Richardson Hall, Suite 252

74 University Ave.

Kingston, ON

K7L 3N9

Queen's University

April 15th, 2021

Dear Mr. Gkotsis and Mr. Splinter,

Please see the attached *Final Report* for the *Rehabilitation of 5th Field Company Lane Project,* prepared by *JEMS Consulting* as a part of the CIVL 460 capstone course. This report aims to outline the details of the final design, including a proposed aboveground layout, stormwater management system, and water distribution system.

Within this report, initial design ideas were evaluated and compared as part of the process to determine the best solution for the project. This report presents *JEMS Consulting's* further understanding of the problem and proposes final solutions. Stakeholder needs have been investigated in detail, and input has been incorporated into the design elements. Within this report, sketches of three design ideas can be found to communicate initial ideas visually. Design ideas have been compared based on criteria such as promotion of social gatherings, sustainability, and innovation. A single final design has been prepared and its sub-components have been evaluated using SWMM 5.1 and EPANet 2.2 modelling. A finalized set of design drawings can be found as part of an extensive appendix summarizing the findings of the design process. Aspects of project management, including a final Work Breakdown Structure, Critical Path, and Gantt Chart, outline *JEMS Consulting's* progress and work to be completed in the near future. Finally, within the Appendices, *JEMS Consulting's* meeting minutes and hour logs, which are required components of the CIVL 460 course, can be found.

Should you have any questions or concerns regarding this report's contents, please do not hesitate to contact the undersigned.

Regards,

Elliott White

14ew24@queensu.ca

JEMS CONSULTING

(Group R)

Jean- Sebastian Young (20100557)
CAD Technician

Elliott White (10184893)
Client Liaison and Cost Estimator

Matthew Grekul (20066337)
Design and Innovation Specialist

Sophia Brown-Andrukaitis (20025948)
Project Manager

April 15th, 2020

DISCLAIMER

The contents of this report are solely to be used in the CIVL 460 Course context and only for 5th Field Company Lane Refurbishment project for Mr. Gkotsis and Mr. Splinter. Should anyone use the contents for any other application outside of its intended purposes, the students, CIVL 460 teaching staff nor Queen's University are liable for any damages.

Team Statement

Our signatures below attest that this submission is our original work following professional engineering practice, we bear the burden of proof for original work. We have read the Policy on Academic Integrity posted on the Civil Engineering departmental web site (www.civil.queensu.ca/undergraduate) and confirm that this work is in accordance with the Policy.

Signature: ____________________ Date: 2021-04-15

Signature: ____________________ Date: 2021-04-15

Signature: ____________________ Date: 2021-04-15

Signature: ____________________ Date: 2021-04-15

Table of Acronyms

Acronym	Name
PPS	Physical Plant Services
CAD	Computer-Aided Design
LID	Low Impact Development
CAP	Climate Action Plan
TA	Teaching Assistant
SWM	Stormwater Management
SWMM	Storm Water Management Model

Executive Summary

5Th Field Company Lane is one of the oldest streets on the Queen's University Campus. Over time, the lane's environment had changed significantly, but the lane itself has changed very little and no longer has the infrastructure to facilitate its current use. *JEMS Consulting* has been working on the *Rehabilitation of 5th Field Company Lane Project,* for which a detailed design and cost estimate had to be provided. Key constraints of the project include narrowing the scope, time management, budget concerns, and technical knowledge limitations.

The project scope focuses on three primary design aspects: vehicular traffic control, site service updates, and aesthetic improvement of the laneway and surrounding area. The project's boundaries extend from the northern to the southern intersections of the laneway and to the doors of the buildings on the adjacent east and west limits of the road. Adjacent alleyways between Clark Hall and Carruthers Hall, and Jackson Hall and Old Medical Building are also included in the scope.

The project requirements were identified using information gathered from background research, client consultations, site visits, and the provided drawings. Nine project criteria (stakeholder needs, sustainability, aesthetic, innovation, social infrastructure, maintenance, cost, feasibility, and time of construction) were created to help guide the design idea generation process. Three design options for the aboveground layout were created, each emphasizing different sets of project criteria. These three designs were evaluated against the project criteria in weight evaluation matrices. The first iteration of the final design for the aboveground layout incorporated elements from both *Design Idea 1* and *Design Idea 2*.

The proposed final design is comprised of four main components: a layout for 5th Field Company Lane, a layout for the Arch St. parking lot entrance, a SWM system, and a watermain system. The 5th Field Company Lane layout improves the pathway connectivity, aesthetic and useability of the area by improving pathway layouts and adding more green space, social infrastructure and aesthetic elements. The Arch St. parking lot access was redesigned to be a functional entrance and exit to the parking lot.

JEMS Consulting proposes a new SWM system that incorporates innovative LID technology, including permeable pavers, rain gardens, bioswales, and bioretention cells, all of which helped improve the area's aesthetics and decrease the amount of runoff generated on-site. The modelling results from SWMM 5.1 showed that there was up to a 66% reduction in direct runoff with this system for the different storms modelled. However, it was less effective in reducing runoff for high-intensity storms (11% reduction). For the watermain system, *JEMS Consulting* proposes a centralized watermain system to service the buildings along the lane. The EPANet 2.2 modelling results for a 24-hour time period showed that the proposed system maintained acceptable pressures under both normal and fire flow conditions. A waste collection plan which reduces the frequency that garbage trucks travel along the redesigned laneway is also proposed. There are two collection locations. The first location is east of Jackson Hall, and the second is northeast of Theological Hall beside the turnaround point. Recommendations for upgrades to the sanitary system and hot water system are also proposed. The total cost of the design is $1,191,485.96.

The table of key dates, Work Breakdown Structure, Critical Path and Gantt Chart were updated based on *JEMS Consulting's* progress and changes in scope. An analysis of the project progress was performed, and assessing the risks associated with the project. The next steps which must be taken before project implementation are laid out as *JEMS Consulting* will no longer be working on the project.

Table of Contents

List of Figures

List of Tables

1.0 Introduction

JEMS Consulting has been awarded the *Rehabilitation of 5th Field Company Lane Project* for the CIVL 460 course. The rehabilitation of the area entails redesigning the aboveground layout and watermain system and proposing an innovative solution for Stormwater Management (SWM). There are currently issues related to safety, usability and functionality, which *JEMS Consulting* had to address in the proposed design solution for the client, Queen's Physical Plant Services (PPS). For the past seven months, the team has been working on this project and has finally completed the project as per the scope of work. This *Final Report* outlines the work that *JEMS Consulting* has completed for this project, details of the final design solution and future recommendations.

1.1 Problem Definition

JEMS Consulting must provide PPS with drawings and a cost estimate for a redesigned 5th Field Company Lane, fulfilling the client's three project goals. The three goals are as follows:

1. Limit access to only pedestrians and service vehicles
2. Upgrade site services
3. Rejuvenate the area to become more aesthetic and environmentally friendly

The areas included for the rehabilitation project are listed below and are shown in) on the following page.

⇒ 5th Field Company Lane from Union St. to Theological Hall

⇒ The area around the lane up to the building doors on either side (Miller Hall, Bruce Wing, Jackson Hall, and Old Medical Building in the east, and Carruthers Hall, Clark Hall, and Nicol Hall in the west)

⇒ The parking lot exit to Arch St.

⇒ The alleyway between Jackson Hall and Old Medical Building

⇒ The alleyway between Carruthers Hall and Clark Hall

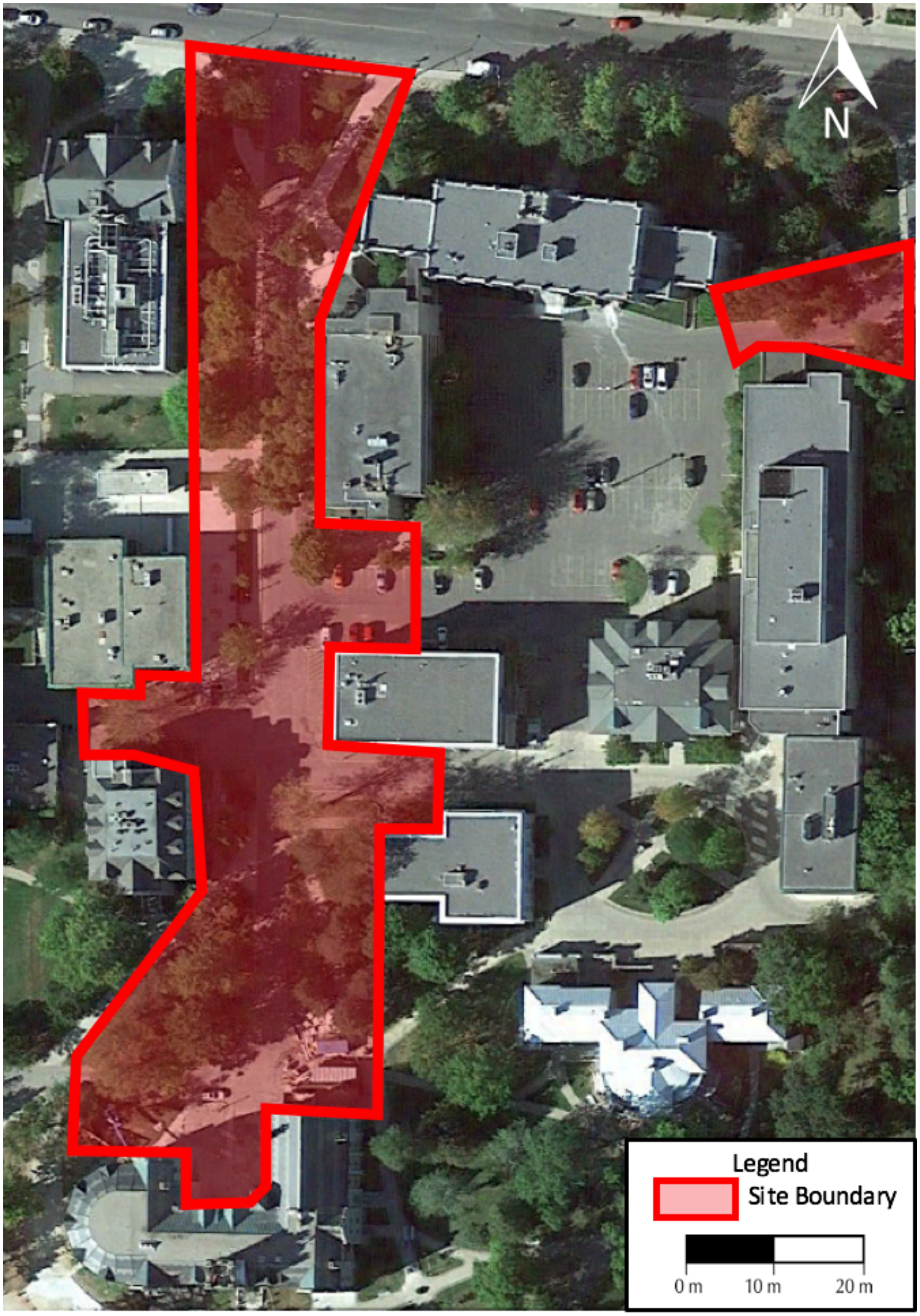


Figure 1: 5th Field Company Lane Project Boundaries (Google Maps 2021)

1.2 Project Scope

This section outlines the scope of the project as agreed upon with the client in preliminary consultations. Aspects removed from the scope have been listed, along with the justification behind their exclusion.

1.2.1 Included in Scope

The project scope includes creating a detailed design and performing a cost estimate for the *Rehabilitation of 5th Field Company Lane*. The laneway, surrounding boulevards, water, and waste service infrastructure must all be considered within the scope of the redesign. The design must encompass the areas listed in Section 1.1 and fulfill the three project goals (also listed in Section 1.1). Figure 2 below summarizes the components of the project scope.

