify. The ranges of carbon sequestration rates for the 45 trees in Harlem Place were highly variable due to the dynamic nature of tree growth and carbon storage, as well as the carbon intensity of the proposed redevelopment. The carbon costs of construction, installation, and maintenance of a redesign likely outweigh any sequestration benefits, at least in the short-term. Livability is the only ecosystem service that we were unable to directly link changes in impact with changes in design features, as this depends greatly on stakeholder input and preferences. For example, there is no metric to determine whether installing benches or lighting features will always improve sense of community and social interaction. In Downtown L.A. residents highly value aesthetics and safety. Therefore, while design features such as lighting, and social ecosystem services such as increased street activity and interaction are not quantifiable, it is important to incorporate these design features nonetheless for their observed effect on human behavior and well-being.

We were able to quantify changes in stormwater and air quality with various models and calculation tools provided by our literature review. The Bioswale scenario could potentially capture all of the rain falling on our case study site, in addition to capturing approximately half of all stormwater runoff generated by the building rooftops lining Harlem Place. Airborne pollutant capture and uptake by specific tree species is quantifiable, but in relation to the degraded air quality of L.A., the impacts were relatively small. The Maximum Area design did not bring the site into EPA compliance for ozone; however, the design could capture approximately 40 lbs of common air pollutants.

6.4 Broader Implications

A key deliverable of our project is the framework it creates for thinking about and informing future greenspace redevelopment projects in a way that is relevant and addresses the local and regional community. Our literature review revealed that there is an overall lack of information on the impacts of greenspace when implemented on a small-scale. Furthermore, there is no one model currently available to measure all the ecosystem services resulting from greenspace design scenarios. Our conceptual models were developed to represent a formalized process for assessing and facilitating ecosystem services within a redevelopment site, and consider design feature options as well as constraints.

By creating visuals of a Harlem Place redevelopment design (Figure 6.1), as well as estimating the impacts of specific design configurations and features, our project serves as an educational tool for the Downtown Los Angeles Neighborhood Council Sustainability Committee. The results of our project will help our client understand how to maximize ecosystem services by varying design features, determine how a greenspace can address the concerns of stakeholders, and mobilize greater participation in the creation of their long-term greening strategy.

Figure 6.1 A sample of sketches of potential Harlem Place greenspace design
Source: AECOM, L.A. Office, 2010

Although we were unable to model the social impacts of greening Harlem Place, literature suggests that our design scenarios would have impacts on livability, health and education. Existing studies previously referenced reveal that well-vegetated, aesthetically pleasing space increases an individual's quality of life, sense of community, and encourages healthy behavior such as increased pedestrian and recreational activity. The more aesthetically pleasing, amenable, and engaging a site is, the more it attracts others' attention, encouraging use of the space, citizen self-policing and thereby increasing safety. All of the biophysical results from our design scenarios are complimented by subsequent impacts on livability. For example, providing shade through increased canopy cover decreases localized temperatures, which also decreases urban smog formation. Both better air quality and mitigating the urban heat island effect also generates more amenable outdoor conditions for people. When properly sited, such as along sidewalks or potential pedestrian and bike corridors, tree shading enhances conditions for human comfort, increasing walkability, and pedestrian movement over other modes of transit.

Education about ecology and urban planning, as well as increased citizen engagement, can be critical results of greenspace redevelopments. Fostering resident involvement in the process of greenspace redevelopment creates a sense of ownership in the community and facilitates neighborhood interactions which are important elements in a community. Additionally, the visibility of a demonstration or case study project can spur curiosity about ecosystem services in urban environments; a positive feedback effect can then occur as education about the ecological functions of greenspace builds momentum to create future greenspace projects.

Discussion

Before beginning to evaluate the impacts of a potential greenspace project, one must select relevant ecosystems services to measure, based upon feasibility specific to the site, community preference, and how one prioritizes the environmental and social issues. Factors which impact feasibility for a particular site include physical, economic, and regulatory constraints. The most pressing constraints in interstitial urban spaces are often available funding and lack of physical space. The question of who pays for the project and who receives the majority of the benefits of the greenspace is critical to local stakeholders. Often, the answer will determine which ecosystem services to focus on, as well as potential partnering possibilities to implement the redevelopment. Based on which ecosystem services are chosen to maximize and the constraining factors of the site, the planner can then select design options to facilitate the desired ecological mechanisms to mitigate the issue.

