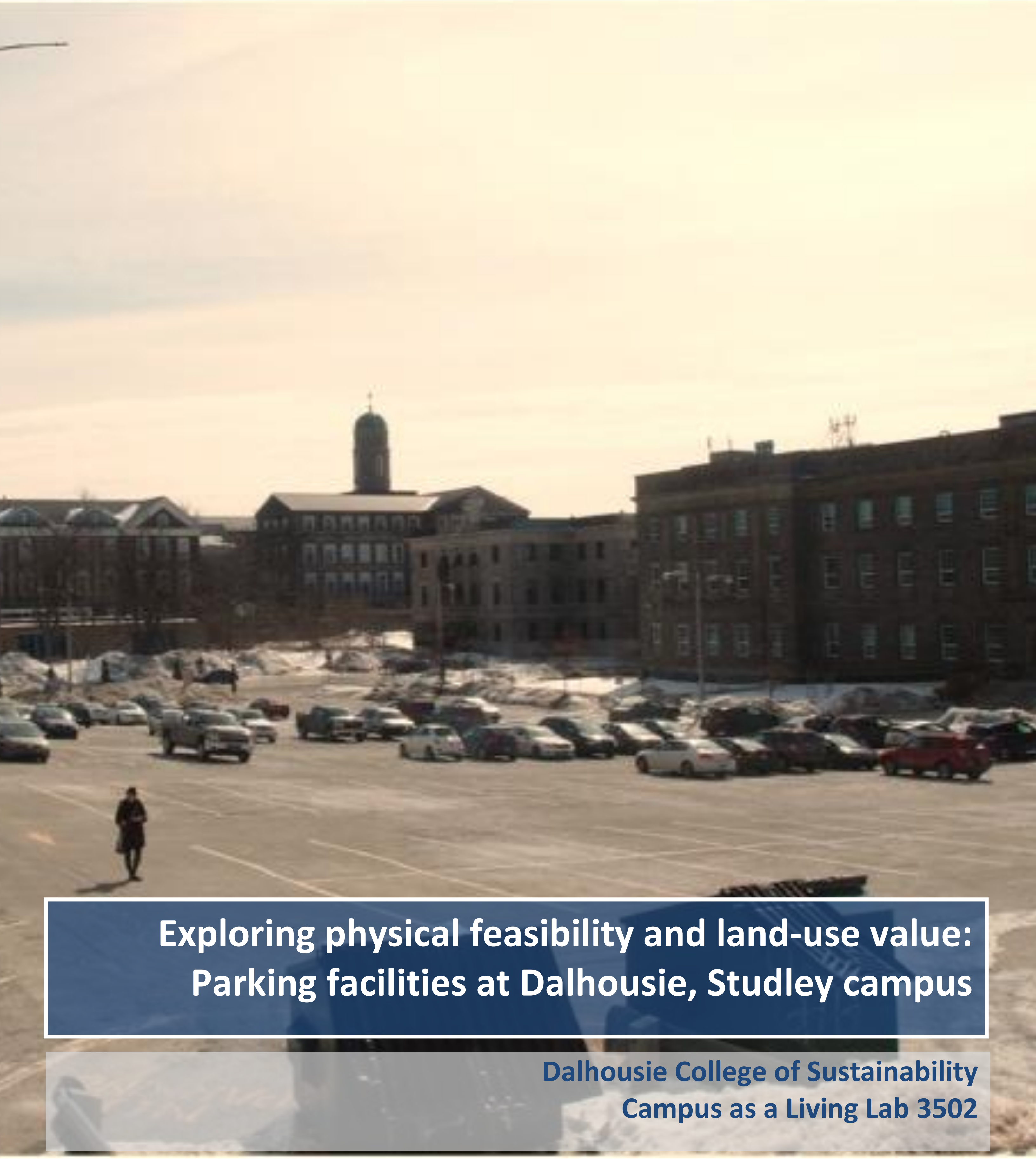


# Exploring physical feasibility and land-use value: Parking facilities at Dalhousie, Studley campus

Dalhousie College of Sustainability
Campus as a Living Lab 3502

## Authors Details

**Adrean Ojoleck**
BSc. Environmental Science

**Cally Baxter**
BSc. Environmental Science

**Camille Dumulon-Lauziere**
BA. Sustainability and Environmental Science

**Malcolm Morrow**
BA. Political Science and Sustainability

**Myra Pennington**
BCD. Community Design and Sustainability

## Table of Contents

# Executive Summary

Land-use in urban environments is an integral component of the functioning and efficiency of a city. It is desirable to design an urban landscape to utilize all of the available space. Dalhousie University in the city of Halifax, N.S has a lot of available space, all of which is found in parking lots. There have been measures taken to increase the sustainability of building infrastructure and transportation methods on Studley campus, however the sustainability of parking lots has been overlooked and underestimated.

The objective of this project was to identify sustainable alternatives and their physical feasibility for each parking -lot on Studley campus. The overall goal was to maintain the same number of parking spaces on campus, as that is an invaluable asset to stakeholders at Dalhousie, and to integrate sustainable infrastructure and biodiversity. From the literature review, consultation with experts, GIS mapping and site visits we were able to create criterion to assess the physical feasibility of integrating solar panels, permeable pavement and biodiversity into parking lots.
The results of our findings were that all of the parking lots that were evaluated were physically feasible for at least one type of green infrastructure.

By redesigning parking lots, Dalhousie University can adhere to the sustainability initiatives plan that was created in 2010. Integration of green infrastructure and biodiversity into parking lots on campus will help Dalhousie University reach several targets that were focused on reducing greenhouse gases, increasing renewable resources and enhancing the natural environment. Our recommendation would be for Dalhousie University to conduct further research on the economic feasibility of a project such as this and to determine if the undertaking would be worth the cost in the long-term.

# 1. Introduction

Located in the heart of downtown Halifax NS, Dalhousie University is a thriving institution that is home to a strong community within the larger city. As this institution continues to grow, future development is confined by the amount of available land on the Halifax Peninsula. Future development on campus would require a design that maximizes the utility of a space and is sustainable in nature. Dalhousie University set out sustainable goals in 2010 that dictates their plans for development and expansion over the next decade. These plans take into account the restriction of space that Dalhousie is confined to and the importance of integrating sustainable technology and infrastructure.

As economies grow and major urban centers develop, the availability of land as a resource diminishes. Basic economic principles dictate that the value of land will increase (Young et. al. 2014). Therefore, maximizing the value being derived from urban land to its fullest extent is becoming increasingly relevant and foregoing green infrastructure development in the absence of available land creates an increasingly expensive opportunity cost (Lynch & Geoghegan, 2011). Currently, parking facilities provide a service to the consumers who use them. However, outside of the usual use timeframe of 9:00 am to 5:00 pm, parking facilities provide very minimal utility to the majority of community stakeholders (Davis et. al. 2010). Our research identifies methods of minimizing the opportunity cost associated with campus value-deserts by enhancing the social, economic, and environmental benefits being derived from parking lots.

Image 1. Parking lots, although essential for access during the day, are extremely under utilized during off hours.

The physical diversity of the parking lots on campus is significant. Determining the type(s) of green infrastructures (i.e. renewable energy technologies, surface material selection, stormwater management, natural landscaping, and irrigation) are most suited to specific parking facilities is paramount to assure that both maximum utility is derived from enhancing land-use value and also to avoid the inefficient allocation of university fiscal resources. Although our research is limited to physical feasibility and does not take into account economics, we believe that this will enable university decision-makers to understand the aggregate benefits of adding green infrastructure to parking facilities on campus.

The objective of our proposed green infrastructure project is to investigate ways in which to reduce the urban heat island effect, achieve cleaner air quality, promote management of stormwater runoff, and enhance visual aesthetics, to meet the Dalhousie Sustainability Initiatives. Given the significant allocation of urban land to parking facilities on campus, green infrastructure will undoubtedly provide significant long-term benefits. Furthermore, the relative costs associated with abating emissions and environmental degradation are steadily increasing (Norton et. al., 2015). To be clear, our research is not aimed at reducing parking on campus. Our objective is to enhance the land-use value of parking lots by diversifying the services they can yield. Parking is an essential service that Dalhousie must provide to ensure that people coming to campus have the ability to effectively commute and station their vehicles.