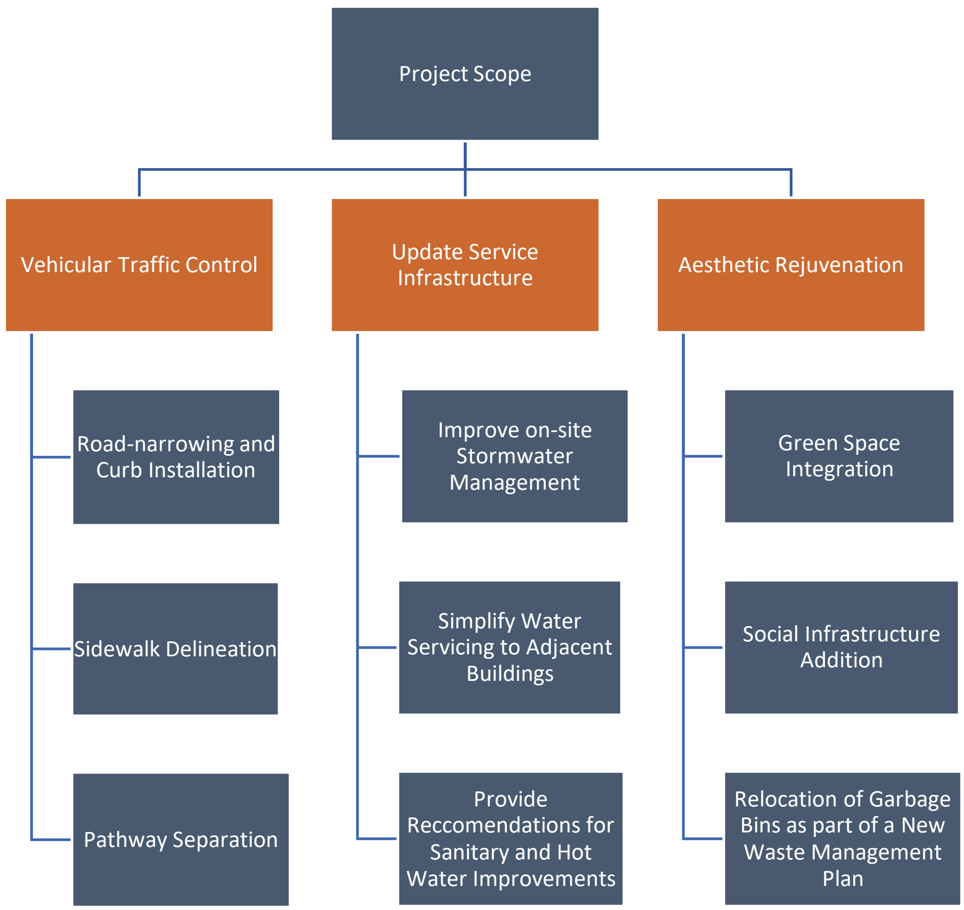


Figure 2: Scope Component Breakdown

The wide asphalt roadway will be converted into a lane that is pedestrian-dominated to limit vehicular access. This change will allow for easy access and increased safety through a central part of the Queen's University Campus. Additionally, removing access from 5th Field Company Lane to the parking lot behind Miller Hall, from here on out referenced as the Arch St. parking lot, will aid in traffic reduction on the lane. However, the entrance to the parking lot at Arch St. will need to be redesigned to accommodate both entering and exiting traffic. Garbage truck access to the lane is currently required as there are several dumpsters along the lane that need to be emptied regularly. A plan for their relocation or a potential combined collection system for multiple buildings will be included. Future development of areas both in and around the project boundaries must also be considered in the final design. Examples are access to the laneway extension west of Theological Hall and pathway extension south of Clark Hall. Climate change considerations, such as introducing green spaces and incorporating sustainable materials, are essential to the final design elements.

In combination with the reduction of vehicular traffic, site service updates along the laneway must be completed. This includes creating a SWM system and the simplification of the watermain system. Initially, *JEMS Consulting* decided that the new SWM system would consist of a traditional underground service system consisting of stormwater conveyance pipes, maintenance holes, and catch basins. However, after a few iterations of the aboveground layout and further client consultations, there was a change in direction towards aboveground alternatives such as LID technologies (as per the client's request). Simplification of watermains and the recommendations for sanitary and hot water system upgrades are also included as part of the technical analysis of this project.

The final component of the scope is the aesthetic rejuvenation in the area. The removal of hardscaping along 5th Field Company Lane allows for the introduction of more green space. This change will improve the area's biodiversity, a concept promoted in the Queen's University Campus Master Plan. The use of garden beds, along with tree canopies, will rejuvenate the large, paved areas. Designs for the sidewalks, multi-use paths, streetlights, benches, and other fixtures must be consistent with Queen's University design standards to maintain campus aesthetics.

1.2.2 Excluded from Scope

To limit the magnitude of the project, multiple aspects of consideration have been removed from the scope. Table 1, below, summarizes the aspects of the project which *JEMS Consulting* will not address as part of the scope of work that the team is taking on.

Table 1: Aspects Excluded from the Project Scope

Aspect Removed from Scope	Justification
Traffic Contributions of Queen's Campus Postal Services and Campus Security	• They are moving their operations out of Fleming Hall prior to when the design will likely be implemented • Results in a notable decrease of vehicular traffic in the area
Detailed Sanitary Sewer System Design	• Buildings along the laneway are serviced from an external cross-campus system that is beyond the site boundaries • Recommendations will be made for improvements of smaller pipes crossing into the site boundaries
Redesign of Gas, Communication, and Electrical Infrastructure	• Beyond the scope of the project as per recommendation from the client • Assumed to be functional as currently installed
Detailed Hot Water System Design	• Beyond the scope of the project to provide detailed thermodynamic calculations for pipe fittings • Only underground layout necessary
High Return Period Storm Design	• Lack of elevation data prevents the effectiveness of a major stormwater system investigation • Aboveground (roadway and boulevard) capacities cannot be accurately determined

It is important to note that should the project be implemented, some aspects which were excluded from the scope of this project may need to be considered for the final design.

1.2.3 Project Constraints

The project constraints are based around knowledge, time, and monetary limitations, as outlined in Table 2 below.

Table 2: Project Constraints

Constraint	Justification
Project Timeline	The *Final Report* submission to the client by April 9th, 2021
Time of Construction	Must provide a design that can be implemented in a timely manner to limit the closure of a central part of Queen's University Campus
Invasiveness to Surrounding Infrastructure	Must limit the effects of any on-site changes on the surrounding buildings and roadways
Technical Knowledge Limitations	*JEMS Consulting* currently has limited engineering design experience
Incomplete Meta-Data for CAD Ground Elevation Points	Limits the opportunity for accurate analysis of the SWM system
Discrepancies Between Existing CAD Drawings	Introduces difficulty in determining the initial/existing conditions
Budget	Want to provide a functional and innovative design while limiting costs
COVID-19 Pandemic	Prevents any in-person meetings, thus limiting the effectiveness of group meetings as well as meetings with clients and stakeholders

Through design iteration, client and stakeholder consultation, and technical evaluation, *JEMS Consulting* has found ways to limit the effects these constraints had on the final design.

2.0 Background

To develop a better understanding of the project, background research was completed. Some main focus areas included the historical significance of 5th Field Company Lane, the Queen's University Campus Master Plan, stakeholder needs, and LID strategies. Performing research related to these topics aided the idea generation process for the proposed design options and helped define the University's expectations for the project outcome.

2.1 Historical Significance

5th Field Company Lane was once the center of the Queen's University Campus and offered road access to the Main Campus buildings at the time. The road, formally known as *Campus Road*, was renamed in 1998 to commemorate the 5th Field Company Unit that the University fielded during WWI (Queen's University 2010). A plaque to commemorate the unit is located at the northern end of the lane. *JEMS Consulting* has preserved historical elements that can be incorporated into the new design. For example, adding a cenotaph or statue and the existing plaque at the Union St. entrance as a future consideration in the next steps of this project. This tribute would pay homage to those in uniform and foster a sense of pride for those who serve in the armed forces.

5th Field Company Lane currently connects eight University buildings to Union St. These buildings are: Nicol Hall, Miller Hall (Bruce Wing), Clark Hall, Carruthers Hall, Jackson Hall, Theological Hall, and Old Medical Building. Most of these buildings were constructed before the 1930s using limestone, mortar and lumber for interior framing. Due to the age of the lumber used in these buildings, they may be more susceptible to fire damage. These older buildings have been retrofitted with the required sprinkler systems since their initial construction; however, in case of a fire, or another crisis, emergency service vehicles must still have access the buildings from 5th Field Company Lane. Adequate emergency service vehicle access to Theological Hall, Carruthers Hall, and Old Medical Building must be considered as part of the new design. These buildings are not currently accessible from any main roads. These buildings are also great examples of 1800 architectural styles, such as Romanesque and Victorian architecture (Queen's University 2020). New additions like lamp posts, social infrastructure, and other elements may take on some design elements that accentuate the architectural designs.

2.2 Queen’s University Campus Master Plan

Queen’s University strives to be a leader and set an example of what an institution can achieve to help create a sustainable, healthy, safe, and exciting learning environment. The Queen’s University Campus Master Plan is a document that details the University’s short-term and long-term goals for campus layouts and any proposed future building projects. To achieve its mission to be an environmental leader, the University has the following principles outlining its plan:

- ⇒ Supporting Queen’s University’s academic mission of promoting learning and discovery (strategic planning)
- ⇒ Enhancing the campus experience, such as learning, counselling, sports, and other activities
- ⇒ Promoting good facilities management
- ⇒ Fostering a more sustainable campus
- ⇒ Integrating the campus with its settings
- ⇒ Creating a campus that supports health and wellness (Urban Strategies Inc. 2014)

These principles help clarify the project expectations and provide a guideline on the future uses of the site. The Queen’s University Campus Master Plan also provides insight into what design elements should be incorporated in the *Rehabilitation of 5th Field Company Lane*. The site is also a specific area of interest discussed in the plan. For example, the use of sustainable materials and LID technologies are aspects that will be considered per the Master Plan. The plan recommends many changes to the lane and its surrounding free space, such as increasing open/green space, adding more social infrastructure, and rendering the area more appealing to pedestrian and cycling traffic. These recommendations provide *JEMS Consulting* with some baseline ideas that have been further developed into unique and innovative design components.

2.3 Stakeholders

Key stakeholders for this project include Queen’s University PPS along with Queen’s University students, faculty, and visitors. Throughout the completion of the project, *JEMS Consulting* has met with representatives from Queen’s PPS regarding needs, such as tree removal/replacement, garbage bin relocation, and service vehicle access. Furthermore, *JEMS Consulting* has had email correspondence with representatives from smaller stakeholders regarding their needs for the new 5th Field Company Lane design. These stakeholders include Clark Hall Pub, Queen’s University Campus Bookstore, and Four Directions Indigenous Initiatives. Figure 3 summarizes the results from these discussions while further outlining all parties' influence and interest. The primary interests listed by each party are based on the evaluation criteria outlined in Section 4.2.

Stakeholder	Primary Interests	Influence	Needs
Queen's University Physical Plant Services (PPS)	Costs, feasibility, sustainability, aesthetics, and time of construction	The primary client and responsible for the funding and oversight of the project	Fulfillment of project goals as listed in the project definition
Queen's University students, faculty, and visitors	Aesthetics, social infrastructure, and time of construction	The everyday users of 5th Field Company Lane	Safe and easily accessible space to gather and travel across campus
City of Kingston	Innovation, maintenance, and time of construction	Responsible for the oversight of roadworks projects	Upholding of the local standards and regulations
Utilities Kingston	Feasibility and maintenance	Responsible for the oversight of utility installation	Easy access to underground services for necessary repairs
Ministry of Environment	Sustainability	Responsible for the oversight of environmental regulations	Project meets environmental regulations
Queen's University Security and Postal Services	Feasibility	The everyday users of 5th Field Company Lane	Easy access through the area to ensure a safe campus and quick deliveries
Queen's University Campus Bookstore	Feasibility and time of construction	Business responsible for heavy traffic in the area	Easy access for customers and weekly deliveries
Clark Hall Pub	Social infrastructure, feasibility, and time of construction	Business responsible for heavy traffic in the area	Waiting space for patrons, improved patio space and easy access for weekly deliveries
Campus Equipment Outfitters	Feasibility and time of construction	Business responsible for heavy traffic in the area	Easy access for customers and deliveries
Kingston Fire Department	Feasibility	Responsibly for building safety and fire prevention	Easy access to hydrants and ensure that fire exits meet standards
Four Directions	Aesthetics	Input on Indigenous land acknowledgement	Acknowledgement of Indigenous Land to promote education

Figure 3: Stakeholder Summary

2.4 Environmental, Economic, and Social Considerations

In the previous *Work Plan*, three main areas of consideration for the project had been considered. These were environmental considerations, economic considerations, and social considerations. In this section, these considerations are expanded upon based on further research and a better understanding of the project.

2.4.1 Environmental Considerations

Climate Action Plan and Carbon

The University's Climate Action Plan (CAP) outlines the steps Queen's University plans to take to reduce its environmental impact and do its part in mitigating climate change (Queen's University 2016). Installing native gardens, planting trees, and increasing the amount of green space are excellent ways to sequester carbon and reduce precipitation runoff. However, one item of the proposed design will be the enlargement of the parking lot entrance at Arch St., requiring the removal of some trees. If any trees are removed, they will be replaced to respect the CAP goals and to meet local regulations, as seen in Section 4.1.1. As per the regulations, every tree must be replaced by two to three trees depending on the condition of the tree being removed. The construction techniques will also have a carbon cost associated with manufacturing, transportation, and installation of materials and structures. *JEMS Consulting* has attempted to incorporate elements of the existing design into the new design to help reduce the amount of carbon emitted by processes associated with the project.