Ecosystem services must be evaluated on both a regional and a local level, as some impacts are highly dependent on the spatial scale. Furthermore, some impacts are easily quantifiable, while others are largely intangible. Ecosystem services that can be quantified often do not align with the priorities of the community. For Harlem Place, stormwater runoff and water quality improvements were most easily modeled and quantified, but these were not as important to local residents; livability and access to recreational park space were prioritized in the DLANC community surveys.

Our research suggests that there are both tangible and intangible effects of urban greenspace, and it is crucial to be able to communicate both. Key reasons to quantify the ecosystem service impacts of small-scale urban greenspace are to create community buy-in for greenspace projects, and to decide which redevelopment design with achieve desired effects. First, calculating biophysical impacts of small-scale greenspace can serve as means to justify these types of projects and educate people about the role of greenspace in environmental and human health. Second, quantification can elucidate the differences between various design techniques and help planners choose between redesign options. However, it is critical to effectively communicate the quantifiable benefits to local stakeholders so they can understand their relevance on local and regional scales. It is also important to communicate the intangible benefits of greenspace redesign, such as increased sense of safety and community interaction. Once a project is implemented, continued monitoring is important to increase the body of data on the measurable impacts of greenspace; the monitoring will increase the accuracy of modeling tools and estimates, as well as document the impacts on livability. For example, after redesigning Harlem Place the DLANC could conduct another survey of residents to see if their environmental concerns and uses of the alley changed. Creating a visual of the possible design scenarios, such as the AECOM sketches of the Harlem Place design features, can generate community and political buy-in and help stakeholders understand what types of greenspace are possible.

7 Concluding Thoughts

The conceptual models and design scenarios created in this project were not intended to be prescriptions for all urban greenspace redevelopments. Rather, they were intended to serve as guidance tools to educate decision-makers and community members about how greenspace can provide relevant ecosystem services in urban areas, and how these services are relevant on different scales. This framework hopefully challenges the traditional definition of greenspace to envision how small parcels of greenspace can provide essential ecological functions, as well as enhance urban livability in constrained settings. It is critical to determine where, or on what scale, the impacts will be realized, and to measure the effect accordingly. While many of the impacts this project modeled were concentrated on the local scale, interstitial greenspace can have a substantial effect if similar projects were implemented throughout an entire region, generating results that cumulatively are significant. As urbanization continues, small-scale greenspace will play a pivotal role in providing healthy, livable urban environments to a population with increasingly strained resources. When designing small-scale greenspace projects, one should consider how a redevelopment can achieve local and regional benefits, as well as engage community, policy, and professional stakeholders to identify opportunities for a design to serve multiple goals. Quantification of the impacts of greenspace, in addition to monitoring stakeholder attitudes over time, helps build political and community support and increase knowledge about the urban ecology. Our project attempts to set forth a transferable approach to reconsider how urban greenspace can mitigate existing urban environmental and social problems, by effectively integrating the natural environment into the built environment.

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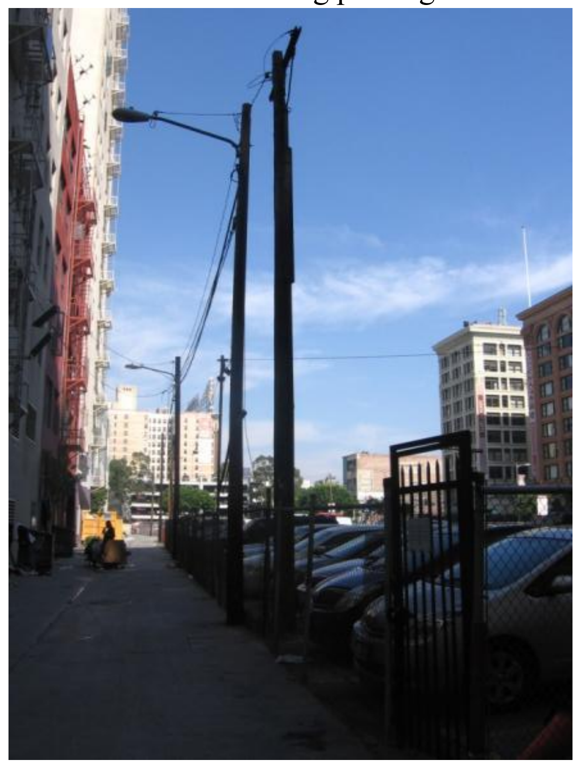
Appendix A: Images of Harlem Place Alley

The following images were taken during the Spring and Fall of 2009, by the GreenLA group project team.