This research explores where the installation of green infrastructure is physically feasible within parking lots on Studley campus. In the context of this study "physical feasibility" means that the existing conditions, including dimensions, topography, sun exposure, and surrounding landscape, at a given parking lot are suitable for the installation of one or more types of green infrastructure(s). Further, this research project is aimed to work in synergy with the Dalhousie Sustainability Initiatives (Dalhousie University, n.d). By enhancing the depth and scope of knowledge that informs Dalhousie University decision-makers. This research examines the land-use value of parking lots while inadvertently questioning the status quo of "what services can be provided by sustainable infrastructure on campus?". To do so, this research project explores the following question: **What types of green infrastructure are physically suitable to be added to parking facilities on Studley campus?**

# 2. Background

Dalhousie University has a student body of more than 18,000 individuals and employs more than 6,000 faculty and staff (McNutt, 2013). With 24,000 people on campus daily, there is a considerable demand for parking spaces. Conventional parking lots can take up a lot of space around campus, they can be aesthetically unpleasant, during heavy rainfall their large impervious surfaces can contribute to flooding, having more parking for cars than for bikes creates incentive for people to drive, and the blacktops facilitate the urban heat island effect (Takebayashi & Moriyama 2009). There is opportunity to enhance parking lots around Dalhousie campus, while continuing to provide the services necessary for those with automobiles travelling to campus.

## 2.1 The Dalhousie Context


Dalhousie University, being home to a large population of students and staff, manages more than 2,000 parking spaces regrouped into multiple parking lots (Dalhousie University, 2011). Thirty-one percent of the Dalhousie population lives in an area where public transit is unavailable or not a viable option. This is why on average the campus parking lots are occupied at a 90% capacity rate (Dalhousie University, 2011). Taking this evidence into account, it is clear that parking lots are a need on campus and cannot be removed. Nevertheless, this does not mean their environmental impacts cannot be improved by better design and green technologies. Outside the hours of 9:00 am and 5:00 pm (Horne, 2015), Dalhousie parking lots provide minimal utility to campus stakeholders, as displayed in image 1 below. Consequently, if green technologies could be included in the design of these lots, these concrete surfaces could provide continuous benefits to campus.

## 2.2 Helping the Dalhousie Sustainability Goals

In the past decades, Dalhousie University has dedicated itself to becoming a sustainable leader and achieving a higher LEED status (Dalhousie University, n.d). For this purpose, the Office of Sustainability has created a report entitled ‘‘The Dalhousie Sustainability Plan’’ (Dalhousie University Office of Sustainability, 2010). This plan outlines two main focus points: ‘‘ecological health benefits and economic efficiencies’’ (Dalhousie University Office of Sustainability, 2010, p.2). This research project could help the university reach these targets. Furthermore, this plan also contains strategies and goals the university is pursuing such as: better design for transportation, reducing electricity per person, increasing renewable energy supply on campus, enhancing urban biodiversity and creating a natural landscape environment (Dalhousie University Office of Sustainability, 2010). Many of these goals could be achieved in collaboration with the solutions of the parking lot re-design outlined in this research. For this reason, this research is timely and could provide a beneficial sustainability project, which could be undertaken by the university in the future.

## 2.3 Sustainable Issues Associated with Parking Lots

The asphalt commonly used in parking lots creates an impervious layer resulting in stormwater runoff. Urban stormwater runoff can be filled with pollution that will end up in receiving waterways (Faucette et al., 2013). Utilizing permeable pavement, which allows the water to filter through, unlike asphalt, will reduce the amount of surface runoff and lower the amount of unwanted metal and oil residues found in the water (Brattebo & Booth, 2003). Incorporating green space and rain gardens into parking lots are other good ways to tackle excess water by providing soil space for the water to percolate into the ground. By minimizing the amount of flow over impervious surfaces we can reduce the amount pollutants found in the stormwater. Also, parking spaces adjacent to any buildings could be better utilized by implementing rain barrels to catch the excess water flowing off the roofs nearby before it travels over the parking lot (Davis, 2005).

More than 50% of the earth’s human population now resides in urban areas (Kennedy, 2009). High commuter rates result in the need for transportation. In 2011 transportation was the largest contributor to Canada’s greenhouse gas emissions (Environment Canada, 2013). In order to encourage the use of alternative transportation, designated areas of parking lots could be re-established as bike sharing systems. Using a bike sharing system would lower environmental impacts of transportation activities, and create health benefits for the users (DeMaio, 2009).

The urban heat island effect results from the absorption of heat from the sun onto urban infrastructure with a low albedo, such as pavement or roofs (United States Environmental Protection Agency, 2013). The heat island effect causes cities to be warmer compared to their rural surroundings; this is especially noted during hot summer days (United States Environmental Protection Agency, 2013). Having a hotter city can lead to higher energy consumption and increased greenhouse gas emissions due to higher demands of cooling, and increased surrounding water temperatures due to heat transfer from the urban infrastructure (United States Environmental Protection Agency, 2013). Trees can be used throughout parking lots to reflect some of the incoming sunlight and help curb the urban heat island effect (Norton et al. 2015). Incorporating solar panel overhangs throughout larger parking lots is another way to limit the heat island effect. The solar panel overhangs could provide energy to nearby buildings or electric cars and also create a sun and precipitation barrier to the parked cars below (Platts, 2009).

As mentioned above, society has become more aware of issues associated with parking lots. They can generate urban heat island effect, increase surface runoff and accumulation of pollutants and they provide almost no value to biodiversity (Davis, Pijanowski, Robinson, & Engel, et al., 2010). However, parking lots still account for a substantial amount of space in urban areas regardless of their environmental impacts (Davis et al., 2010). In North America, the ecological footprint of a parking lot is often higher than the building it services (Davis et al., 2010). Ultimately, because of the demand and needs associated with the present human lifestyle the ecological footprint of parking lots will inevitably increase. Nonetheless, better technologies and design could help lessen their impacts. For this reason, research and project development in this area has been accumulating.

### 2.4. Case Studies of Parking Lot Infrastructure Projects

Considering the evidence gathering around this issue, many cities and universities have recently decided to take action and conduct their own projects (Table 1).

**Table 1. Selected examples of green parking lot infrastructure projects.**

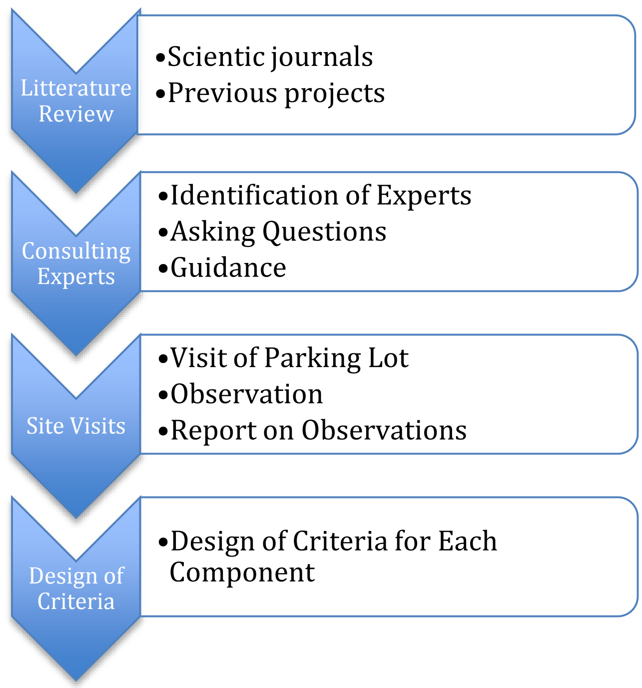
| Location | Institution | Project |
|---|---|---|
| **Toronto, Canada** | City Planning Department | Creation of new guidelines for greening surface parking lots. These guidelines outline possible modifications and adjustments to parking layout, stormwater management system, permeable paving surfaces and implementation of solar panels (Toronto City Planning, 2013). |
| **San Diego, United States** | National University | Development of a solar carport which will provide 1.4 million kWh of electricity annually (National University, 2012) |
| **New Brunswick, United States** | Rutger University | Transformation of a 28 acre parking lot into the biggest solar carport in the United States. It provides 60% of the electricity for one of the campuses (Solaire Generation, 2013). |
| **Vancouver, Canada** | Vancouver Island University | Implementation of permeable pavement which has helped the university reach a higher LEED status (Vancouver Island University, n.d) |
| **Halifax, Canada** | Dalhousie University, ENVS 3502 Project in 2012 | Investigation of the problem associated with runoff on the Dunn parking lot. Proposed solutions such as rain barrels, rain gardens and permeable surfaces (DeCoste et al., 2012). |

Based on these and other existing projects, it is apparent that recently many organisations have decided to move towards sustainable parking structures and design. Consequently, this issue is timely and could help Dalhousie become a leader in sustainable design. Nevertheless, not every solution is viable for the particular context at Dalhousie.

# 3. Research Methods

The goal of this research project is to use a transformative research method to identify what types of green infrastructure could be introduced to diversify the value derived from parking lots on Dalhousie University's Studley campus. This process used the following four steps: 1) conducting a literature review; 2) consulting experts 3) site visits and 4) designing criteria (See table 2). From this information the feasibility of each parking lot to accommodate specific green infrastructure was assessed.