Stormwater and Sanitary Sewage

Studies show that there may be a relationship between climate change and the increased frequency of high return period storms (Seneviratne et al., 2012). Turning portions of the existing hardscape into green space, such as grass or gardens, will change the area's hydrology to mitigate the effects of climate change. The unintentional pooling of water in the laneway demonstrates inadequate SWM. Failure to address this issue may lead to accelerated concrete and asphalt deterioration due to freeze-thaw, resulting in a reduced lifespan of these materials. Additionally, pooling can also pose a slip fall hazard during freezing temperatures. Increasing and changing the topography can reduce runoff and pooling; however, a new stormwater collection system will be needed since runoff is still generated. This system can consist of underground pipes or aboveground channels, or some combination of both. The use of LID technologies can also be considered to manage the stormwater. Section 2.5 of this report discusses LIDs in more detail.

Increasing the size of the watermain pipes is necessary to meet the current demand; however, along with an increase in water consumption, there will also be an increase in effluent flow. Reviewing existing condition reports will be necessary to determine if the existing sanitary sewers need to be excavated and replaced. Extra precautions should be taken for any excavation work because older buildings may have their stone and concrete foundations damaged by excavators. Collisions with the foundation could result in structural instability.

Waste Management

Since 5th Field Company Lane will be converted into a pedestrian-dominated pathway with service vehicle access, it may be difficult for garbage trucks to access the bins should the road width be reduced. Some bins are also in plain view from the lane and can be accessed by the sidewalks, making them easy targets for vandalism and wild animals. As part of the project, *JEMS Consulting* must select locations for the waste bins that consider the safety of the custodial staff since the waste from some buildings must be regularly brought outside to these bins. This task becomes more of a risk during the winter months, where slipping becomes a significant workplace hazard, especially if they must walk a long distance to the bins. New locations and perhaps even some recommendations for an updated waste management/collection plan should be considered. In addition to waste generated by the Queen's University Campus, the construction process will also generate waste. Keeping some existing pathways and existing elements would reduce demolition waste and keep waste removal costs to a minimum.

2.4.2 Economic Considerations

Economic considerations for this project include the monetary cost (labour, material, etc.), maintenance, and the impact on nearby businesses associated with the project during and after construction. *JEMS Consulting* must determine the financial cost of the project and try to minimize it. Various paving surfaces require specialized construction techniques, equipment and labour. For example, asphalt pavement is relatively quick to install but requires many different types of heavy equipment, whereas concrete can be poured in-situ from a single concrete truck, but it takes time to cure. Paving stones are another alternative; however, it may require more workers to lay the stones in a reasonable time frame, and the stones/bricks may be expensive.

It should be noted that even though cost is a factor, different paving techniques may offer other non-monetary advantages that outweigh the cost. If paving stones are chosen, they would offer many non-monetary advantages. If a paver should break, it can be easily replaced. If a rut develops, pavers can be removed, and sand can be added to level the surface before the pavers are laid back down. Access to upgrade or repair underground utilities is also less costly than excavating an asphalt road since removed pavers can be stored and reinstalled after the required excavation work is completed. In contrast, asphalt needs to be recycled or replaced entirely when removed/excavated.

Depending on the location and type of service, some utilities may require regular monitoring or easy access. Common examples of such utilities are maintenance holes and fibre optic service hatches. Figure 4 below exemplifies a common type of access box used for service hatches. These services are susceptible to water damage, so precautions must be taken when determining their location, to avoid the pooling of water near them.

Figure 4: Fibre Optic Access Hatch (Purdue University 2000)

The project timeframe is also a factor since a prolonged timeframe would impact traffic and nearby services and businesses. Deliveries would be more difficult, and traffic to businesses would likely be reduced while construction is going on. There are three local businesses within the site limits, all of which are based out of Clark Hall. These businesses include Clark Hall Pub, Campus Equipment Outfitters, and the Campus Bookstore. They would be affected because the loading dock for deliveries is located on 5th Field Company Lane. Any work involving narrowing the road might make it more challenging to perform deliveries.

2.4.3 Social Considerations

Social considerations include anything regarding the aesthetics, culture, community, and safety of the University's students and staff as well as other members of the public. It is important to note that the current Covid-19 Pandemic would have an impact on this project. Still, it is assumed that project construction would only commence once the pandemic is under control and working conditions are safe enough to begin construction. Therefore, the social considerations are taken into account as pre-pandemic since this best reflects the social conditions after the pandemic. However, it is essential to note the psychological impact of the pandemic on individuals highlights the need for good mental health. There should be many spaces which facilitate the maintenance of good mental health on campus. Creating outdoor green spaces with social infrastructure where people can socialize or take a step away from a stressful environment would help those who feel isolated, anxious or stressed.

Fostering a Welcoming Atmosphere

For the project to be a success, the lane must be functional and aesthetically pleasing. Having additional streetlights, benches, and statues will encourage more pedestrian traffic since it would redesign 5th Field Company Lane into a scenic route. The lane would not only be used by Queen's University students and staff but would be used by residents and visitors as well. The Queen's community is part of the broader Kingston community, which should be reflected in the design. Connecting 5th Field Company Lane to the city's cycling network would be a great way of promoting the connection between the city and the campus. Acknowledgement of the traditional lands of the indigenous people of the Haudenosaunee Confederacy and Anishinabek Nation would help connect the culture of the campus and the city of Kingston with members of these indigenous groups. Enhancing the lane's overall presentation would also impress any potential Queen's students during campus tours and perhaps be a factor in choosing Queen's as their post-secondary school. This welcoming atmosphere is vital since Queen's University hopes to expand further and add new programs to their roster.

Maintaining Queen's Traditions

Within the site's project limits, areas have been the host to many engineering faculty activities, specifically first year-related activities. Orientation Week sees a massive influx of engineering students and the students of many other faculties. Redesigning the lane to be more pedestrian-friendly would improve the safety of orientation events and other students who patronize Clark Hall's bookstore and pub. The Clark Hall Pub mainly attracts long lines of people that spill out onto the sidewalk along the existing lane almost every Friday from 12:00 pm to 5:00 pm. The redesign would have to avoid impacting the student association activities as much as possible. The required closure of the 5th Field Company Lane entrance to the Arch St. parking lot may affect any future yearly concerts held in the parking lot for Orientation Week. This consideration will influence the redesign of the Arch St. entrance to the parking lot because this will be the only viable entrance after the redesign. Figure 5 below shows a gathering of first year engineering students completing their “jacket slam” tradition on 5th Field Company Lane.

Figure 5: Queen's Engineering Jacket Slam Tradition (Queen’s Journal 2012). Credit: Timothy Hutama

Promotion of On-Campus Safety

The last social consideration would be the response time and access to emergency and security services. The redesign should allow medical and security services to have the same ease of access with vehicles to areas along the lane. Otherwise, an increase in the response time during an emergency could be a matter of life or death for someone having a medical emergency where minutes or seconds make a difference. Another area of consideration is the field of view and lighting of the area. The Queen’s campus is a relatively safe area; however, there is still the risk of encountering dangerous circumstances. Reducing the amount of unlit regions and sheltered areas would minimize the risk of fall injuries or, worse, any potential assaults and muggings (Farrington and Welsh 2002).

2.5 LID Technology

2.5.1 LID Overview

LID is a SWM design strategy that aims to manage stormwater runoff close to the source to mitigate the effects of large volumes of runoff and stormwater pollution (Credit Valley Conservation 2011). The main goal of LID is to minimize runoff that would be collected by invasive structures such as underground pipes and channels by promoting processes such as infiltration, evaporation, and storage/detention. Some of the benefits of using LID technology in new developments include:

- ⇒ Protection of downstream resources through enhanced upstream treatment (Credit Valley Conservation 2011)
- ⇒ Reduction of pollution (Credit Valley Conservation 2011)
- ⇒ Groundwater recharge (Credit Valley Conservation 2011)
- ⇒ Water quality and animal habitat improvement (Credit Valley Conservation 2011)
- ⇒ Decreased volumes of direct runoff (Credit Valley Conservation 2011)
- ⇒ Conservation of water and energy (Credit Valley Conservation 2011)
- ⇒ Aesthetic improvement of the new development

The primary mechanisms of common LID technology are infiltration and storage, which is the process of surface runoff entering the underlaying soil or storage unit. As urbanization of natural land continues in the developing world, impervious surfaces such as asphalt and concrete have become increasingly prevalent, reducing the surface area of natural terrain. In turn, this decreases the amount of infiltration/storage on these sites and drives the increase of surface runoff. This is further illustrated in Figure 6 below, which compares the percent of infiltrated rainwater for some urban and natural watersheds.

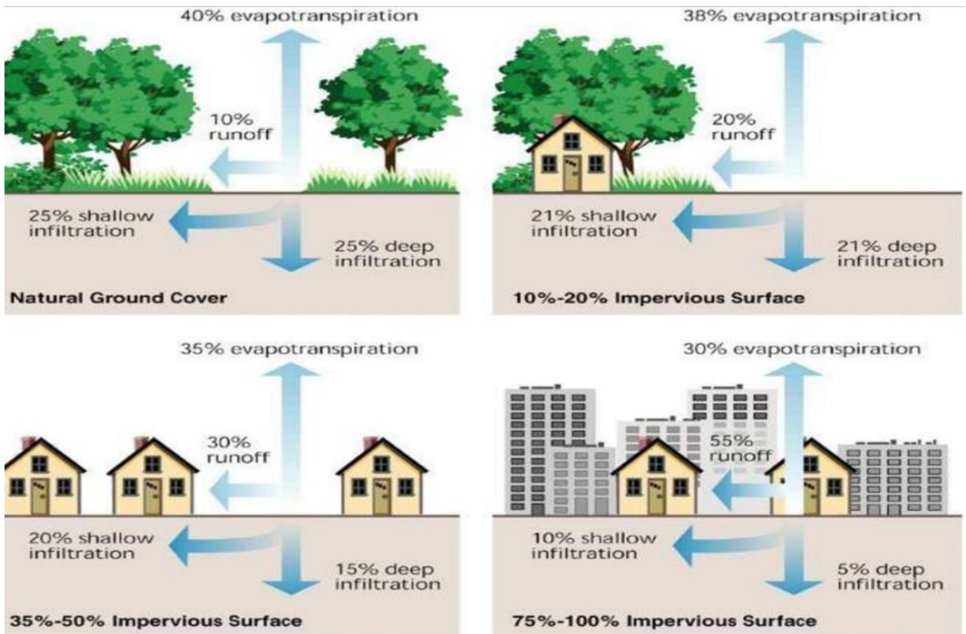


Figure 6: Comparison of Urban and Natural Watershed Infiltration (Credit Valley Conservation 2011)

5th Field Company Lane, with its large sprawls of asphalt, concrete, and buildings, can be represented by the 50-75% impervious surface model in Figure 6. Figure 6 shows that infiltration and storage in the urban watershed, such as 5th Field Company Lane, is less than half of what occurs in a watershed with more natural terrain. Oppositely, runoff is increased by a factor of five, thus introducing the need for a developed stormwater collection system. When the lack of area available for infiltration/storage is combined with an ineffective stormwater management system, as observed on 5th Field Company Lane, pooling and flooding occurs. Incorporating LID technology into the new design for 5th Field Company Lane would promote storage and infiltration, limit the amount of direct runoff generated, and improve the aesthetics of the area.

When implementing LID technology, there are five main principles outlining the effectiveness of the systems. Figure 7 outlines these iterative principles used in the preliminary design stages to integrate LID technology in new developments.

Figure 7: Principles of LID (Credit Valley Conservation 2011)

A key principle crucial to the effective use of LID technology is number five: *Education and Maintenance*. Understanding how LID technologies work allows for more accurate modelling in the early design stages, thus increasing their potential effectiveness. Educating current and future engineers about LID design promotes innovation and improves the likelihood of LID integration. Understanding the required maintenance of these systems, such as landscaping needs, increases their lifespan.

2.5.2 Climate Change Effects and the Potential for Innovation

The continuous warming of Earth's climate is predicted to have a noted effect on direct runoff produced by large storms in future years. As climate change progresses, the increased temperatures result in an increase in evaporation from the Earth's surface water, found in oceans and lakes, which makes up 70% of Earth's surface (Climate Central 2019). In turn, this leads to an increased frequency of extreme storms and more intense rainfall during these storms (Climate Central 2019). For example, it is projected that the current 100-year storm will become the future 50-year storm, and the current 10-year storm will become the future 5-year storm in Ontario (Ingebrigsten and Nimmrichter 2017). Over time, this will lead to an increased demand on current stormwater infrastructure, and if this demand cannot be accommodated, an increased prevalence of flood events will be observed. As these trends continue, future infrastructure must find a way to accommodate these high volumes of runoff caused by more extreme storms. One important way to ensure that the stormwater collection system in place will not be overwhelmed by the increased volumes caused by climate change is by promoting the treatment, retention, and infiltration upstream from the collection systems. One possible solution is the incorporation of LID technologies to help manage on-site runoff. LID technologies help to decrease the runoff generated from lower return period storms which helps to decrease the load on large-scale urban stormwater collection systems. This increases the available hydraulic capacity of the system when these larger storms occur. It is not expected that LID technologies handle the runoff generated from high return period storms.