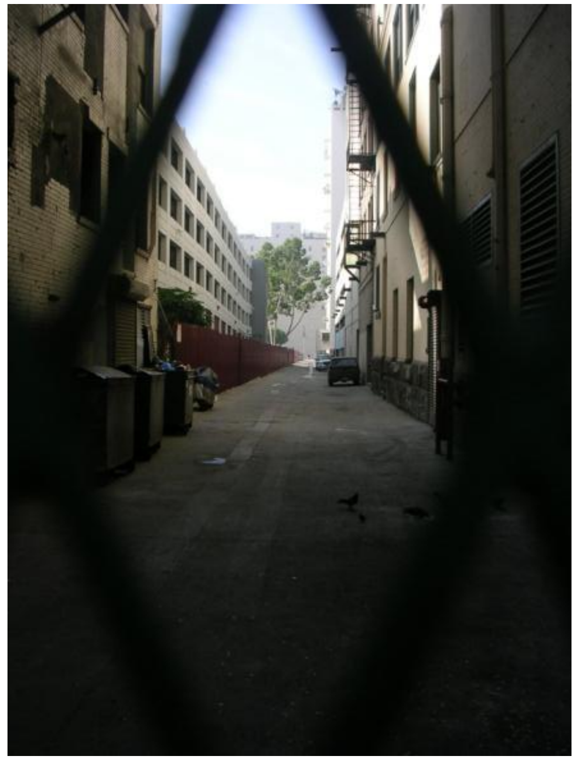
Between 5th and 6th St., towards 6th.

Block 6-7. Note abutting parking lot.



Between 5th St. and 6th St., towards 5th.

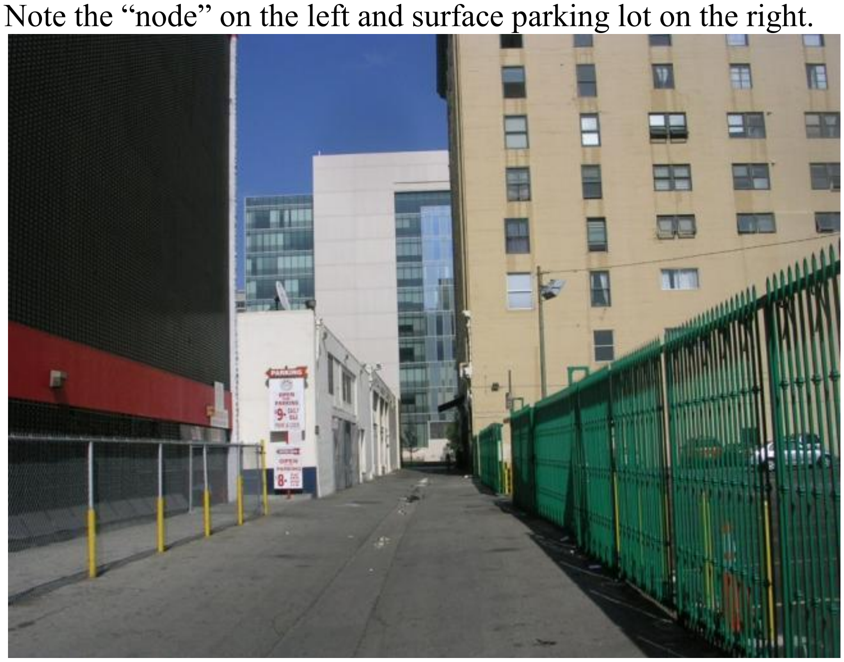
A view into block 5-6 from 5th St.



A pedestrian access point

Dumpsters lining the alleyway

Between 2nd St. and 3rd, view towards 2nd St.
Note the “node” on the left and surface parking lot on the right.



Water collecting in the middle of the alley due to sloping towards the center

Block 6-7. Note solar exposure.