**Table 2. Flow of methodology employed during this research study project.**




First, the literature review is an evaluation of current studies and research around these green infrastructure project. Second, an expert from each of these three fields of study (solar research, stormwater management and biodiversity benefits) was approached via email to gather more detailed guidance on the specifics of implementation in the context of Dalhousie. Following was a site visit conducted by two researchers observing and recording the current state of parking lots on Studley Campus. The final step in the information-gathering phase was designing the final criteria based on the past three steps as well as the use of GIS data interpretation.

### 3.1 Characteristics of research methods

Assessing the feasibility of a parking lot can both qualitative and quantitative. We chose a qualitative analysis. It is about observing the environment and determining if changes can be implemented. This research does not require interaction with the public. Therefore, sampling, surveying or interviewing the population is not required. Evaluating if changes to the parking lot are feasible must be done by means of research and observation. This is why for this particular case a literature review, an analysis of space and talking to experts are much more suitable measurement choices.

Our objective was to adhere to a high level of validity, reliability and trustworthiness in the research procedures while conducting the study. Reliability is the degree to which repeated measurements yield the same response (Creswell, 2014, 249). When extensive literature reviews and consultation with experts provided the same result we were able to formulate reliable criterion for assessing physical feasibility. The criteria for assessing physical feasibility were based upon research procedures, such as, contacting various experts, exploring several types of green infrastructure, use of GIS software and conducting site visits with two researchers. These methods also demonstrate the validity of the study. Validity is defined as being the accuracy of findings (Creswell, 2014, 250). To ensure that a true portrayal of the study was given, the research procedure was constructed to minimize bias and to maximize representativeness. One area where validity may have been compromised in the research procedure was during the use of GIS software to reconstruct the aspect and slope of the sites that were under assessment. The GIS data has a margin of error that is a result of not being precise or accurate and potentially being out-dated.

A large effort was made to ensure that the research procedures conformed to the standards of trustworthiness. Trustworthiness is demonstrated by having sound and strong evidence for the study that is maintained through high credibility and objectivity (Creswell, 2014, 206). The foundation of trustworthiness is maintained by dependability, credibility and confirmability. Having dependable research requires that the research be logical, traceable and documented. Throughout the study the research procedures were well documented and cited. Conversations with the experts were recorded and inserted into the final report appendix as a transcript. The credibility of research is a result of taking respondents views and reconstructing the main idea.

Lastly, the attribute of conformability is to link results of findings and create an interpretation of the situation. Preceding the literature review the consultation with experts was used as a research procedure to confirm the best type of green infrastructure to implement in the parking lots on Dalhousie.

Studies are always faced with limitations and factors, which are beyond the control of researchers. Considering the scope of this particular study many limitations were identified. First, this research was limited by time. Ultimately, the goal was to examine more criteria for each component. However, because of time constraint, criteria became fewer and simpler than originally planned. The weather was another uncontrollable factors, which restricted the extent of this study. The many snow storms interfered with data collection time and accuracy. Snow made it impossible to clearly see all the characteristics of each parking lot such as the number of drains. Limitations of this study were obstructions to the development of precise and complex results.

Throughout the process of constructing and executing our research study, certain delimitations were imposed to make the study manageable with given temporal, educational and material resources. In order to limit the scope of the study, only certain criteria were accounted for. It should be recognized that these are not the only influences on the feasibility of implementation for the projects in question, but by limiting the scope to two criteria for each, we were able to begin important measurements and make general conclusions. Intentionally, economic feasibility was not computed, as it is often difficult to measure the benefits of sustainable infrastructure as a monetary value. Another delimitation to note is the bounded geographic scope. Three parking lots on the Studley parking lots were examined in this study; others located on the campus were omitted based on their surface area. The three lots chosen were identified as spatially significant and therefore more suitable locations for successful sustainable infrastructure projects. Finally, important to note is the delimitation placed on expert advice. Only one expert was approached for each of the infrastructure projects in question.

## 3.2 Literature review

Initially, a systematic review of literature pertaining to the idea of green parking lots was employed. The search focused on three areas or themes believed to be the most applicable greening methods within the study area. These three main options consist of solar panel energy production, stormwater management systems and introducing green space. Online databases were the main research source for the literature review, inputting key search words similar to those used in ENVS/SUST 3502 Lab 1, that reflect the parking lot valuation and greening goals of this project. During this literature review process, important questions were identified and collected to ask experts about later on.

A preliminary literature review was conducted and background information was gathered regarding the greening of parking lot infrastructure; this showed a variety of options to be considered when retrofitting parking lots. Projects already implemented in different parts of North America were reviewed (Table 1). The options identified for greening parking lots included solar overhangs, bike sharing systems, pervious pavement, swales, rain gardens, rain barrels and trees and biodiversity. It was decided the topics listed must be limited to enable thorough analysis. In the interest of time and resources, three main options were looked at; solar overhangs, permeable pavement, and biodiversity. Bike sharing was not taken into consideration because previous studies have shown that it is not successful in the Halifax area, largely due to the requirement of helmets (Blenman, 2012). The research showed four options of stormwater management practices that could be further looked into. Pervious pavement was decided upon for the main focus because swales and rain gardens could be a form of biodiversity integration and could therefore be included in that category. Rain barrels were not further studied; they would not be a retrofit to the parking lot themselves but be placed under adjacent buildings.

### *3.2.1 Solar Panels*

The literature available on the implementation of solar panels over parking lots is quite limited. The first journal article analyzed by Neuma, Schar and Baumgartner described the key characteristics needed for the installation of solar panels. This article identified the process of choosing a parking lot, how much emission a certain size parking lot can help reduce and the different type of technologies available. Furthermore, this article explained the amount of time needed for their specific studied parking lots to bring in profit. The second article examined by Butler and Lottie describes the implementation of a 56 spot solar carport. Being a very short article, it focused on the potential power generated by the studied parking lot. The last article researched by David Hopwood discussed the installation of solar panels at the headquarter of an organisation in Germany. From this article new knowledge was acquired about the inclination solar panel must posses in order to be useful.

These articles were useful in gathering background information about the characteristics qualifying solar panel implementation to be physically feasible. Nevertheless, these articles were mainly descriptive and very limited in scope; they were each specific to one particular situation. For this reason, the knowledge acquired was sometimes inapplicable and irrelevant to the Dalhousie parking lot context. These articles did however help us to formulate better-informed questions to ask experts. These questions could be:

- Based on what characteristic should we choose a parking lot?
- How big should a parking lot be?

- What are the different types of solar panels?
- On average what it the payback time?
- Based on certain types of solar panels what is their energy generation capacity?

### 3.2.2 Stormwater Management

Conventional asphalt parking lots are a disadvantage in terms of stormwater runoff and pollution management (Toronto City Planning, 2013). The asphalt creates an impervious layer resulting in the accumulation of parking lot stormwater, which is often laden in heavy metals and oil residue. This contaminated runoff leads into proximate drains or water bodies without any water treatment services (Reddy et al, 2014).

A study by Reddy, Xie, and Dastgheibi tests four different filter materials to see which one would remove the greatest percentage of six common heavy metals from urban stormwater runoff. It was determined that a mix of two or three of the filter materials would be the best option in capturing the highest percentage of heavy metals. Guidelines drawn up by the City of Portland outline site evaluation criteria for stormwater management practices, this criterion indicates if site conditions allow, pervious pavement should be implemented to assist with stormwater management. An article published by Rushton describes the benefits of man-made and natural swales, coupled with pervious paving, used to combat stormwater runoff and pollutants.

The amount of data on stormwater management is quite extensive; the literature examined was very helpful in giving an introduction and overview of common stormwater management practices. The articles helped to limit the amount of applicable stormwater management practices of the Dalhousie University parking lots that will be examined. For example, using swales for stormwater management has shown to be advantageous, but if man-made swales are implemented they take up a large amount of space adjacent to the parking lot; the parking located on Studley campus do not have vast amounts of space adjacent to them. The literature focusing on the implementation of pervious pavement was all very positive and concluded that if the resources were available and the parking lot criterion allowed, pervious pavement should be implemented to mitigate stormwater runoff and pollutants. The articles examined provided background information to formulate questions to ask experts in the field of stormwater management. These questions include:

- Based on the size of the parking lot, what are the best stormwater management practices to implement?
- What are the most common heavy metal pollutants found in runoff in the Halifax, NS area?
- What are the positive and negative environmental implications of retrofitting an existing asphalt or concrete parking lot with the most appropriate pervious pavement?

### 3.2.3 Ecological Services

Parking lot infrastructure has an important role in the functioning of cities. It has been estimated that by 2050, two thirds of the global population will be living in cities (Kattel et al., 2013). Not only is there an expected increase in demand for parking spaces but it is also expected that it will be accompanied by environmental degradation.