Planning for the influence of climate change on stormwater systems goes hand-in-hand with the potential for innovation within these systems, especially in the City of Kingston. Due to the city's age, many sewers are undersized for the current stormwater demand and should be upgraded in Kingston. However, rather than implementing the traditional stormwater system, there is the potential for innovation through the use of LID technologies that are not commonly found across the city. Furthermore, at Queen's University, there have been limited innovative upgrades made to the stormwater collection system. For instance, large areas of impervious surfaces are common across campus. The opportunity to incorporate infiltration/storage drivers such as green spaces and native gardens was missed. Due to the effectiveness of stormwater collection modelling, the "status-quo" for the design and implementation of SWM systems is the use of invasive underground infrastructure such as catch-basins, maintenance holes, and PVC/concrete pipes. While the integration of these systems may be simple in new developments, implementing these systems is invasive and expensive in an already developed areas like 5th Field Company Lane which is part of the existing Queen's University Campus. Thus, *JEMS Consulting* has been requested by the client to think beyond the traditional confines of SWM design. The innovation component of this project will be focused on the integration of these LID technologies in the SWM system to pair aesthetics with functionality.

2.5.3 Types of LID Technology

Table 3 outlines LID applications that are commonly implemented in urban drainage areas such as 5th Field Company Lane.

Table 3: Potential LID Applications for 5th Field Company Lane (Credit Valley Conservation 2011)

LID Technology	Purpose	Potential Concerns/Limitations
Disconnection of Impervious Areas	Reduce impervious surface area to decrease the potential for runoff generation	• Redirection of pedestrian and vehicular traffic • Cost of excavation and removal of existing material
Permeable Pavement	Promote infiltration and storage into underlying soils/storage systems	• Groundwater contamination from roadway surface pollutant • Winter operation in frozen sub-base • Site topography promoting drainage too fast for proper infiltration
Bioswales	Slowdown, treat, and convey stormwater from roadways	• Underlaying soil infiltration rate • Bioswale slope must be appropriate to promote infiltration rather than convey flow • Increased maintenance • Underground contamination • Salinity effects on vegetation • Performance in freezing conditions
Bioretention Ponds	Temporary storage, treatment, and infiltration of runoff	• Must have an overflow into an outlet • Underlaying soil infiltration rate • Groundwater contamination • Performance in freezing conditions • Available hydraulic head for downward gradient

Furthermore, Figure 8 shows examples of LID applications implemented in urban drainage areas across North America.

Permable Pavers for the Laneway (1800 Sweeper n.d.)

Example Bioswale implemented in Seattle (TIP of the MITT Watershed Council n.d.)

Example Bioswale fronting a Toronto School (Toronto and Region Conservation Authority 2020)

Bioretention pond at the University of Toronto Scarborough Campus (Sustainable Technologies Evaluation Program 2016)

Figure 8: Example Applications of LID Technology (reference in descriptions)

2.5.4 Plants for LID Technologies

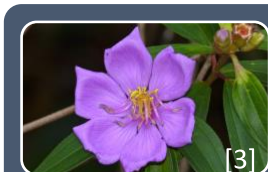
Different types of plants should be incorporated into the redesigned 5th Field Company Lane as part of LID technologies (where appropriate), native gardens, and green spaces. All plants help (to varying degrees) to decrease direct runoff by promoting evapotranspiration and infiltration of rainfall and to improve the local ecosystem and aesthetic of the area in which they are planted. Some plants also have other functions which benefit an area, such as filtering out pollutants from the soil, providing shade, and feeding the local wildlife. Figure 9 below shows some types of plants, their function and some examples of plant species that could be incorporated into the area.

Trees

- Incercepts rainwater promotting evapotransipration
- Produces oxygen and provides shade as well as shelter for wildlife
- Examples: White Oak, Red Pine, Silver Maple, White Spruce, Yellow Birch and Red Oak (Government of Ontario 2021).

Native Grasses

- Low water use, deep root systems and can become natural fertalizer (Roach n.d.).
- Increase evapotransipration and groundwater infiltration
- Big Bluestem, Indian Grass, Little Bluestem, Switch Grass and Praire Cord Grass (Quinlan 2005).



Phytoremediation Plants

- Extract and/or degrade contaminants in the soil (Roach n.d.)
- Examples: Pot Marigolds, Flamingo Feathers, Malabar Melastome, and Cattails (Lui et al 2018)

Pollinator-Friendly Plants

- Improve reproductive success of other pollinating plants
- Good for bees, butterflies, hummingbirds and other pollinators
- Examples: Aster, Blazing Star, Milkweed, Joe Pye Weed, and Anise Hyssop (Balogh n.d.).

Wildlife-Feeding Plants

- Feed local wildlife which would help improve the local ecosystem
- Increase likelihood of wildlife sightings attracting visitors to this area of campus
- Examples: Canadian Serviceberry, Winterberry, Wild Strawberries, and Black Walnut Trees

Native Ornamental Plants

- Native plants which do not have a specific function still contribute to improving the aesthetic of the area
- Examples: Trilliums, Coneflowers, Yarrow, Blanketflower, and Swamp Milkweed (Ontario Native Plants 2021).

Figure 9: Types of Plants which could be Incorporated into Final Design. References for the photos are as follows: [1] (Gardenia n.d.), [2] (Master Gardeners of Northern Virginia 2018), [3] (Wikimedia Commons 2020), [4] (HGTV n.d.), [5] (Not So Hollow Farm n.d.), [6] (All Ontario 2019)

A variety of all these types of plants should be incorporated into the area. Ideally, the chosen plant species should: be native to Kingston, Ontario; be drought-tolerant; require little maintenance; be perennial; be aesthetically pleasing; and serve a function that is beneficial to the area. The chosen plants' needs in terms of sunlight and other requirements must be considered when choosing which species of plants to use and where to plant them. Additionally, the time of year that the flowering plants bloom should be considered to maximize the aesthetic of the area year-round. Native grasses and phytoremediation plants should be included in the bioswale and bio-retention ponds to help filter out pollutants from the runoff and improve infiltration.

3.0 Existing Conditions

Prior to the idea generation phase of the project, the existing 5th Field Company Lane conditions were evaluated. Analysis of the current aboveground layout and underground infrastructure allowed *JEMS Consulting* to better understand functional and dysfunctional areas. Functional elements can be combined with the proposed improvements to limit costs and maintain consistency with Queen's University's design standards.

3.1 Aboveground Conditions

JEMS Consulting conducted a site visit on Friday, October 23rd, 2020, to better visualize the areas of opportunity for the *Rehabilitation of 5th Field Company Lane Project*. Along 5th Field Company Lane, it was noticed that there are multiple areas of wasted space that could be better used as green space or as areas with social infrastructure. This was consistent with what was illustrated by the client in early progress meetings and will continue to be a focus of *JEMS Consulting* moving forward. One of the main staples within the site boundary is Clark Hall, which currently uses a large loading dock area and patio along with the western site limit. However, this infrastructure is ageing and is just one example of the many areas within the site limit displaying noticeable wear. Additionally, garbage collection bins are located in multiple areas along 5th Field Company Lane, reducing the area's aesthetics. Figure 10 below further illustrates the aboveground site conditions with reasoning for improvement.

Figure 10: Aboveground Existing Conditions (credit for photos: Elliott White)

3.2 Underground Conditions

There are currently multiple types of underground service lines located within the area of 5th Field Company Lane. These services include high voltage electrical cable, gas lines, telecommunication lines, sanitary sewer leads, storm sewer leads, watermains, and steam ducts (with cold water return lines). In Figure 11 below, a few examples of the plan drawings of existing underground infrastructure relative to the surrounding aboveground locations are presented. Larger and more detailed drawings can be found in Appendix B.

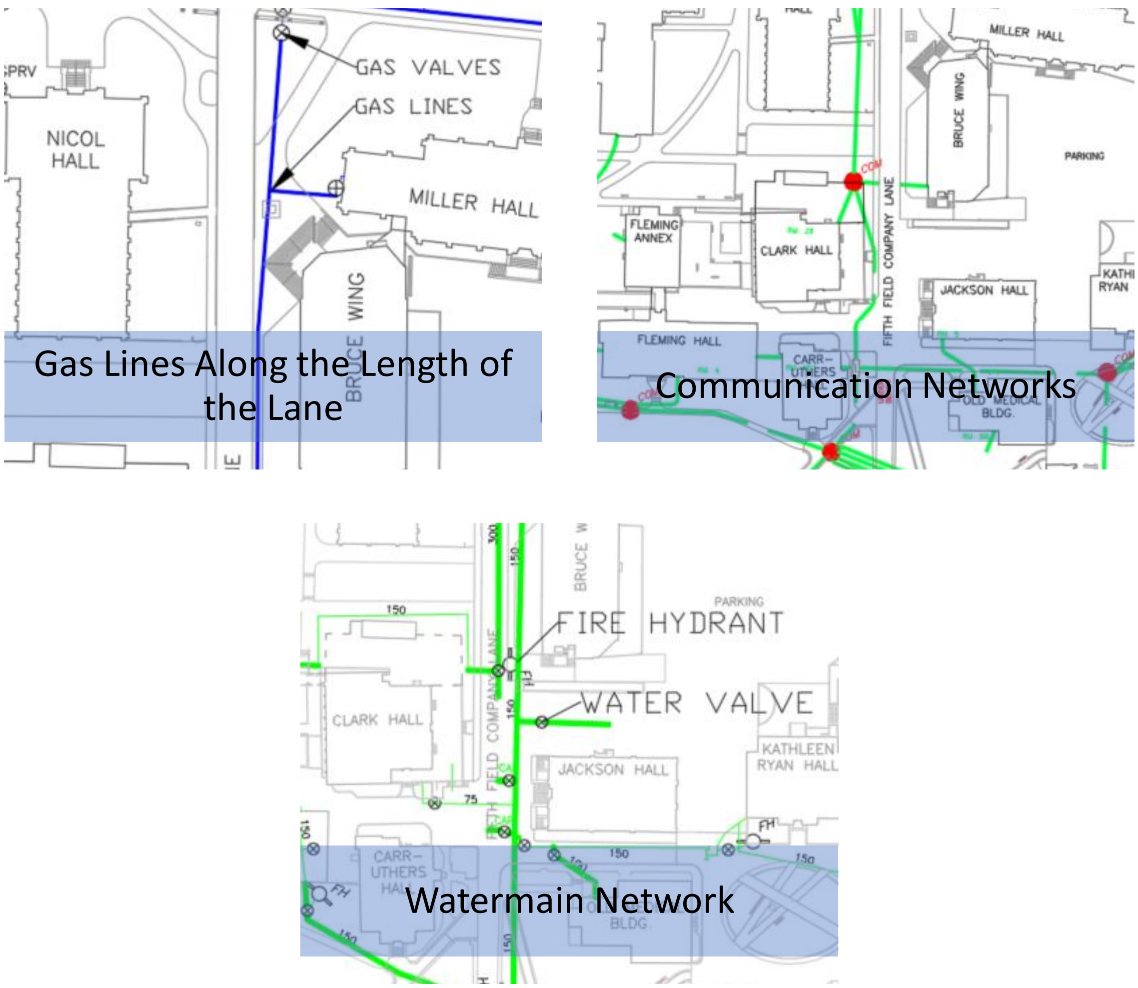


Figure 11: Underground Service Drawing Examples (source: PPS)

The lane currently has no storm sewer conveyance system. The only stormwater infrastructure in place is a lead collecting rainwater from the roof of Nicol Hall. This pipe is connected to the storm sewer on Union St. The lane has many pooling areas resulting from inadequate or lack of drainage for runoff, contributing to the deterioration of the paved areas. Areas near Theological Hall have also been known to form deep puddles that sometimes reach the building's back entrance. A photo of the pooling near Theological Hall can be seen in Figure 12.

Figure 12: Pooling at the Back Entrance of Theological Hall (credit for photo: Matt Grekul)

The buildings along the lane are serviced by two watermains running along the center of the existing lane. There are two watermains because one of the pipes was installed to service Bruce Wing after being constructed in the 1970s. The increased demand by the extension to Miller Hall and the fire suppression retrofits meant the building needed more water to meet the new demand. The client has expressed their desire to replace the two watermains with one centralized system. According to the existing conditions, specific buildings are being serviced from watermains, which are on the opposite side of the laneway. This layout created a crisscross pattern that would not allow the installation of a storm sewer or bioswale.