Commercial establishments in the alley

Appendix B: iTree and L-THIA Model Guidance Documents

These Guidance Documents provide additional information on how the iTree Streets and L-THIA models were used for the Harlem Place case study.

iTree Streets

To use iTree:

1. The user begins by naming their project file to the desired location on their computer, and selecting "complete" under inventory type.
2. The user then defines the climate zone of their project site. For Harlem Place, this is the "Southern California Coast" zone.
3. Next, choose the country, state, county, and city of the project site. Define the Total Land Area of the project site (in sq. mi), the Average Sidewalk Width (in ft), the Total Linear Miles of Streets (in sq. mi), and the Average Street Width (in ft). Only if desired, define the budget and population of the project.
4. Define costs if desired.
5. Benefit prices are built into the model for the selected city but can be changed if the numbers are outdated or inaccurate to the specific project site.
6. The User Defined Fields can also be adjusted if necessary.
7. Choose the Input option the main toolbar and select "Records". This will allow the user to input species of trees (and any number of the trees) into the project area. Cross reference with external Tree Guide sources when determining appropriate tree species for a project site. Click "New" and select the Tree Info tab. This enables the user to choose the type of tree desired. Search by either a tree specie's Latin name, or its common name. Not all tree species in existence are included in the iTree database.
8. Choose a DBH (diameter at breast height) for each tree. To have multiple trees of the same species, click "Duplicate" and choose the number of additional trees desired.
9. To quantify the Ecosystem Services of the trees in the project site, select "Reports" from the main toolbar, then Benefit-Cost Analysis, followed by Annual Benefits, and choose from either: 1. Energy, 2. Stormwater, 3. Air Quality, 4. Carbon Dioxide, 5. Carbon Stored, 5. Aesthetics, and 6. Summary of all services. This will give the user the impacts of either each tree, or the trees on a per-species basis.

The summaries of the services we applied to Harlem Place are shown below:
Energy: iTree's measurement of tree impact on energy estimates the effect of the trees on energy conservation within buildings. This energy conservation, from reduced conditioning demand, is measured in terms of reduced natural gas use (in therms or gigajoules) in winter as the result of trees buffering winds and decreasing outside air infiltration, and reduced electricity use (in kilowatt-hours or gigajoules) for air conditioning in summer as a result of tree shading on the building exterior.

Stormwater: iTree quantifies trees' impact on urban stormwater by estimating annual reduction in stormwater runoff as a result of precipitation interception by trees.

Air quality: iTree quantifies the local impact of trees on four criteria air pollutants (O_3, NO_2, SO_2, PM_{10}) by estimating the amount of pollutants deposited on tree foliage and surfaces. iTree also quantifies the regional impact of trees on certain air pollutants as a result of reduced emissions from power plants (NO_2, PM_{10}, VOCs, and SO_2) by the preclusion of some electricity use due to the cooling effect of trees on buildings.

Carbon dioxide: iTree quantifies reductions in atmospheric CO_2 by estimating the quantity of carbon tree species can sequester, and, in the same manner as its air pollution estimates, the reduced carbon emissions from precluded energy use due to trees, and thus reduced power plant demand and carbon emissions. iTree's model does account for the life cycle of the tree, by factoring in the carbon released from tree mortality, decomposition and associated with tree maintenance (McPherson et al., 2005).

L-THIA

To use L-THIA:
The user must only supply basic information as L-THIA model inputs: location (state and county), the category of land use, the area of the land use (in sq. miles, hectares, sq. km, or acres), and the hydrologic soil group. For Harlem Place,

1. Location information is Los Angeles County in California.
2. Our land use areas for the six design scenarios are "Parking/Paved Spaces" for any impermeable surfaces, "Forest" for the trees, "Grass/Pasture" for the vegetated nodes, and a Custom Land Use with a Curve Number of 72 for the permeable paver surfaces in our design scenarios. Based on literature review, we determined permeable pavers absorb water at the capacity of the soil underneath. For Downtown Los Angeles, the predominant soil type is sandy loam, which has a curve number of 72.
3. The areas for each land use will vary for each of our six design scenarios.
4. Sandy loam is a Type A soil, thus we choose "A" for the Hydrologic Soil Group. Soils are classified by the Natural Resource Conservation Service into four Hydrologic Soil Groups based on the soil's runoff potential.

The event mean concentration (EMC) values built into L-THIA that are based on land use classifications are shown below in Table 1.

Table 1 Event Mean Concentration by land use classifications from Baird and Jennings (1996).