The literature available has proposed that in order to make up for the increasing population, cities need to implement more green spaces, integrating the use ecological services that trees and plants provide. Ecological services are defined as 'the conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfill human life' (Jansson, 2013, p.285). Ecological services are provided by biodiversity and they help to maintain the stability and integrity of ecosystems (Freedman, 2010, p.83) Examples of the services that are provided by biodiversity are nutrient cycling, carbon storage, biological productivity, phytoremediation, cleansing of water and air and provision of atmospheric oxygen (Freedman, 2010, p.83). Future planning for sustainability should ensure that green spaces are integrated throughout the urban landscape (Barthel, p. 263).

The first article focused solely on the importance of ecological services and how they can be used to our advantage in urbanized areas to lesson $CO_2$ emissions, flooding and the urban heat island effect. The second article presented the idea that increasing biodiversity in the cities would strengthen the social ecological relationship between people and nature. By increasing the biodiversity in cities humans can reconnect with nature and benefit from the ecological services that are provided. Both articles provided insight to the importance of ecological services and established that further research in this field would include explicitly quantifying the role of biodiversity for ecosystem service generation. The literature provided thorough background information on ecological services that helped the researchers to formulate informed questions to ask the experts. The possible questions may be:

- Where are the best locations to integrate biodiversity in an urbanized environment?
- What are the best species to use in urban environments? Specifically, what species are best to integrate in the City of Halifax, N.S?
- Are native species better to use than exotic species?

## 3.3 Consulting Experts

Following the literature review, experts within these topics were contacted for further insight on project considerations and specifications. Experts were contacted primarily via email messaging with questions identified from the literature review, outlined above. As responses were received (see appendix B), comments from our experts were incorporated into the identification of criteria.

### *3.3.1 Solar Panels*

The expert contacted for expertise on solar panel implementation was a company called Schletter Canada. This company was chosen based on proximity and experience. It is an Ontario based company that claims to have done over 3000 solar projects (Schletter Canada, n.d). Schletter Canada also offers multiple configurations of solar carports, a service not available through every company.

Their email response was very informative. This company discussed how southern slope would have the greatest sun exposure and would therefore be ideal for solar panel implementation. The different types of solar panels and their capacity were also mentioned. In addition, Schletter indicated that solar carports can be useful for snow and sun protection which are added benefits to the implementation. After reviewing the information, many conclusions and considerations were gathered to move ahead in designing feasibility criteria.

### *3.3. 2 Stormwater management*

Stephen Cushing, Office of Sustainability Natural Environment Officer, was contacted as an expert on stormwater management. Stephen is currently enrolled in his Masters of Environmental studies at Dalhousie University and has completed a Master's in Landscape Architecture from the University of Guelph and a Bachelor's degree in Environmental Horticulture from the Nova Scotia Agricultural College.

This expert's answer helped identify many new aspects of stormwater management, which must be considered. Cushing mentioned how drains in Halifax are often overwhelmed and better stromwater management practices are key. Other methods of stormwater management such as rain gardens or holding ponds were also discussed. This expert stated the negative impacts of permeable pavement and other methods. This information was taken into account during the design of criteria.

### *3.3.3 Biodiversity*

The expert that was contacted for expertise on biodiversity implementation in the urban landscape was Dr. Rajesh Rajaselvam a professor at Dalhousie University from the Faculty of Environmental Science. Dr. Rajaselvam completed his Ph.D from Oxford Universities and is a registered Forester in both England and Ontario. This expert was chosen based on his experience and accessibility.

No response was received from this expert.

## 3.4 Site Visits

The site visits were conducted by two of the researchers on the team. The site visits included visiting all of the nine outdoor parking lots on Dalhousie University's Studley Campus to evaluate which parking lots met the criteria for the different types of redesign (see image 2, below). The researchers used a standardized set of questions to narrow in on characteristics that they were seeking to evaluate. There was a strong emphasis to seek out qualitative characteristics of the space that aren't available through online data source; such as how pedestrians and traffic moved through the space, the number of parking spaces, the sun exposure, objects that obstruct sunlight, the topography, location of water drains, the flow of water throughout the space, surrounding green space and the location of trees, plants and grass.

Image 2. Collage of pictures collected during the site visit of Dalhousie Studley campus parking lots. All photos by Adrean Olojeck.

Using two researchers for qualitative observation made the task safer for both individuals and it aided in minimizing the bias of observation (Creswell, 2014). Qualitative observation gives the researchers a firsthand experience with the locations being targeted for valuation, allowing the researchers to record relevant information and any unusual aspects as they came across it (Creswell, 2014). A comprehensive report of the qualitative and quantitative attributes of the parking lots, such as the number of parking spots, topography and the amount of green space, can be viewed in Appendix A.

Site visits, literature reviews and the asking of outstanding questions to local experts were all conducted. It was determined that for the purpose of this study, and in the interest of time, doing a full review of all nine parking lots considered on Studley Campus was not feasible. A group discussion about time frame and delegation of tasks concluded that three parking lots was an appropriate number for the group to assess. The three parking lots chosen for further physical feasibility of green infrastructure assessment were the Dalplex parking, Howe Hall parking and Wickwire Field parking (see Image 3). The Howe Hall parking lot was chosen because it had the largest number of parking spots. The Dalplex parking lot was chosen because of its large size, flat area and excellent sun exposure. The Wickwire Field parking lot was chosen because it had the closest number of parking spots to the overall average of 88. If further research is conducted on this topic it is recommended that the other parking lots also be examined.

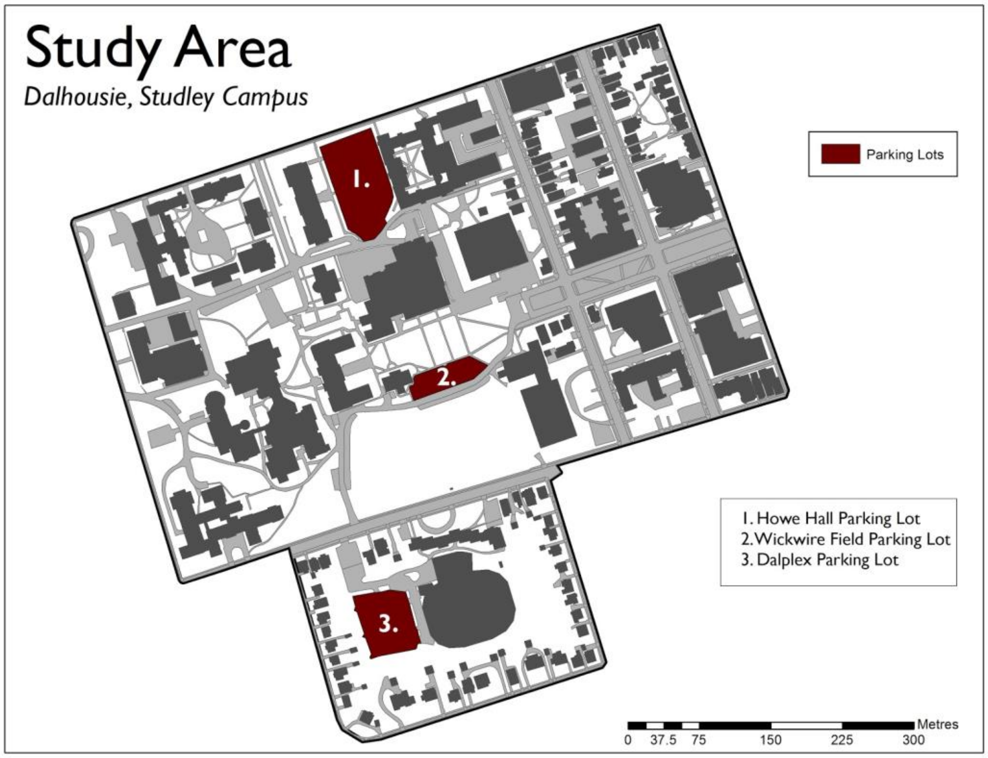



Image 3. A map of the finalized study area, three parking lots were chosen for further analysis following the site visits. Only these three parking lots will be considered further for their suitability to house green infrastructure projects.

## 3.5 Finalized Criteria

The final criteria were the basis on which the physical feasible of each parking lot was evaluated. Two criteria were identified for each component. These criteria are based on the information gathered through the literature review, the site visit and the conversations with experts.

**Table 2. Feasibility criteria for each green infrastructure**

| | Solar Panels | Stormwater management | Biodiversity |
|---|---|---|---|
| **Criterion 1** | Number of parking spots | Slope of the parking lot | Pre-existing biodiversity |
| **Criterion 2** | South facing exposure | Number of drains | Space available to add biodiversity |

### *3.5.1 Solar panels*

The first criterion identified for the solar panel is the size of the parking lot. The literature review shows that most solar carports are spatially significant. Through extensive research the smallest solar carport identified contained 56 parking spots. Therefore, for solar panels to be a viable option, there must be enough land area to install a profitable amount of solar panels. This is why the criterion for size will be **50 parking spots and over.** Smaller parking lots are not considered viable.