There are three sanitary sewer lines that lay within the boundaries of the site. The first is located south of Clark Hall and crosses the laneway heading southeast and ends at Arch St. According to the client's most recent records, this sewer line is composed of two pipes. The first section is made of iron and connects to the south side of Clark Hall. It measures 8 m. The pipe has a life expectancy of 50 years and was slated to be replaced in 2013. The pipe has not been replaced because inspections have concluded no leaks in the pipe to date. The cost to replace the pipe was estimated to be $5,995 (Queen’s University 2017). The second portion of the line is constructed out of concrete and is 177.9 m long. The line has a life expectancy of 50 years and was slated to be replaced in 2013 with an associated replacement cost of $257,850; however, no leaks have yet been recorded (Queen’s PPS 2017).

The second and third lines originate from Carruthers Hall, one from the southwest and one from the southeast side of the building and end at the same line originating from Fleming Hall. The southwest line is made of iron and measures 13.11 m long and is slated for a replacement for 2025. No leaks have been reported, and the cost to replace the pipe was estimated to be $9,825. The other pipe is also made of iron and measures 58.5 m. Like the south-west line, it is slated to be replaced in 2025. The pipe had no leaking signs, and the replacement cost was estimated to be $43,840 (Queen’s PPS 2017).

The location of some of the underground services is also near some trees. Currently, the university uses “cells” to prevent these trees' roots from creeping near the service ducts/pipes and below the sidewalks and road surface. These cells are geogrids that allow trees to root within the cell while stopping them from reaching out too far (Deeproot.com 2010). If new trees are planted along the road or near any underground services, additional cells may need to be installed to prevent root migration.

4.0 Design Requirements and Project Criteria

This section discusses the design requirements as per the governing codes and standards for the above ground and site service design. The chosen project criteria and their assigned weights are also detailed.

4.1 Requirements

4.1.1 Aboveground Requirements

Table 4 below lists the various above-ground design elements, their governing regulations, and their requirements.

Table 4: Aboveground Design Elements, Regulations, and Requirements

Design Element	Governing Regulation(s)	Requirements
Sidewalks	• OPSS 351 • O. Reg 413/12 • OPSD 310.010-030 • OPSD 600.080 • QFADS	• Minimum width of 1500 mm (Government of Ontario 2014) • Contraction joints maximum spacing of 4.5 m • If width is 2.5 m or greater, contraction joint spacing is maximum of 2.5 m (Road Authority 2019)
Road	• OPSS 310 • OPSS 311 • OPSD 561.010	• Minimum width of 3.3 m per lane (Road Authority 2017b)
Curbs	• OPSS 353 • OPSD 0310.0100 • O. Reg 413/12 • OPSD 600.110-030 • QFADS	• 12 mm thick joint filler (Road Authority 2016) • 6 mm recess on exposed surfaces (Road Authority 2016) • 50 mm in height (Road Authority 2019)
Accessibility Ramps	• O. Reg 413/12 • QFADS	• Maximum running slope of 1:8 (Road Authority 2019)
Accessibility Parking	• O. Reg 413/12 • QFADS	• Minimum width of 3400 mm for "van accessible" spaces and 2400 for "standard spaces" (Road Authority 2019)
Signage	• Ontario Traffic Manual Ch. 5	• Ra-1t = 15 cm x 30 cm (Stop Signs) • Ra-9A = 30 cm x 30 cm (Road Crossing Signs) (Ministry of Transportation of Ontario 2000)
Lamp posts	• OPSS 2423 • OPSS 2452 • CSA G164 • CSA G40.20 • CSA G40.21 • Queen's Building Design Standards Division 26 (25 50 00)	• Lamps only specified by PPS Approved Lamp List (Queen's University 2019) • Only 1 weld required for up to 9 m (Road Authority 2017a) • 2 lux illuminance, 0.2 foot candles illuminance (Queen's University 2019)

Trees	• City of Kingston By-Law 2018-15	• Replacement rate:
		  ○ Moderate condition 1:1
		  ○ Good condition 2:1 (City of Kingston 2018)
		• Recommended replacement rate of 2:1

4.1.2 Site Service Requirements

Table 5 below lists the various site service design elements, their governing regulations, and their requirements.

Table 5: Underground Design Elements, Regulations, and Requirements

Design Element	Governing Regulation(s)	Requirements
SWM System	• Credit Valley Conservation "Low Impact Development Planning and Design Guide" (2011) (Credit Valley Conservation 2011)	• 80 mm depth concrete paver stones with 10% surface area gaps filled with GW-SW aggregate • Underlaying storage layers composed of ASTM C33 No. 57 Clear Stone for permeable paver, bioswale, and bioretention systems • Minimum Depth of underlaying storage layer given by Equation 1: $d_{min} = \frac{(Q_c xR)+P-(ixT)}{V_r}$ (1) • Required aboveground retention cell capacity is given by Equation 2: $d_{cellMax} = \frac{i(t_s-\frac{d_p}{i})}{V_R}$ (2)
Water Distribution	• City of Kingston Technical Standards (2014) • OPSS 407 • OPSS 410	• Maximum pressure of 700 kPa and minimum pressure of 280 kPa(City of Kingston 2014) • Minimum pressure of 140 kPa during fire hydrant use (City of Kingston 2014) • Minimum mainline pipe size of 200 mm • Minimum depth to cover of 1.7 m (City of Kingston 2014) • AWWA C900-PVC SDR-18 pipe to be coloured blue. • Minimum fire hydrant distance of 75 m (City of Kingston 2014)

While this section outlines the regulations and standards set in place for the design of storm and water distribution infrastructure, it is important to note that LID technology design is based on design guidelines. LID technology application is site-specific, depending on variables such as total area, percent of impervious surfaces, and infiltration rates of existing soils. The Credit Valley Conservation *Low Impact Development Planning and Design Guide* combines the findings of LID studies and provides guidelines to be followed for effective LID implementation.

4.2 Project Criteria

JEMS Consulting has decided on nine project criteria that will be used to evaluate each design option in weighted evaluation matrices. Each criterion was given a weight that reflects its importance to the project. A criterion with a weight of five has more significant importance, and a weight of one being of little importance. The project criteria, their respective weights and a short description of each can be seen in Table 6 below.

.

Table 6: Project Criteria

Criteria	Weight	Description
Stakeholder Needs	5	The stakeholder needs are paramount. Given that the whole reason why the project is being undertaken is to serve their needs better, this criterion was given a weight of 5 as it should heavily influence the chosen design.
Sustainability	5	This criterion considers the amount of green space, the incorporation of green alternatives, and the carbon footprint of the design. It was given a weight of 5 because this criterion was crucial to the client. Also, as stated in the Queen's Master Plan, the University plans to transform the campus into a more sustainable space, so the chosen design should align with this plan.
Aesthetic	4	A great deal of importance was placed on this criterion by the client. Aside from the lack of useability, the lack of aesthetics was another main driver for this project's undertaking. The aesthetic of the design is less critical than the stakeholder needs and sustainability, so it was given a lower weight.
Innovation	4	*JEMS Consulting* strives to provide its clients with innovative design solutions. Having an innovative design will likely help the client secure funding and donations for the project. This criterion was given a weight of 4 as it is important for the project's success, for the CIVL 460 class and the team as future engineers. Also, a high level of innovation will be required to provide a highly sustainable solution.
Social Infrastructure	4	Social infrastructure plays an essential role in the useability of the space and, therefore, in fulfilling the stakeholder needs. Given this contingency, this criterion was given a weight of 4. Additionally, incorporating social infrastructure into the design was outlined as an essential criterion in the Queen's Master Plan.
Maintenance	3	The maintenance of the area must be considered in terms of lawn and garden upkeep, snow removal, and replacements and repairs. If the site requires a great deal of maintenance, but PPS is unable to maintain it regularly, people may not be able to use the space for all its intended purposes consistently. This criterion must be considered, but it should not have a heavy influence on the design (hence the weight of 3).
Cost	3	Cost is a less important criterion as the client has provided no budget. All required funding can be put together for the project as long as all costs are justifiable. Giving this criterion a lower weight (of 3) also allows for a higher degree of freedom to create an innovative design.
Feasibility	2	The feasibility of design implementation must always be considered. Given the high level of importance placed on sustainability and innovation, this criterion was given a weight of 2 so that it would not conflict with them. Feasibility was included more as a check to ensure that the design can be implemented instead of a criterion that should influence the design.
Time of Construction	2	The construction time must be considered as many people use 5th Field Company Lane daily during the school year. Therefore, ideally, construction should occur over the summer to not interfere with campus flow during the semester. The time of construction, whether the design allows for the project to be phased, and what the plan would be if there are delays in the project schedule must all be considered. The construction time was given a weight of two as it should not have a heavy influence on the design.

5.0 Design Ideas

Many different design ideas were presented through the progression of the *Background Research* phase of the project. Client and stakeholder meetings brought many issues to the forefront, making it difficult for the team to organize ideas. To address this, the team organized ideas using a mind-map. Three aboveground conceptual designs and an underground conceptual design are proposed in this section.

5.1 Preliminary Design Brainstorming

Preliminary design ideas were focused on four main aspects: roadway installation, pathway integration, free space use, and collection/distribution systems. Options considered for roadway design included using a two-lane versus a single-lane roadway or the separation of the laneways by a treed boulevard, similar to that which was previously found on University Ave. Ideas for pathways were then generated. Thus, a comparison of the existing system was completed against the introduction of a central pathway and a branched path system. The appropriate use of free space is an important consideration outlined by the client. Options considered for the use of free space includes the use of native gardens (tree plantings), social infrastructure (tables and benches), and different combinations of them all. Finally, schematics for a stormwater collection and water distribution systems were compared against the existing layout. Plans for stormwater management were also devised. Figure 13 below outlines the mind-map used for the idea generation stage of the project.

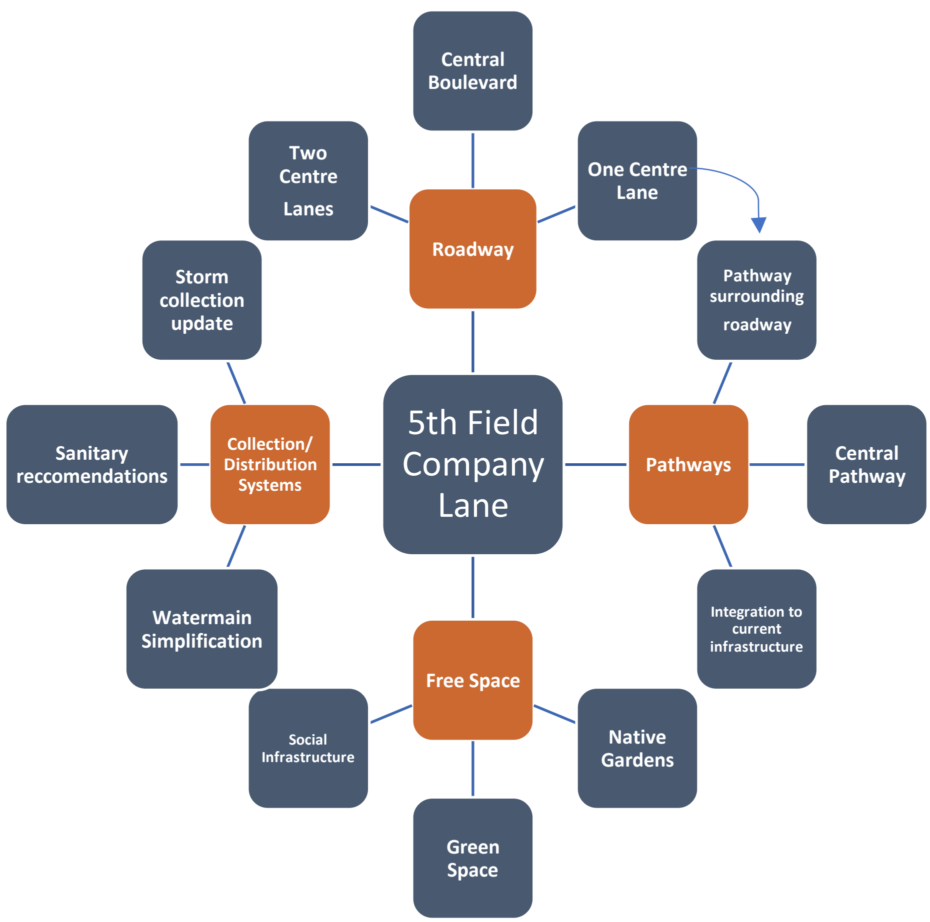


Figure 13: Idea Generation Mind-Map

Using the ideas generated by the mind-map, three conceptual design options were created for the aboveground layout for 5th Field Company Lane. Multiple design options were not compared for Arch St., and the collection/distribution systems as the solutions for these systems were straightforward. For example, the Arch St. parking lot entrance only required a single lane widening with median installation to direct traffic to and from the one-way road. Due to the limited space in the area, the entrance can only be expanded to the north. Additionally, underground services only required a connection of the current water systems and sanitary sewer update, as stormwater could be collected using overland LID technology. The following three sections discuss each of the three design options in detail.