NPS Pollutant	Land use classification						
	Residential	Commercial	Industry	Transition	Mixed	Agricultural	Range
Total Nitrogen (mg/L)	1.82	1.34	1.26	1.86	1.57	4.4	0.7
Total Kjeldahl Nitrogen (mg/L as N)	1.5	1.1	1.0	1.5	1.25	1.7	0.2
Nitrate+Nitrite (mg/L)	0.23	0.26	0.3	0.56	0.34	1.6	0.4
Total Phosphorus (mg/L)	0.57	0.32	0.28	0.22	0.35	1.3	0.01
Dissolved Phosphorus (mg/L)	0.48	0.11	0.22	0.1	0.23	---	---
Suspended Solids (mg/L)	41	55.5	60.5	73.5	57.9	107	1
Dissolved Solids (mg/L)	134	185	116	194	157	1225	245
Total Lead (µg/L)	9	13	15	11	12	1.5	5.0
Total Copper (µg/L)	15	14.5	15	11	13.9	1.5	10
Total Zinc (µg/L)	80	180	245	60	141	16	6
Total Cadmium (µg/L)	0.75	0.96	2	1	1.05	1	1
Total Chromium (µg/L)	2.1	10	7	3	5.5	10	7.5
Total Nickel (µg/L)	10	11.8	8.3	4	7.3	---	---
BOD (mg/L)	25.5	23	14	6.4	17.2	4.0	0.5
COD (mg/L)	49.5	116	45.5	59	67.5	---	---
Oil and Grease (mg/L)	1.7	9	3	0.4	3.5	---	---

Mathematics of L-THIA:

The runoff curve number, "curve number", or "Soil Conservation Service runoff curve number" (CN) values help distinguish the hydrologic soil group, surface/land use, treatment and hydrologic condition of the soil. Curve Numbers were derived from the USDA Soil Conservation Service. The CN is used in an empirically based formula used in hydrologic analysis to determine the amount of rainfall from a given rainfall event that becomes direct surface runoff or infiltration. The relationship between rainfall, runoff and CN value is non-linear, as relatively minor changes in land use or rainfall can yield significant changes in runoff. CN is commonly used in hydrologic predictions for its efficiency in estimating the quantity of direct runoff from a rainfall event in a particular location. The equation for runoff is shown below:

$$\frac{(P - I_a)^2}{P - I_a + S} = Q$$

where Q denotes runoff, P is rainfall depth, S is the potential maximum soil moisture retention after runoff starts and I_a is the initial abstraction or the amount of water before runoff, such as infiltration, or rainfall interception by vegetation (i.e. the amount of rainfall that the soil can absorb). Generally it is assumed that $I_a = 0.2S$. CN ranges from 30 - 100; lower numbers indicate low runoff potential; larger numbers indicate increasing runoff potential. In other words, a land use or soil type with a large curve number will likely have more runoff occurring because the infiltration capacity is not adequate.

The preexisting moisture content within the soil before the rain event also impacts runoff quantity. This preexisting condition is known as the Antecedent Moisture Content (AMC) in the soil. Curve Numbers can be adjusted to incorporate the various moisture conditions ranging from dry, AMC 1 or CN_1 moist, AMC 111 or CN_{111}. AMC is estimated by the local precipitation data, and L-THIA adjusts the CN correspondingly. L-THIAs rainfall and AMC figures are based upon 30 years of daily precipitation for the local climate specified (using a distributed rainfall-runoff model). Rainfall characteristics that are important factors in runoff quantity include rainfall event duration, total amount, intensity and distribution.

Appendix C: DLANC Survey Questions and Results

The DLANC conducted a survey of Harlem Place residents to gather information about their knowledge and opinions of greenspace in their community and the greater Downtown area. In total, 26 residents responded to the survey. The breakdown of the survey data is presented below.

Survey Analysis (26 Total Respondents – Residents of Downtown)

Question 1: What do you think when you heard the word GREENSPACE?

Answers:

- "Land for non-commercial, public use."
- "I think of community space with greenery of some sort (trees, grass, garden), that's not as large as a park."
- "A place with a distinct green identity - somewhere with a true sense of place."
- "Good, beautiful, lush, inviting and a place to relax."
- "The words "green," "environment," "sustainability," and other similar words are overkill. Must we incorporate such words with everything these days? Sure, it's important, but how about we focus on a drug-free, clean and safe habitat for the community."
- "An environmentally-friendly space that incorporates outdoor spaces for the community, incorporates living plants and trees and helps to improve the natural elements such as light, water and air."

Question 2: What impact would greenspace have on the value of your property?

Answers:

- All respondents answered that greenspace would INCREASE the value of their property.