The second criterion established for solar panel implementation is sun exposure. Evidently, a solar carport not exposed to sun would be ineffective. It was identified through research that southern exposure is the optimal direction for sun exposure (Lave & Kleissl, 2011). This criterion was identified with GIS (appendix C). Therefore, parking lots **with southern exposure** are considered viable.

### 3.5.2 Stormwater

The first criterion for stormwater retention potential was the gradient of the slope. The gradient of the slope was calculated with GIS (Appendix C) . The smaller the slope the more effective the permeable pavement becomes. If the runoff is too intensified by a steep slope in one area of the parking lot, the potential permeable pavement water storage capacity will decrease. Research shows that an area with a slope higher than 5% is not considered viable for permeable pavement (New Jersey Stormwater BMP Manual, 2004). For this reason, a parking lot with **a slope of 5% or less** is considered feasible.

The second criterion identified for stormwater capture is the number of drains. Parking lots already possessing a certain number of drains can help to deal with surplus flow if the permeable pavement stormwater storage capacity is overwhelmed (New Jersey Stormwater BMP Manual, 2004). The criterion requires a minimum of **two drains.**

### 3.5.3 Biodiversity

The first criterion examined the pre-existing biomass in the area. Parking lots that lack trees or any kind of native plants were prioritized. The goal is to increase biodiversity. This was measured through an examination of the existing tree stands in each study area. The amount of trees was reviewed with GIS (Appendix C). Therefore, the parking lot with the **least existing biomass is considered the most feasible.**

The second of the biodiversity parking lot criterion is the amount of available space. The city of Toronto planning recommends a distance of 1.5m between cars and trees (Toronto City Planning, 2013). It also recommends a 3m green space on the edge of the parking lot. Consequently, evaluating if there is enough space to add these areas is key (Toronto City Planning, 2013). The evaluation of this criterion was done visually and was simply given a **grade of feasible or infeasible.**

# 4. Results

## 4.1 Evaluating the feasibility of each parking lot

Evaluating the feasibility of each of the three parking lots based on the criteria outlined above. This examination occurred through qualitative analyses informed by site observation as well as GIS online mapping data. Each of the parking lots will receive a conclusion of either feasible or not feasible for each of the criteria.

### *4.1.1 Howe Hall Parking lot*

Image 3. Howe Hall Parking lot, image courtesy of Adrean Olojeck.

**Solar panels**

Criterion 1: Parking lot contains more than 50 parking spots. Considering criterion 1, this parking lot is **feasible** for the implementation of solar panel**.**

Criterion 2: Parking lot contains south facing slopes. Considering criterion 2, this parking lot is **feasible** for the implementation of solar panel**.**

**Stormwater**

Criterion 3: The surface of this parking lot contains a substantial amount of area with greater than 5% slope. Considering criterion 3, this parking lot is **not feasible** for the implementation of permeable pavers**.**

Criterion 4: Parking lot contains 2 drains. Considering criterion 4, this parking lot is **feasible** for the implementation of permeable pavers**.**

**Biodiversity**

Criterion 5: This parking lot has the most trees in its surroundings in comparison to the other study areas. Considering criterion 5, this parking lot is **not feasible** for the implementation of green space**.**

Criterion 6: This parking lot is large. Considering criterion 6, this parking lot is **feasible** for the implementation of green space**.**

### *4.1.2 Wickwire Parking Lot*


Image 4. Wickwire parking lot, image courtesy of Adrean Olojeck.

**Solar Panels**

Criterion 1: Parking lot contains more than 50 parking spots. Considering criterion 1, this parking lot is **feasible** for the implementation of solar panels**.**

Criterion 2: Parking lot contains south facing slopes. Considering criterion 2, this parking lot is **feasible** for the implementation of solar panels**.**

**Stormwater**

Criterion 3: The surface of this parking lot contains areas with greater than 5% slope. Considering criterion 3, this parking lot is **not feasible** for the implementation of permeable pavers**.**

Criterion 4: This parking lot does not contain any drains. Considering criterion 4, this parking lot is **not feasible** for the implementation of permeable pavers**.**

**Biodiversity**

Criterion 5: There are many trees surrounding the study area. Considering criterion 5, this parking lot is **not feasible** for the implementation of green space**.**

Criterion 6: This parking lot is narrow. Considering criterion 6, this parking lot is **not feasible** for the implementation of green space**.**

### *4.1.3 Dalplex*

Image 5. Dalplex Parking lot, image courtesy of Adrean Olojeck.

**Solar panels**

Criterion 1: Parking lot contains more than 50 parking spots. Considering criterion 1, this parking lot is **feasible** for the implementation of solar panels**.**

Criterion 2: Parking lot contains south facing slopes. Considering criterion 2, this parking lot is **feasible** for the implementation of solar panels**.**

**Stormwater**:

Criterion 3: The surface of this parking lot is all under 5% slope. Considering criterion 3, this parking lot is **feasible** for the implementation of permeable pavers**.**

Criterion 4: Parking lot contains 2 drains. Considering criterion 4, this parking lot is **feasible** for the implementation of permeable pavers**.**

**Biodiversity:**

Criterion 5: There are lots of trees surrounding the study area. Considering criterion 5, this parking lot is **not feasible f**or the implementation of green space**.**

Criterion 6: This parking lot is large and spacious. Considering criterion 6, this parking lot is **feasible** for the implementation of green space**.**

**Table 1. Physical feasibility of parking lot sites based upon criteria**

| | **Solar Panels** | | **Storm Water** | | **Biodiversity** | |
|---|---|---|---|---|---|---|
| Location | 50 parking spots or more | South facing exposure | 5% slope and lower | 2 drains or more | Amount of existing biomass | Large area available |
| **Howe** | ✓ | ✓ | ✗ | ✓ | ✗ | ✓ |
| **Wickwire** | ✓ | ✓ | ✗ | ✗ | ✗ | ✗ |
| **Dalplex** | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ |

After critical analysis of literature, consultation with experts and site visits to the proposed areas; some conclusions were drawn about the physical feasibility of implementing different types of infrastructure to various parking lots on Dalhousie's Studley campus.

Looking at the parking lots individually, based on the criterion for solar panels, storm water management and biodiversity, the Howe Hall parking lot was feasible for implementation of solar panels. The implementation of permeable pavement and biodiversity were not regarded as the best options for the site, however a look at other criterion, might change the grading of physical feasibility for implementation. The Wickwire field parking lot was deemed physically feasible for implementation of solar panels however the criterion for the physical feasibility of permeable surface pavement and biodiversity were both pronounced not feasible for this location. The evaluation of the Dalplex parking lot concluded that the site was feasible for the implementation of solar panels and permeable pavement. It was concluded that implementation of biodiversity is not the best option for this site, yet it was feasible for criterion number 6, so other criterion not considered here could be looked at in the future to assess the physical feasibility more thoroughly.

# 5. Discussion

The goal of this research was to identify how the value of parking lots can be enhanced by the implementation of green infrastructure. To do so, this research project aimed to answer this question: What types of green infrastructure are physically suitable to be added to parking facilities on Studley campus? During this research, many parking lots were visited but only three were selected for study: Howe, Dalplex and Wickwire. These parking lots were then evaluated to see if they could house solar panels, permeable pavers and increased biodiversity. The research conducted provided results demonstrating that, based on the six criteria determined in this study, parking lots on Studley campus could accommodate certain green technologies.

The six criteria determining the physical feasibility of solar, stormwater management and biodiversity implementation were examined for each of the three parking lots; the results are shown in Table 2. All three parking lots have shown to be physically feasible for the implementation of solar panel overhangs. Therefore, it is recommended that a pilot project of solar overhangs be implemented in each of the parking lots to gauge practicality, efficiency, and overall acceptance by the parking users. The Dalplex parking lot was also identified as being a physically feasible site for the implementation of permeable pavement. Further study on the financial feasibility of this project should be undertaken. As mentioned by Stephen Cushing, the lack of companies offering this service might make the project too expensive for real consideration. A further evaluation of different types of stormwater management projects may be in order, such as the possibility of rain gardens, bioswales or rain barrels may be more suitable. Unfortunately, none of the sites were identified as feasible for the implementation of green space under the studied criteria. This may be due to the restrictive and loosely defined nature of criterion 5. Further studies might omit this criterion and base physical feasibility of green space on some form of desirability or current use instead.

Further recommendations that we believe are critical to enhancing the criteria that assess the feasibility of green infrastructure/technology implementation to parking facilities would be to examine economic feasibility. For solar panels, this would include a rate of return on investment. As solar panels increasingly abate the need for outsourced energy, they reduce grid demand and subsequently costs. Determining when the rate of return is greater than the sum of the initial investment could spur University decision-makers to more actively seek solar panel installation.