5.2 Design Idea 1: Queen's Central Park

This design idea puts a heavy emphasis on sustainability and social infrastructure. It was designed to be the '*Central Park*' of Queen's Campus. A conceptual not-to-scale drawing of the design can be seen below in Figure 14.

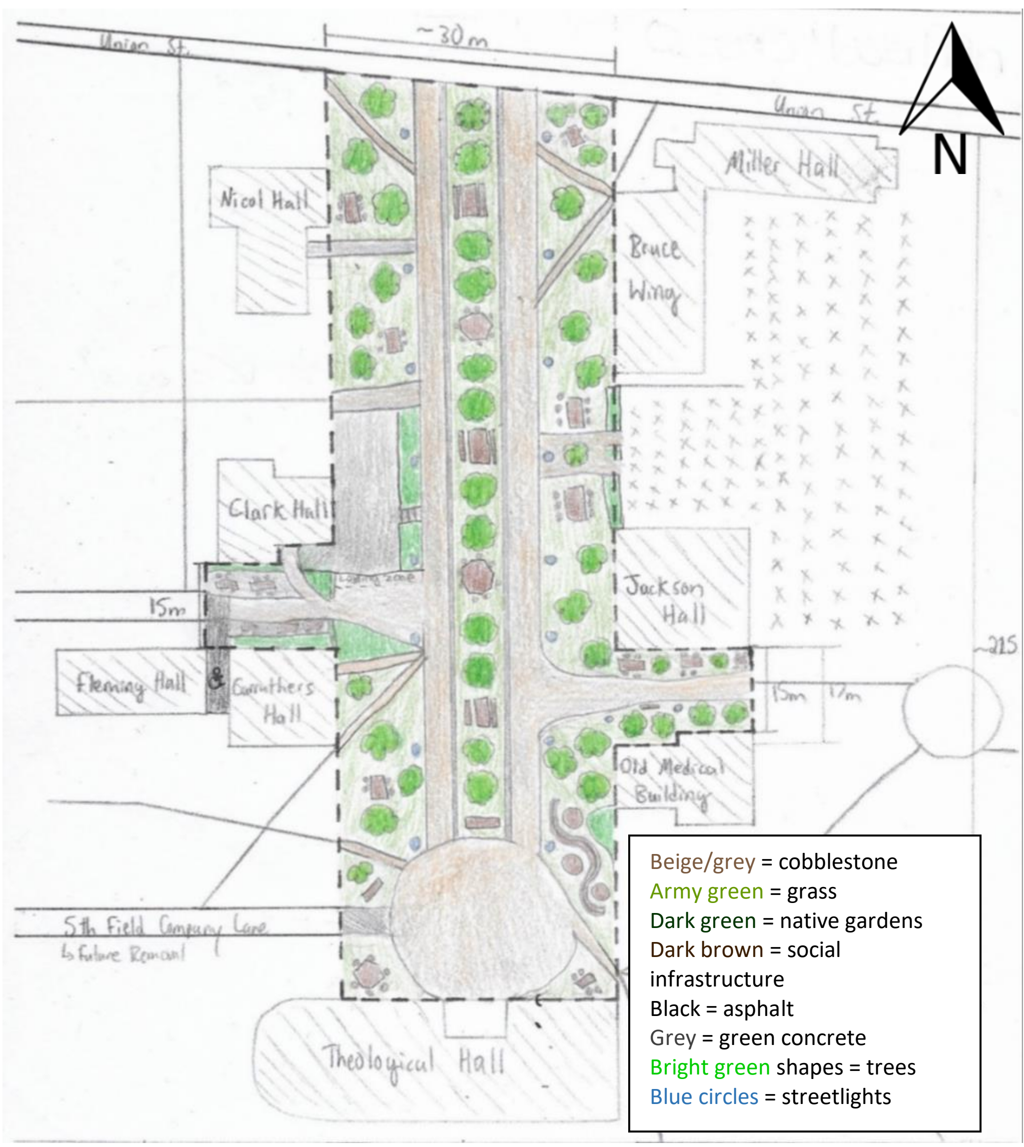


Figure 14: Design Idea 1: Queen's Central Park – Conceptual Design Drawing (Not to Scale)

The laneway will consist of two lanes, which are made of paver stones. Using this material allows for better drainage and easy access if repairs are required beneath the road. It is also one of the more aesthetic options. The two lanes will be separated by a median consisting of a line of trees, benches, tables and grass. There will be trench drains on either side of the median, which will collect runoff from the laneway and surrounding area.

The extra space on either side of the lane will consist of trees, benches, tables, streetlights, grass, native gardens and other social infrastructure. Existing paths will be continued through the free space and connect with the lane. The lane that currently leads to the Arch St. parking lot will be narrowed and turned into a path with garden boxes filled with native plants acting as bollards. The existing concrete area around Clark Hall will be re-done with more aesthetic stones or concrete tiles. The staircase will also be replaced, and the gardens on either side will be revamped. The gardens will feature an array of native plants and will each be contained by a small retaining wall.

The alleyway between Clark Hall and Carruthers Hall will consist of a path, a new accessibility ramp, native gardens, tables and chairs. Small retaining walls will contain the gardens to match the ones at the entrance to Clark Hall. The loading area will remain in its current location. In between Fleming Hall and Carruthers Hall, there will be two accessible parking spaces. The alleyway between Jackson Hall and Old Medical Building will have a pathway, tables, chairs, benches and trees.

The turnaround point near Theological Hall will be a cul-de-sac that connects the two lanes with the western extension of 5th Field Company Lane. It will be made of paver stones arranged aesthetically to form the letter “Q” and have a stormwater maintenance hole at the center to collect runoff from the area. The area immediately around the cul-de-sac will include grass, trees, tables, benches, native gardens and a statement social infrastructure piece.

5.3 Design Idea 2: Queen’s Central Bypass

This design idea emphasized functionality and accessibility and was designed to be a central ‘bypass’ for Queen’s students, faculty, and visitors through a central part of Queen’s Campus. Figure 15 below shows a conceptual not-to-scale design drawing for the *Queen’s Central Bypass*.

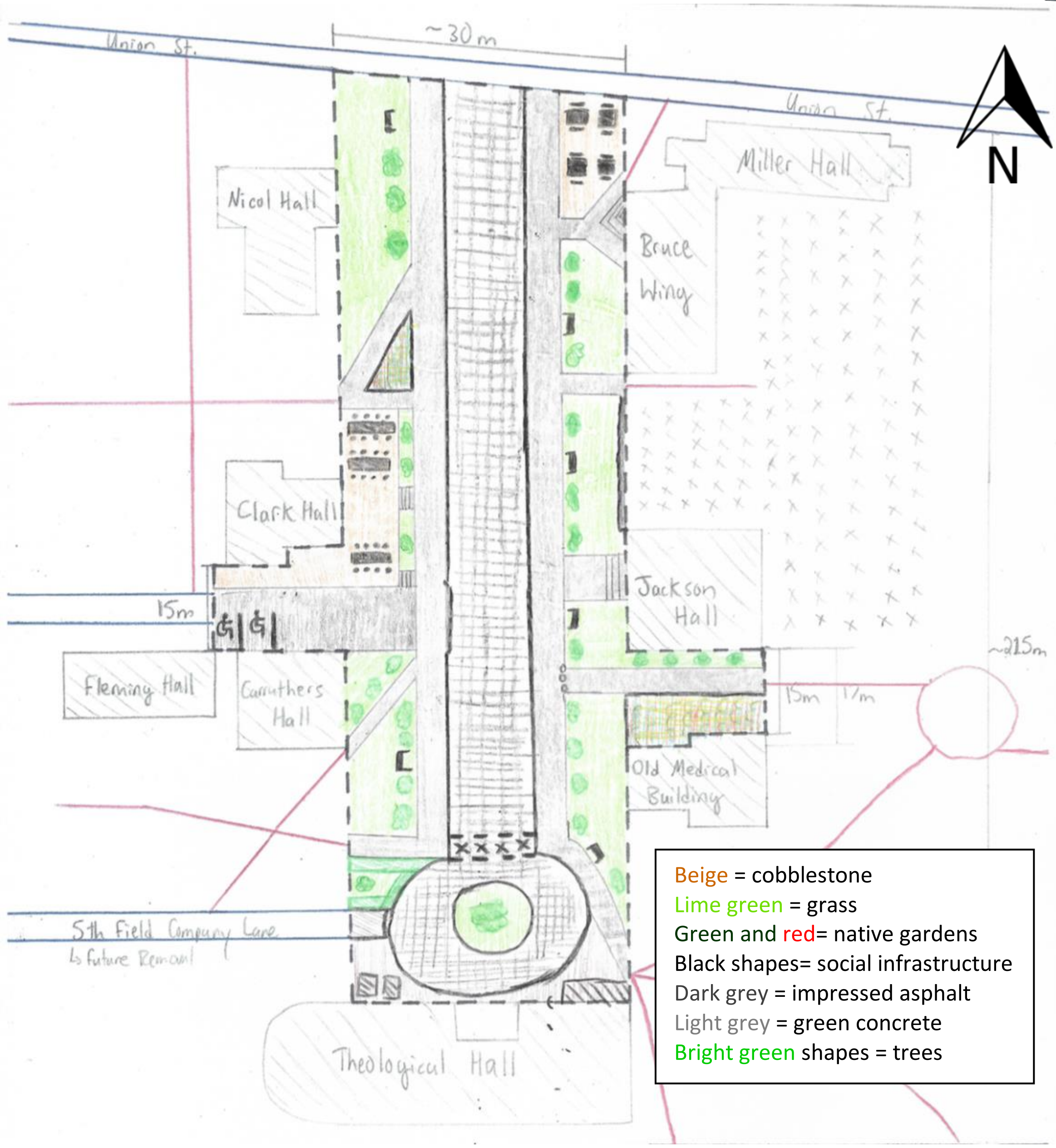


Figure 15: Design Idea 2: Queen's Central Bypass – Conceptual Design Drawing (Not to Scale)

In this design, the laneway is also two-laned, but it will be a traditional central road design. This allows space for both bikers and service traffic. The laneway will be made of impressed asphalt, which is easier and more cost-effective to install than paver stones while improving the aesthetics of the area. The central laneway will be flanked by two concrete sidewalks made of concrete, separated from the road by a full curb. Implementing the sidewalks allows for the complete separation of pedestrians, bicycles, and service vehicles – a feature that the current infrastructure is missing. Achieving complete traffic separation will improve pedestrian and bicycle safety in the area. The southern end of the laneway makes use of a round-about with a central median, which provides a structure for traffic flow to Theological Hall. The central median can have trees, a native garden, a statue, or some combination of these components to improve the area's current lackluster aesthetic.

Similar to *Design Idea 1*, the free space surrounding the central pathway makes use of social infrastructure and native gardens to make the area more inviting to visitors while directing traffic flow. Native gardens can be planted along the northern side of Old Medical Building and adjacent to Clark Hall and Nicol Hall's pathway. The use of native gardens in this design directs traffic to the pathways adjacent to Clark Hall and Jackson Hall, limiting the creation of 'mud paths' due to pedestrian shortcuts. Hedges are used similarly towards the southern end of the laneway. The remaining free space makes use of the existing grass areas with additional tree plantings to help reduce the campus carbon output, which is per the CAP.

One key aspect of this design is the social gathering centers located on the new Clark Hall patio and the new Bruce Wing patio. Tables, chairs, and benches will be used to promote social gatherings on Clark Hall's extended patio. This patio is open to visitors during non-business hours; however, they can be utilized by Clark Hall during business hours to improve their outdoor events such as 'Patio Ritual.' Additionally, a seating area was placed near Bruce Wing's entrance to allow for an outdoor eating area in the summer months. Food trucks are commonly found near the intersection of 5th Field Company Lane and Union Street; thus, the implementation of this seating area will allow people to have a comfortable spot to eat.

5.4 Design Idea 3: Queen's Artery

In this design idea, the emphasis is placed on practicality, green space, and feasibility. It was designed to be an "*Artery*" that functions as a service road as well as a walkable path for the large number of students passing through the area. Figure 16 below shows a conceptual not-to-scale drawing of the design.