Question 3: In what ways do you currently use the alleyway?

Answers (including # respondents):

- As access to adjacent parking areas - 11
- As access to businesses along Harlem Place - 13
- As a thoroughfare through Downtown - 7
- Walking pets - 2
- I do not currently use Harlem Place - 3
- Access to my home and parking garage - 3

In summary:

- 50% of respondents use Harlem Place to access business along the alleyway.
- 42% use the alley to access adjacent parking areas
- Only 27% of respondents use Harlem Place as a thoroughfare through Downtown
- 16% use the alley to access their home or parking garage
- Only 8% responded that they use the alley for walking pets (although pet waste was listed as a main concern among half of respondents)

Question 4: How often do you use the alleyway?

Answers (including # respondents):

- Once a month – 8
- Daily - 13
- Never - 3
- Several times a week – 3

In summary:

- 50% of respondents use Harlem Place on a daily basis
- 16% never use the alley, and 16% use the alley several times per week
- 31% use the alley around once a month

Question 5: Do you feel safe walking in Harlem Place?

Answers:

- YES – 17
- NO – 8

In summary:

- 65% of respondents feel safe walking through Harlem Place.

Question 6: What issues concern you about Harlem Place?

Answers:

- Safety - 14
- Appearance - 20
- Odor - 18
- Trash/litter - 20
- Pet waste – 13
- Drugs/alcohol/graffiti – 1
- Lighting – 2

In summary:

- Downtown residents were most concerned about the appearance of Harlem Place (77%), including the trash and litter (also 77%) that is left in the alleyway.
- Respondents were also concerned about safety (54%) and odor (69%) in the alley, and exactly half were concerned about pet waste.
- Very few residents were concerned about lighting (8%). One resident wrote in that they were additionally concerned about drugs/alcohol/graffiti (not included on the survey), which could be considered an issue of both safety and appearance.

Respondents were then asked to rate their levels of concern regarding different urban issues: water pollution and stormwater runoff, available shade, amount of vegetation, access to park space, and local air quality. These could be rated as “low”, “medium”, or “high” concern. The breakdown of the data is shown in the table below.

Question 7: What is your rated level of concern?

Level of concern for:	Low	Medium	High
Water pollution and stormwater runoff	5	8	11
Amount of shade available in Downtown	8	9	4
Amount of vegetation/plants in Downtown	2	7	16
Access to recreational park space	2	3	20
Local air quality	4	2	19

Among respondents, levels of concern were highest regarding local air quality (77%), access to recreational park space (77%), and amount of vegetation Downtown (62%). There was less concern regarding water pollution/stormwater runoff (44%) and amount of shade available Downtown (18%). This information should be considered for the design scenarios of a greenspace project, and also for the growth of a knowledge base surrounding ecosystem services provided by greenspace. Perhaps respondents were less concerned about water quality and shading because they are not fully aware of all the problems associated with these issues, or how greenspace can ameliorate these problems.

Appendix D: Harlem Place Physical Site Survey

Based on Seymour et al., 2007, SPACES for Alleys (Systematic Pedestrian and Cycling Environmental Scan): Instruction Manual and Audit Form

Methodology Surveying Harlem Place on 10/18/09

1. Printed out Google maps (schematic view) of each accessible block of Harlem Place to provide base layer for sketches and notation of features and conditions within and proximate to the site.
2. Walked the length of each block of Harlem Place and documented on maps:
    a. Garage doors (GD)
    b. Dumpsters (D)
    c. Minor access points (MA) – pedestrian access to the alley
    d. Property access (PA) - – doors, storage doors into buildings
    e. Unofficial access (UA) – broken fence, etc.
    f. Alley access (AA) – an alley intersecting Harlem Place
    g. Light (L)
    h. Utility (U)
    i. Waste disposal area (WDA)
    j. Street access (including through parking lot gates)
3. Made note and measured any currently existing trees or small greenspaces. Noted unused areas or excess spaces created by building or parking lot footprints that were not flush with the surface area of the service road. These areas were noted as they could possibly serve as more flexible opportunities for future greenspace and design feature installment.
4. Photographed alley
5. After marking the maps, we completed the “Survey: Physical Characteristics of Alleys (SPACES)” for each block. This survey report prompted documentation about utilities found in the alley, percentage of impermeable surfaces, litter, “signs of life”, noise, graffiti, visibility, and lighting.