For permeable pavement, this would include evaluating current stormwater management costs on campus and whether current costs will be abated through the installation of permeable pavement, or not. Determining precipitation levels that would result in the current stormwater management systems being over-capacitated would be the first step. Subsequently researchers would determine the probability of x precipitation and create a rate of return on investment (how much money does not need to be spent due to the installation of permeable pavement) to economically justify the installation of permeable pavement.

Landscape biodiversity would be the most difficult category to justify in economic terms. There is no current market price for carbon sequestration in Nova Scotia and furthermore, evaluating the social benefits that green spaces create in a community is seemingly difficult. Many University stakeholders may express an interest in utilizing green spaces, but many would not be willing to pay for them. This raises the question “should green spaces be an area that individuals pay-per-use or are green spaces a common commodity that the University should provide to stakeholders because of the empirically proven mental health benefits of green spaces?”.

Ultimately, this research shows that the type(s) of green infrastructure possible is specific to each parking lot. During the preliminary site visit, it was already clear that some of the characteristics of certain parking lots would not be suitable for particular green technologies. Nevertheless, by using GIS, research and gathering expert advice, some parking lot evaluations gave surprising results. Based on six criteria, this research found that there is no parking lot, which can accommodate all types of infrastructure. However, this does not mean green technologies should not be installed. Furthermore, research could be done on whether or not this project is something that is desired by students, and the social license on campus could be explored. It is clear that these parking lots can house green infrastructure. The next step will be to investigate if this is a timely project for the university.

# 6. Conclusion

This research project evaluated where it is physically feasible to introduce green infrastructure/technology to the Howe Hall, Wickwire, and Dalplex parking facilities. Our goal was to enhance the land-use value of these parking lots by diversifying the services they can sustainably provide. As a result of increasing urbanization, the value of Dalhousie’s urban land will continue to rise. The services that land-types provide should reflect and maximize market value. Through research, consultation, and examination, we developed specific criterion to determine how and where it is physically feasible to diversify land services on parking lots to enhance their value by installing green infrastructure and technology such as solar panels, permeable pavement, and natural landscapes/biodiversity.

The results and outcomes that our transformative research has yielded is not a surprise and largely coincides with published literatures examined for this study. Diversifying the services that parking facilities provide will increase its value and furthermore, limiting its services will restrict its value. Our research was delimitated to the physical feasibility of enhancing the land-use value of parking facilities at Dalhousie University. Therefore, we did not evaluate how much the proposed green infrastructure or technology would add social, environmental, or market value.

Our research provides a foundation for determining where the introduction of a greater variety green infrastructures and technologies is physically feasible on Studley campus. This study could become the starting point to which future researchers can utilize and effectively expand on the benefits of green infrastructure on university campuses.

## Acknowledgements

The authors of this proposal would like to thank Geoff Renaud, Stephen Cushing and Dr. Rajesh Rajaselvam for their expertise in answering the questions that were drawn up from the literature reviews.
This group would also like thank Dr. Tarah Wright and our mentor Nathan Ayer for the great support provide during this research process.

## References

Blenman, J. (2012). Bike share congestion. *The Dalhousie Gazette.* Retrieved from: http://dalgazette.com/news/campus/bike-share-congestion/

Brattebo, B., & Booth, D. B. (2003). Long-term stormwater quantity and quality performance of permeable pavement systems. *Water Research, 37*(18), 4369-4376. doi:10.1016/S0043-1354(03)00410-X

Butler, & Lottie. (2010). *Pick of the parking lot. Green Futures, 75*. Retrieved from: http://connection.ebscohost.com/c/articles/53012171/pick-parking-lot

City of Portland (2008). *Storm Water Management Manual*. Retrieved from: http://www.portlandoregon.gov/bes/article/449695

Dalhousie University. (2011). *Transportation Demand Management Plan For Dalhousie University.* Retrieved from: http://www.dal.ca/content/dam/dalhousie/pdf/sustainability/2012Dalhousie%20Transportation%20Demand%20Management%20Report%20Final%20November.pdf

Dalhousie University Office of Sustainability. (2010). *Dalhousie University Sustainability Plan*. Retrieved from www.sustainability.dal.ca

Dalhousie University Office of Sustainability. (n.d). *Mission Statement and Goals*. Retrieved from www.sustainability.dal.ca

Davis, A. (2005). Promote low-impact development. *Environmental Science and Technology*. Retrieved from: http://pubs.acs.org/doi/pdf/10.1021/es053327e

Davis, A. Y., Pijanowski, B. C., Robinson, K., & Engel, B. (2010). The environmental and economic costs of sprawling parking lots in the United States. *Land Use Policy*, *27*(2), 255-261. doi: 10.1016/j.landusepol.2009.03.002

Decoste, B., Pettinger, T., Pirie, R., Power, N., Simone, & Westlund, P. (2012). *Best Stormwater Management Designs using Bioretention retrofits at Dalhousie University*. Retrieved from: http://www.dal.ca/content/dam/dalhousie/pdf/science/environmental-science-program/ENVS%203502%20projects/2012/Stormwater_Management.pdf

DeMaio, P. (2009) Bike-sharing: history, impacts, models of provisions and future. *Journal of Public Transportation.* Retrieved from: http://www.nctr.usf.edu/jpt/pdf/JPT12-4DeMaio.pdf

Environment Canada. (2013). *Canada's emissions trends*. Retrieved from: https://www.ec.gc.ca/ges-ghg/985F05FB-4744-4269-8C1A-D443F8A86814/1001-Canada's%20Emissions%20Trends%202013_e.pdf

Faucette, B., Cardoso, F., Mulbry, W., Millner. (2013). Performance of compost filtration practice for green infrastructure stormwater applications. *Water Environment Research, 85(9),* 806-814. doi:10.2175/106143013X13736496908915

Gómez-Baggethun, Erik, & Barton, David N. (2012). Classifying and valuing ecosystem services for urban planning. *Ecological Economics, 86*, 235-245. doi: 10.1016/j.ecolecon.2012.08.019

Hopwood, D. (2007). ISES drives solar concept: The new SolarCarport at the ISES headquarters in Germany was officially unveiled in March this year. *Refocus, 8*(2), 42-44. doi: 10.1016/S1471- 0846(07)70049-5

Horne, L. ( Personal Communication, March 30th, 2015).

Jansson, &. (2012). Reaching for a sustainable, resilient urban future using the lens of ecosystem services. *Ecological Economics, 86*, 285-291.

Kattel, Giri R., Elkadi, Hisham, & Meikle, Helen. (2013). Developing a complementary framework for urban ecology. *Urban Forestry & Urban Greening, 12*(4), 498-508. doi: 1 0.1016/j.ecolecon.2012.06.013

Kennedy, C. et al. (2009). Greenhouse gas emission from global cities. *Environment, Science and Technology.* 43(19), 7297-7302. doi: 10.1021/es900213p

Lave, M. & Kleissl, J. (2011). Optimal fixed orientations and benefits of tracking for caoturing solar radiation in the continental United States. *Renewable Energy*. 36(3), 1145-1152. doi: 10.1016/j.renene.2010.07.032

Lynch, L., & Geoghegan, J. (2011). The Economics of Land Use Change: Advancing the Frontiers. *Agricultural and Resource Economics Review*. Retrieved from: http://ageconsearch.umn.edu/bitstream/120679/2/foreword%20december%202011%20-%20current.pdf

Manes, Fausto, Incerti, Guido, Salvatori, Elisabetta, Vitale, Marcello, Ricotta, Carlo, & Costanza, Robert. (2012). Urban ecosystem services: Tree diversity and stability of tropospheric ozone removal.(Report). *Ecological Applications.* Retrieved from: http://www.ncbi.nlm.nih.gov/pubmed/22471095

McNutt, R. (2013). 18,500 and Counting. *Dal News.* Retrieved from: http://www.dal.ca/news/2013/10/31/18-500-and-counting.html

National University. (2012). *National University and SPG Solar Complete Multi Carport and Rooftop.* Retrieved from: http://www.nu.edu/News/National-SPG-Solar.html

Neuman, H., Schar, D., & Baugmgartner, F. ( 2011). The potential of photovoltaic carports to cover the energy demand of road passenger transport. *Progress in Photovoltaics: Research and Applications,* 20, 639–649. doi: 10.1002/pip.1199

New Jersey Stormwater BMP Manual. (2004). *Chapter9.7: Standards for Previous Paving System.* Retrieved from: http://www.njstormwater.org/tier_A/pdf/NJ_SWBMP_9.7.pdf

Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., & Williams, N. S. G. (2015). Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and Urban Planning, 134*, 127-138. doi:10.1016/j.landurbplan.2014.10.018

Platts, L. E. (2009). The beauty of parking. *PERC Reports, 27*(3). Retrieved from: http://perc.org/articles/beauty-parking