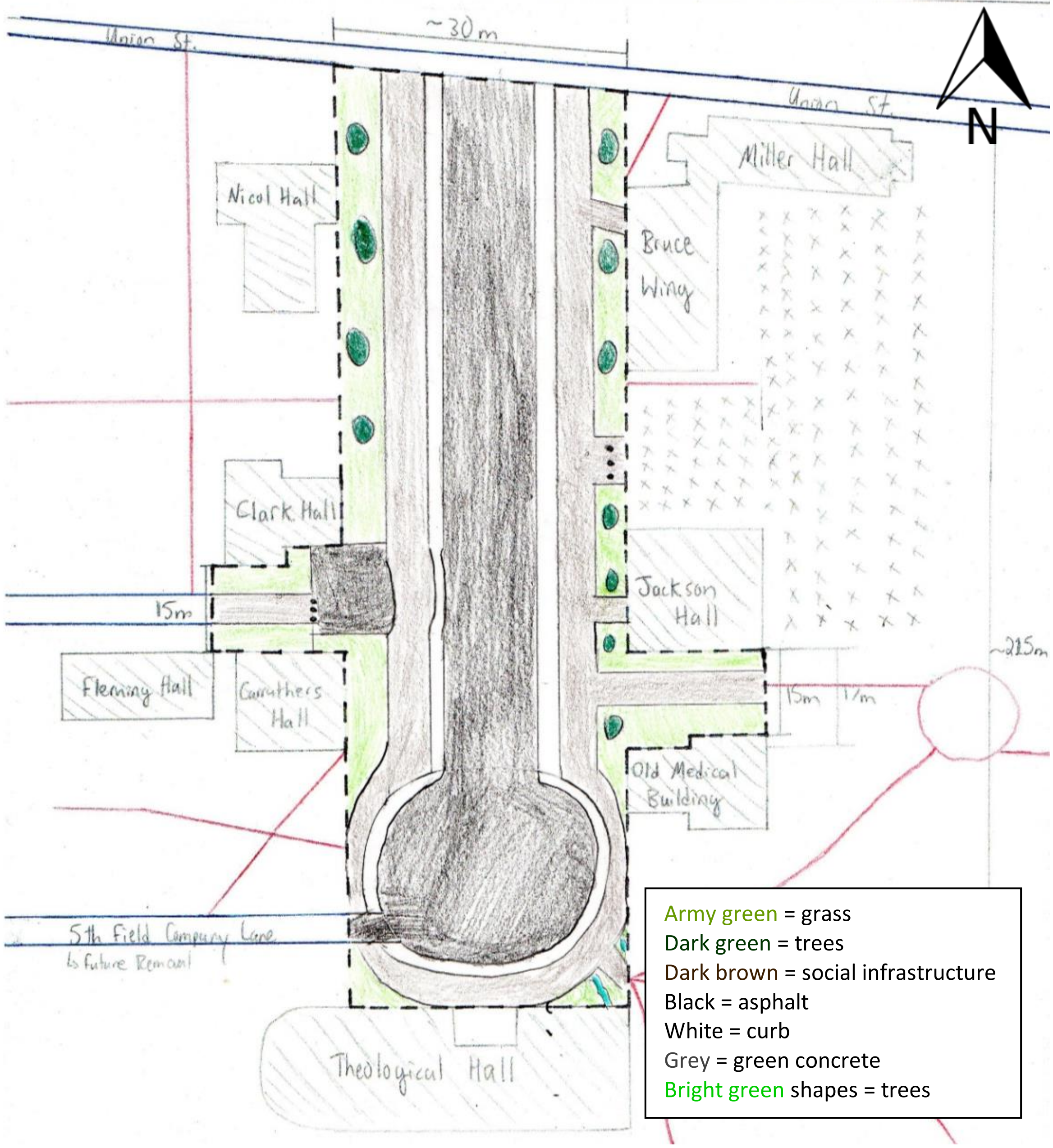


Figure 16: Design Idea 3 - Queen's Artery - Conceptual Design (Not to Scale)

This design idea consists of a two-way asphalt road, with sidewalks and curbs along its entire length. Mountable curbs between Clark Hall and Carruthers Hall allow for Clark Hall Pub and Campus Bookstore delivery access. Bollards can be found to the west of the delivery area, separating delivery vehicle access from the pedestrian pathway and surrounding green spaces.

Along with the eastern site limit, bollards are used to separate the pedestrian access pathway between 5th Field Company Lane and the Arch St. parking lot. Combining the full curb along that boundary, full separation of laneway and parking lot will be achieved with new tree plantings and will occupy the remaining areas surrounding the laneway.

At the southern site boundary, a cul-de-sac made of asphalt provides a safe turnaround point for service vehicles. The use of a cul-de-sac was chosen as it simplifies turning for vehicles with a larger turning radius, such as a delivery truck or emergency vehicle. The many walking paths in this area are directed to the sidewalk that loops around the cul-de-sac. This allows for the cul-de-sac to be the central connection point for the existing walking paths, thus directing pedestrian traffic through *Design Idea 3* to other central portions of the campus.

6.0 Design Evaluation

In this section, the three proposed design ideas are evaluated in four weighted evaluation matrices, each centralized around a specified design element. Client and stakeholder feedback have been taken into consideration for the evaluation of each design. The results from the evaluation and feedback from the client are used in combination to create the first iteration of the final design.

6.1 Client and Stakeholder Feedback

JEMS Consulting has had continuous client contact throughout the idea generation phase of the project. The three design ideas outlined in Section 5 were presented to the client for feedback. Multiple design ideas received positive feedback from the clients. For example, the paver stone roadway with a central boulevard in the *Queen's Central Park* (*Design Idea 1*) gathered positive remarks, as the client liked the improved aesthetics in the area. Similarly, the conversion of the many hard-scaped spaces to native gardens and was appreciated as it improved both the aesthetics and the sustainability of the area. However, the client had important considerations that had been neglected in the original design ideas. Firstly, 5th Field Company Lane is currently an important service route for garbage removal in a dense part of campus. During consultations with the client and Queen's Custodial Services, it was expressed that a consolidation plan for garbage bins was necessary for the detailed design in the later stage of the project. There are currently multiple bin locations within the project's scope, including east of Nicol Hall and north of Theological Hall. *JEMS Consulting* must research the feasibility of combining the bins into one central location, possibly in the Arch St. parking lot or between Clark Hall and Caruthers Hall. The entrance path and turning radius of garbage trucks will have to be considered before choosing a final location. This will have implications on the path and free space layout on the finalized design.

Additionally, *JEMS Consulting* presented ideas regarding the underground infrastructure along 5th Field Company Lane. Early ideas for the underground services included installing a typical stormwater management system underground to account for the poor drainage currently observed along the laneway. However, upon discussion of the needs of the area, it was agreed that the implementation of LID concepts allowed an opportunity for innovation in the project. Finally, stakeholder input was sought to accommodate multiple parties' needs, as summarized in Table 7 below.

Table 7: Stakeholder Feedback Summary

Stakeholder	Correspondence Type	Feedback
Queen's PPS	Microsoft Teams Meeting	• Convert "hardscapes" to pervious surfaces wherever possible. • Tree plantings should be consistent with City of Kingston requirements • Tree plantings should be durable and size appropriate. • Redirect traffic flow as seen fit
Queen's Custodial Services	Microsoft Teams Meeting	• Garbage bin consolidation in a centralized area is important for the functionality of the laneway
Queen's University Campus Bookstore	Email	• Peak times (September/January) see up to 5,600 customers (pedestrians and vehicles) per day in the bookstore. • Need to accommodate overflow as well as incoming deliveries
Clark Hall Pub	Email	• Deliveries are received 1-3 times a week. • With a capacity of up to 400 patrons (patio ritual), overflow of lineups is common along the laneway. • Need to accommodate staff parking and patio capacity
Four Directions	Email	• A land acknowledgement, such as a plaque, native garden, or flags would be an appropriate way to acknowledge the territory

Although initial feedback from Four Directions was well received, communication with their representatives was lost as the project continued. Therefore, all future discussions of a land acknowledgment in the final design will be suggestions based on their initial feedback. Should this project be implemented, consultation with Four Directions is recommended before deciding on a land acknowledgement.

6.2 Evaluation Matrices

To evaluate the designs, they were broken up into four components. These components are the lane, free space, alleyways and turnaround point. Breaking up the designs into components allowed for easier comparison and for the final design to comprise the best designs for each component. The evaluation rubric used to evaluate each design component against the criteria can be seen in Appendix C. Each team member used the evaluation rubric to fill out their weighted evaluation matrix for each component's design. The scores were compared to one another, and the final scores were determined by taking the majority or average score of each team member's matrix. The final evaluation matrices for each component can also be found in Appendix C. A summary table with the weighted score for each design component can be seen below in Table 8.

Table 8: Summary of Weighted Scores from Weighted Evaluation Matrices

	Lane			Free Space			Alleyways			Turnaround Point		
Criteria\Design	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Stakeholder Needs	15	25	25	22.5	25	5	25	25	17.5	25	22.5	25
Sustainability	25	15	10	25	20	15	15	15	10	20	15	12.5
Aesthetic	20	16	8	18	18	8	20	16	14	16	18	10
Innovation	16	10	6	16	12	8	16	12	8	12	12	10
Social Infrastructure	18	4	4	20	16	8	20	10	8	12	8	6
Maintenance	9	15	15	9	15	12	12	15	13.5	10.5	12	15
Cost	6	12	15	10.5	12	15	9	13.5	13.5	9	15	13.5
Feasibility	5	10	10	8	10	10	8	10	10	10	10	10
Time of Construction	2	8	10	6	8	10	6	9	10	6	8	9
Total	**116**	115	103	135	**136**	91	**127**	125.5	100.5	**120.5**	**120.5**	111

These results show that *Design Idea 1* received the highest scores for the lane and alleyway design component, *Design Idea 2* received the highest score for the free space design component and *Design Idea 1* and *Design Idea 2* tied for the highest score for the turnaround point design component. This means that these design components will be considered for the final design. Sections 6.3 to 6.5 discuss the performance of each design against the evaluation matrices in further detail.

6.3 Evaluation of Design Idea 1

The *Queen's Central Park* (*Design Idea 1*) was the highest-ranked design for the lane and alleyway components and tied for the highest-ranked design for the turnaround point component. This design was also ranked second for the free space design component making it the highest scored design. Overall, the design scored well against the stakeholder needs, sustainability, aesthetic, innovation, and social infrastructure criteria because of:

- ⇒ Its emphasis on sustainability and social infrastructure made the design highly aesthetic, sustainable and useable for social gatherings.
- ⇒ Its use of sustainable material options (including paver stones and green concrete), plants and trees will help reduce the carbon footprint and thus increase the area's sustainability.
- ⇒ Its laneway design and overall use of soft scaping is an innovative way to help with stormwater management.

However, the design received moderate to low scores against the stakeholder needs criterion for the lane component and construction time, cost, feasibility and maintenance criteria for all four components. The reasoning behind the lower scores is because of:

- ⇒ The fact that the lane will be shared by both service vehicles and pedestrians could be a safety concern.
- ⇒ The use of paver stones will result in an increased time of construction, cost and maintenance.

⇒ The large number of trees, native gardens and other plants will all require maintenance.
⇒ Feasibility concerns related to the implementation of the laneway design and placement of the paver stones.
⇒ The overall higher cost of the design due to the chosen materials, quantity of materials and increased labour costs because of the long-time of construction.

Based on the evaluation results, all design components should be considered for the final design, including the free space design, since its score only trailed *Design Idea 2* by one point.

6.4 Evaluation of Design 2

The *Queen's Central Bypass* (*Design Idea 2*) was the highest-ranked option for the free space design. It had a close second place ranking for the lane and alleyways designs and tied as the highest-ranked option for the turnaround point component. Evaluation of this design was based on its key features, including:

⇒ Its promotion of the safety of pedestrians leading to a score of 5 for stakeholder needs for the lane and alleyways design.
⇒ Its pathway consistency with existing walkways beyond the project boundaries led to a high aesthetics score for the free space and alleyways design.
⇒ Its incorporation of native gardens yielded a score of 4 in sustainability for the free space design.
⇒ Its simplicity resulted in higher scoring in cost, feasibility, and time of construction across the board.

However, there were limitations to this design that yielded lower scores in multiple areas. These limitations include:

⇒ Its increased use of asphalt compared to *Design Idea 1* resulted in a decreased sustainability score of 3 for the lane design.
⇒ Its lack of social infrastructure for the lane yielded a score of 1.
⇒ Its simplicity resulted in low scores in innovation across the board, which is an important criterion for the success of this project.

The free space and turnaround point designs should be incorporated into the final design based on the evaluation results. However, the team should also consider incorporating the lane design elements as the difference in scores between *Design Idea 1* and *Design Idea 2* was only one point.

6.5 Evaluation of Design 3

The *Queen's Artery* (*Design Idea 3*) was the lowest-ranked option across all categories, resulting in the lowest weighted score. Evaluation of this design was based on its key features, including:

⇒ Its promotion of pedestrian safety through traffic separation resulting in a score of 5 for stakeholder needs for the laneway and turnaround point.
⇒ Its low cost and time efficient design thus yielding high scores in cost and time of construction categories.
⇒ Its simplistic design yielding a high score for feasibility and maintenance for all design aspects.