Reddy, K. R., Xie, T., & Dastgheibi, S. (2014). Removal of heavy metals from urban stormwater runoff using different filter materials. *Journal of Environmental Chemical Engineering, 2*(1), 282-292. doi:http://dx.doi.org/10.1016/j.jece.2013.12.020

Schletter Canada. (n.d). *About us*. Retrieved from: http://www.schletter.ca/

Solar Generation. (2013.) *Rutger University*. Retrieved from http://solairegeneration.com/project/rutgers-university

Takebayashi H., Moriyama M. (2009). Study on the urban heat island mitigation effect achieved by converting to grass-covered parking. *Solar Energy, 83(8).* doi: 10.1016/j.solener.2009.01.019

Toronto City Planning. (2013). *Design Guidelines for Greening Surface Parking Lots.* Retrieved from: http://www1.toronto.ca/city_of_toronto/city_planning/urban_design/files/pdf/greening_p-lot_guidelines_jan2013.pdf

Vancouver Island University. (n.d*). Sustainable Site Development*. Retrieved from: http://www.cc.viu.ca/leed/SustainableSite.htm

Young, R., Zanders, J., Lieberknecht, K., & Fassman-Beck, E. (2014). A comprehensive typology for mainstreaming urban green infrastructure. *Journal of Hydrology*. Retrieved from: http://www.sciencedirect.com/science/journal/00221694/519/part/PC

## Appendix A- Qualitative Synopsis of Findings on Site Visit

| Parking Lot | Characteristics | |
|---|---|---|

| | | |
|---|---|---|
| Dalplex<br>(157 parking spots) | Sun Exposure | Great - High |
| | Drainage | Low lying areas that collect water, few drains |
| | Slope | Flat |
| | Greenspace | Lots of mature trees to the west, greenspace (residential) surrounding parking lot |
| | Other | Paving infrastructure is very cracked and weathered, lots of pedestrian traffic |
| Eliza Ritchie Hall<br>(41 parking spots) | Sun Exposure | Some - in afternoon |
| | Drainage | Poor - No drains |
| | Slope | S slope |
| | Greenspace | Surrounded by tall mature trees to the north |
| | Other | Paving infrastructure is very cracked and weathered, lots of pedestrian traffic |
| Henry Hicks (38 parking spots) | Sun Exposure | Obstructed by trees in Summer/fall |
| | Drainage | 3 drains, no low lying areas |
| | Slope | S slope |
| | Greenspace | Parking lots surrounded by greenspace and many mature trees |
| | Other | Very small parking spots, pedestrian traffic |
| Howe Hall (233 Parking Spots) | Sun Exposure | Great - High sun exposure |
| | Drainage | Two drains, a few low lying areas that collect water |
| | Slope | W slope |
| | Greenspace | 32 surrounding trees, not tall enough to obstruct sunlight |

| | | |
|---|---|---|
| | Other | Paving infrastructure is severely degraded, high levels of pedestrian traffic , 5 and 3 storey building to East and West |
| Le Merchant (50 parking spots) | Sun Exposure | Good sun exposure |
| | Drainage | 3 drains |
| | Slope | Flat |
| | Greenspace | Two trees, not much greenspace |
| | Other | 5 storey building to the East, paving infrastructure in good |
| LSC (133 Parking Spots) | Sun Exposure | Good sun exposure |
| | Drainage | 2 Drains |
| | Slope | NNW Slope |
| | Greenspace | 42 trees, some surrounding greenspace |
| | Other | 8 storey building to the S, and 3 storey building to the N, Small parking lot off to the side, some pedestrian traffic |
| Ocean Science (37 Parking Spots) | Sun Exposure | Obstructed by trees in Summer/fall |
| | Drainage | No drains |
| | Slope | Flat |
| | Greenspace | Lots of surrounding greenspace, many mature to the South and West |
| | Other | Large hill down to Oxford st., little pedestrian traffic |
| Risley Hall (37 parking spots) | Sun Exposure | Okay – moderate |
| | Drainage | Two drains |
| | Slope | E slope |

| | | |
|---|---|---|
| | Greenspace | Surrounding trees on blvd, many young trees to the south |
| | Other | little pedestrian traffic |
| Wickwire Field (68 spots) | Sun Exposure | Great sun exposure |
| | Drainage | No drains, a few low lying areas |
| | Slope | Flat |
| | Greenspace | Surrounding greenspace, mature trees to the North |
| | Other | Lots of pedestrian traffic, cracked infrastructure |

**Appendix B- Talking with experts**

**Schetler Canada**

Sent email on March 29th
To whom this may concern,

My name is Camille Dumulon-Lauzière and I am a presently a student at Dalhousie University in Halifax. I am conducting research about the possibilities and feasibility of installing solar carports on the university campus. I am trying to gather information from different experts in the field. Therefore, I was wondering if you could answer a couple of questions. This would be greatly appreciated.
Based on what characteristic should we choose a parking lot?
What is the minimum size of a parking lot?
What are the different types of solar panels?
On average what it the payback time for solar panels?
Based on certain types of solar panels what is their energy generation capacity?

Thank you for your help.
Camille

Received answer March 31
Good Morning Camille
I hope you are doing well today.
The Schletter "Parl@Sol" or Solar Carport system is very interesting indeed. It will offer protection from weather such and sun and snow, while offering power generation as well!
Ideally, the park spots should run N-S, however we can still have E-W arrays. Due south is typically desired for module performance.
There is no minimum size, however the smallest it typically 10KW
There are many different solar panels in the industry, however we typically do not comment on them or power performance we are module mount specialists.
Again, payback would depend on many factors. Is this off grid, net meter, or apart of some type of FIT program? All would be offering different rates, which means different paybacks. This too of course depending on module orientation, tilt, location, etc, etc.
In the industry, there is typically two sizes, 60cell (250W), and 72cell (300W). As per above, generation is dependent of many factors.
PVSol, and Solar Pathfinder are a couple of products that may assist you in project development.
Please let me know if you have more questions, it would be really great if we were able to supply a carport for the university.
http://schletter.ca/carport.html
http://schletter.ca/support/Park@Sol-Product-Sheet.pdf
Thank you.

Kind Regards,
Geoff Renaud, Sales Manager

Email sent on March 31st, 2015
Hello Stephen,

I am a student of Eric Rapaport's Site infrastructure class that you guest lectured in a couple of weeks ago! Thanks for the talk, I for one really appreciated it! For a different class project, Tarah Wright's Campus as a living lab, I've been working with a group researching potential for stormwater management systems on Studley Campus. Specifically, we have been interested in incorporating better stormwater management practices into the parking lots on campus. We are most interested in the researching the potential for implementing permeable surfaces, and I'm wondering, since you seem to be quite the expert on stormwater management practices, if you wouldn't mind answering a few general questions for our study? I know this is a busy time of year, but any information would be greatly appreciated!

Here are the questions we are hoping you might have some insight on:
What would you suggest are the best stormwater management practices to implement in general?
What practices would you suggest are best to implement in open, paved areas such as parking lots?
What are the most common heavy metal pollutants found in runoff in the Halifax, NS area? Is this a concern when dealing with stormwater management?
What are some of the positive and negative environmental implications of retrofitting an existing asphalt or concrete parking lot with the most appropriate pervious pavement?

Looking forward to hearing from you,
Myra Pennington
Myra.pennington@dal.ca
902-802-1776

Email Received on April 8th, 2015
Hi Myra:

Below are some of my thoughts in red. Let me know if you have follow up questions. Happy to help. Good luck.

Cheers,
Stephen

What would you suggest? Are the best stormwater management practices to implement in general? What practices would you suggest are best to implement in open, paved areas such as parking lots?
As a best practice, I don't think we need as much paving as we have inherited in cities. If I was to design a parking lot or to retrofit a parking lot to have more stormwater potential I would first try

and break up paved expanses to create areas for water capture, storage, or drainage. There are a few examples of what I mean here: http://imgarcade.com/1/rain-garden-parking-lot/. A lot of the flooding/run off problems we have around Halifax is because our storm systems are overwhelmed. If we can divert some of this water away from the storm system it will reduce the pressure and hopefully flooding in many areas.

What are the most common heavy metal pollutants found in runoff in the Halifax, NS area? Is this a concern when dealing with stormwater management?
I guess there are a few parts to this. Our current stormwater/sewer treatment facility is easily overwhelmed. When we receive heavy rains this system shuts off and the waste water is diverted into the harbour. So, the pollutants from this stormwater overflow will be much more severe as there will be raw sewage in the water. If we are talking about pollutants that wash from impervious surfaces into the stormwater system - then we are looking more at gasoline, car oil, trash, fertilizers, sediments. The heavy metal pollution will be specific to areas in town that have industry or in some areas of Halifax, exposed bed rock. You should investigate further the heavy metals in stormwater around construction sites in the city. We have lots of pyritic slate in the city, when exposed to water this forms sulfuric acid. Some of this water is pumped into the stormwater system. There are many neighbourhoods in Halifax where this is a big problem. Most of our subdivisions that grew up around lakes feed our stormwater into the fresh water. This activity has killed many lakes. Look up Settle Lake in Dartmouth or Papermill Lake in Bedford, two lakes where stormwater has really damaged those ecosystems.

What are some of the positive and negative environmental implications of retrofitting an existing asphalt or concrete parking lot with the most appropriate pervious pavement?
A well planned retrofit will slow water flow into existing stormwater systems or will divert water away from in-pipe collections and downward into the groundwater. A vegetated stormwater collection system, like rain gardens or holding ponds can remove pollutants from the stormwater which is a large benefit before water moves downward into the ground. Some pollutants are bound by soil particles and some digested by organisms in the soil. More ornate systems can use screening filters or UV filters to clean the water. A really important question to ask before retrofitting paved areas to capture stormwater is, 'Where is the water going"? There is no point in putting water into the ground if it will cause flooding or problems down the line. This could be a major drawback to stormwater systems (e.g. rain gardens, permeable paving). I am finding that permeable paving in particular isn't very well known around Halifax. Finding a good (affordable) supply and finding people to maintain (e.g. sweeping of the surfaces) is difficult. This will be the case until more people are installing these systems.

______________________________

Stephen Cushing, BTech, MLA

Communications and Natural Environment Officer
Office of Sustainability

Email: stephen.cushing@dal.ca
Telephone: 902-494-2015
Cell: 902-579-1041

1236 Henry St., Central Services Bld. Room 512B
PO Box 15000 Halifax NS  B3H 4R2 Canada
Good Evening Rajesh,

I'm currently taking an evening class, ENVS 3502: Campus as a Living Lab. The class is focused around everyone doing a group project that focuses on an environmental aspect on campus. Our group is doing a physical feasibility study on implementing green infrastructure into parking lots on Sexton Campus. Part of our research includes talking to experts in the fields of solar power, storm water management or ecological services/ biodiversity.

You were the first person to jump to mind as an expert in ecological services, where we are specifically looking into green spaces around and throughout parking lots. A researcher in the group has done a literature review on ecological services and created questions based off of the research.

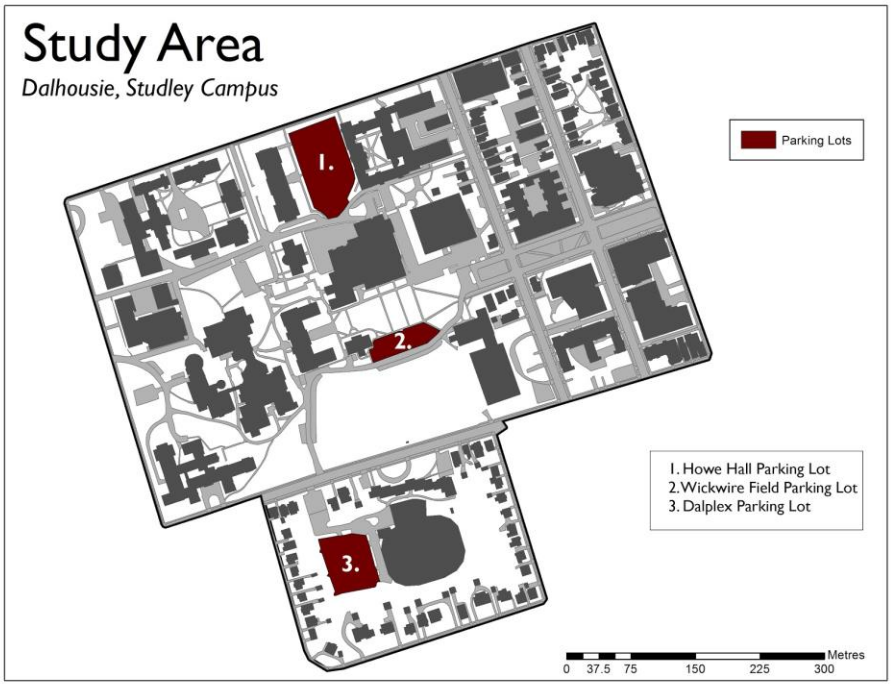
If you have time throughout the next week would you be willing to answer the questions with your expertise? The questions are as follows:

Where are the best locations to integrate biodiversity in an urbanized environment?
What are the best species to use in urban environments? Specifically, what species are best to integrate in the City of Halifax, N.S?
Is there an advantage to using native species rather than exotic species?
What are common barriers to implementing green space in a urban environment?
What are the benefits to implementing green space in a urban environment?

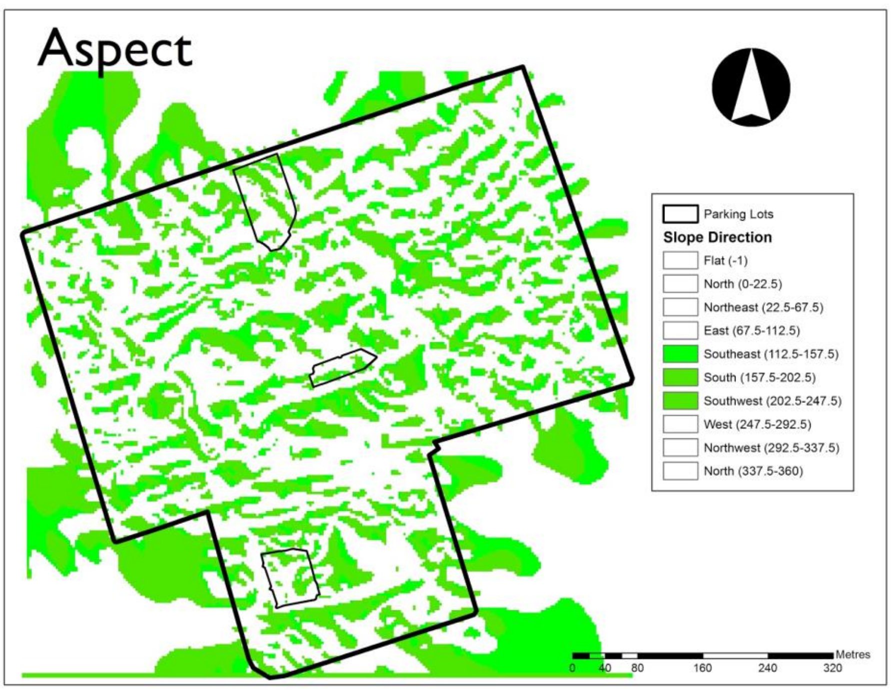
I understand this is a very busy time of year, if you cannot find the time to complete the questions that is okay, but could you let me know?

Thank you so much for your time, have a lovely long weekend!

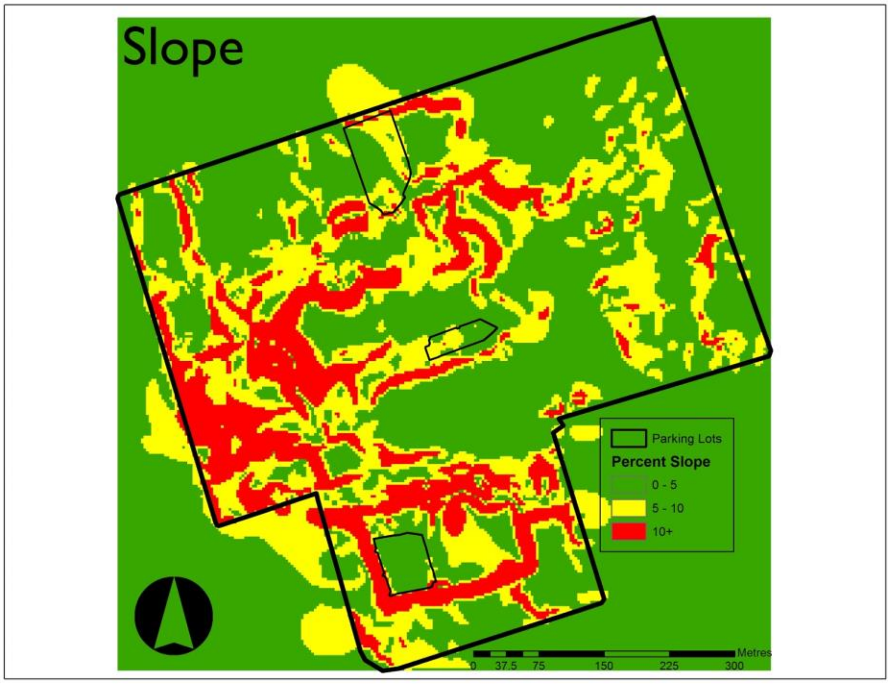
**Appendix C- Maps**




**Criterion 2**



**Criterion 3**




**Criterion 5**