The design's limitations became evident during the evaluation since the emphasis was placed on criteria including stakeholder needs, innovation, and sustainability. These limitations include:

- ⇒ Its decreased sustainability score compared to the other designs due to carbon-intensive material use.
- ⇒ Its lack of social infrastructure in available free spaces
- ⇒ Its lack of plant diversity in its design led to comparably lower scores.

Based on the evaluation results, components including the turnaround point and laneway designs can be incorporated into the final design.

7.0 First Iteration of Final Design

Using the client feedback and results from the evaluation matrices, the first iteration of the final design for 5th Field Company Lane was computed. A preliminary design for the Arch St. parking lot exit was created and is detailed in this section. A preliminary cost analysis was performed and is included, as well.

7.1 5th Field Company Lane

The first iteration of the final design comprises the three design options' best components and incorporates some of the client's suggestions. This design was evaluated using a modified weighted evaluation matrix (shown in Appendix C) Table 27: Modified Weighted Evaluation Matrix for First Iteration of to ensure it was indeed the best design to move forward with. The weighted scores are all higher than those of the three design options, which validates it as the best design option. A conceptual not-to-scale drawing of this design can be seen below in Figure 17.

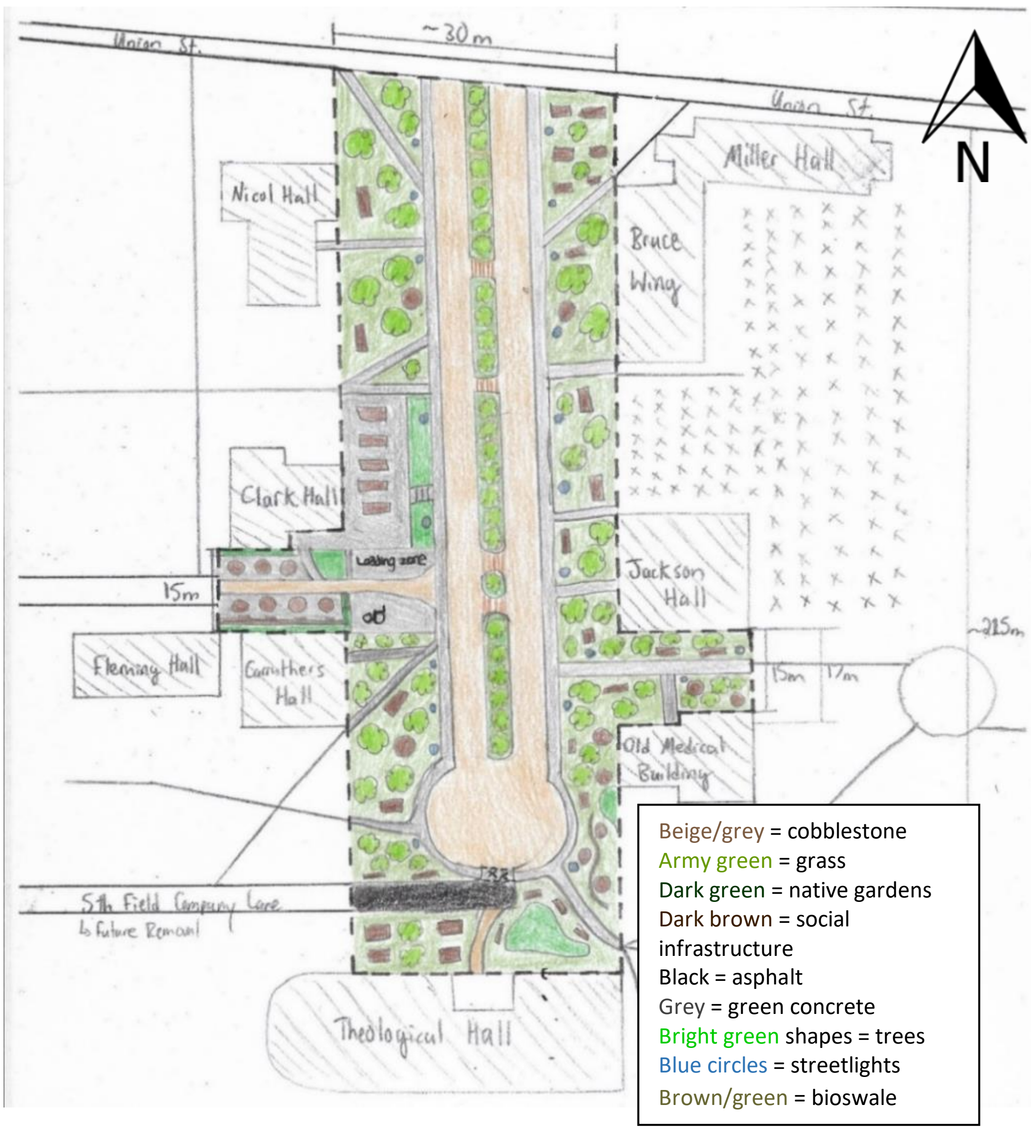


Figure 17: First Iteration of Final Design – Conceptual Design Drawing (Not to Scale)

7.1.1 First Iteration Laneway

The lane will be a two-lane path made out of paver stones. Paver stones were chosen due to their permeability, aesthetic, sustainability, durability and increased ease of access to underground services. The permeable nature of paver stones will allow for an increase in rainwater infiltration into the ground and reduce surface runoff. The paver stones will go with the limestone buildings in the surrounding area and compliment University Ave., which runs parallel. It is a more sustainable option than asphalt or concrete because the processes and materials used to make paver stones have a more negligible adverse environmental impact and a more durable material. Paver stones are more expensive and more labour-intensive to install; however, this material's positives outweigh the negatives due to the high importance placed on sustainability. In addition to clear signage, the lane will be raised compared to Union St. and the other part of 5th Field Company Lane to help distinguish the route as a service vehicle-only road.

Down the center of the lane, there will be a bioswale as opposed to the green space as proposed for *Design Idea 1*. The client suggested this conversion. The bioswale will be one of the main focal points of the area as it is an innovative and sustainable solution for stormwater management. It is less intrusive to the existing underground services and is more sustainable than laying a stormwater pipe. The rainwater is being used to water trees and other vegetation instead of simply being collected and taken away as stormwater. In critical locations along the lane, bridges will be installed to allow pedestrians to cross the bioswale. The bridges will be made of wood as well as steel if required.

There will be full curbs on either side of the lane, which will separate the laneway from the sidewalks. A significant safety concern with *Design Idea 1* was that service vehicles and pedestrians would share the same space. The sidewalks will provide pedestrians space to move to should a vehicle need to use the lane, and the curb will provide some separation between the two spaces. The curb will be mountable at the bottom of the turnaround point and in between Clark and Carruthers Hall.

7.1.2 First Iteration Free Space

Similar to *Design Idea 1* and *Design Idea 2*, the free space will be designed to be primarily green space with connecting pathways and social infrastructure throughout. Soft scaping this area with grass, trees, and native gardens will help with SWM. It will also increase the area's aesthetics and sustainability, shaping it into a natural oasis in the heart of a hardscaped campus. Native gardens, trees, hedges and social infrastructure will be strategically placed to help direct traffic flow and avoid the creation of “mud paths”. Higher concentrations of social infrastructure will be installed in key locations, including outside of Bruce Wing, where a food truck is located nearby (on Union St. in front of this area) and the Tea Room (just across the street).

The lane that currently leads to the Arch St. parking lot will be completely blocked off to vehicles. Two paths will be installed to provide pedestrian access to the parking lot, one along with Bruce Wing and the other along with Jackson Hall. The existing concrete area around Clark Hall will be redone with aesthetic interlocking with four large concrete areas outside the front doors. These concrete areas will be reserved for engineering students to continue to paint their year crests in this location. The stairs and gardens in front of this area will be redesigned to be more aesthetic as well.

7.1.3 First Iteration Alleyways

The alleyway between Clark Hall and Carruthers Hall will be transformed into a space for people to study, eat, and socialize. There will be a paver stone pathway down the center with seating areas on either side. The area will be primarily made of green concrete. However, there will be native gardens (contained by retaining walls) along both Clark Hall and Carruthers Hall to collect rainwater and add an aesthetic touch to the area. Along the Carruthers Hall retaining wall, there will be a bar-level seating area. A ramp will be installed to replace the existing staircase to the south side of Clark Hall to make the Clark Hall patio and Campus Bookstore more accessible. This alleyway area will be closed off from the accessibility parking spot and loading area by small walls. The loading area was kept in its current location because the service elevator and other required infrastructure would have been difficult to relocate. An accessibility parking space was added close to this loading area so the whole area could be paved to be close to the ramp to Clark Hall. The alleyway between Jackson Hall and Old Medical Building will have a pathway down the center with trees, tables and benches on either side.

7.1.4 First Iteration Turnaround Point

The turnaround point will be made of paver stones aesthetically arranged, encircled by sidewalks surrounded by green spaces. The turnaround point location has been moved further north compared to its placement in the three design ideas. This change was done because if the turnaround point were centered with the lane, the mechanical infrastructure beside Theological Hall would be in the way. Aesthetically and practically, it did not make sense to center the turnaround point with Theological Hall's entrance, hence the relocation. The western part of 5th Field Company Lane will be extended to the bottom of this turnaround point with asphalt paving and a mountable sidewalk.

There will be a rain garden that will collect any runoff from the turnaround point/lane to the northeast side of the Theological Hall entrance. The turnaround point will have a gradual slope towards the garden, and there will be a small pipe that will carry the runoff to it from the sidewalk curb in front. The area near Theological Hall entrance will be regraded and transformed into social infrastructure and a paver stone path leading to the front doors.

7.2 First Iteration Arch St. Parking Lot Access

Since the new design requires removing the Arch St. parking lot entrance from 5th Field Company Lane, the parking lot entrance from Arch St. must be upgraded. The redesign is necessary due to traffic complications when trying to enter and exit Arch St. The current layout has the road curved northwards to allow easy entrance from the one-way street. However, there is no simple way to exit the parking lot using this route. The exit maneuver is difficult as drivers must make a right-hand turn due to Arch St. being a one-way street. Figure 18 below shows the current layout of the Arch St. parking lot entrance.

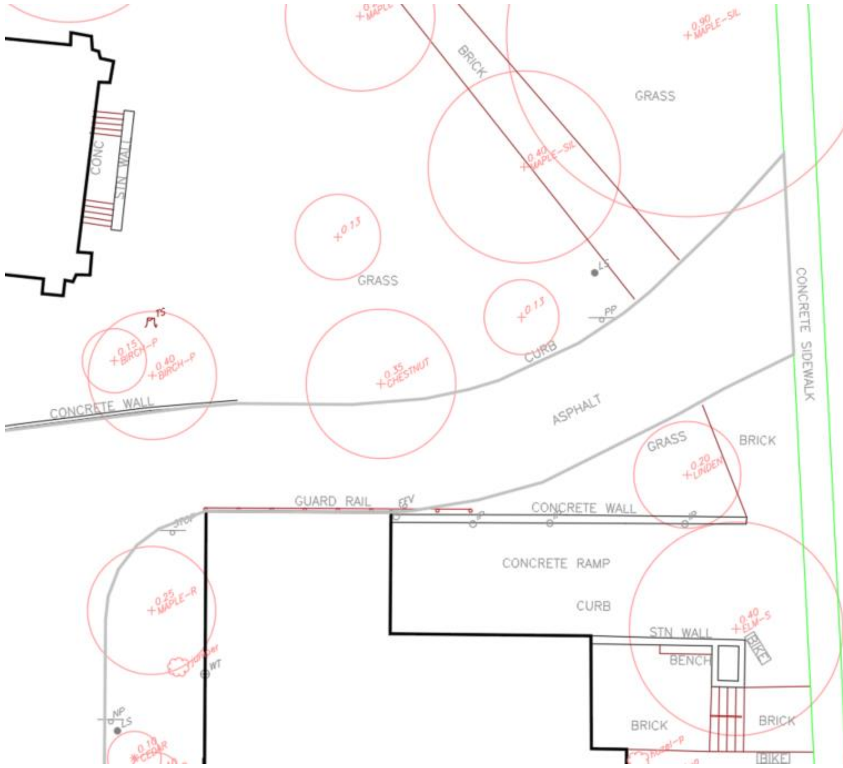


Figure 18: Current Layout of the Arch Street Entrance

Consultation with the PPS Grounds Manager revealed that multiple trees along the entrance were removed during the last year due to disease, thus simplifying the lane-widening process. The proposed design will incorporate straight lanes and an offset away from Humphrey Hall to make the exit less jarring for drivers. Other significant changes include the partial relocation of the concrete wall south of Miller Hall and the removal of multiple trees still in place to the north of the entrance to allow for widening to create a distinct two-laned road. Figure 19 displays *JEMS Consulting's* initial proposed design.

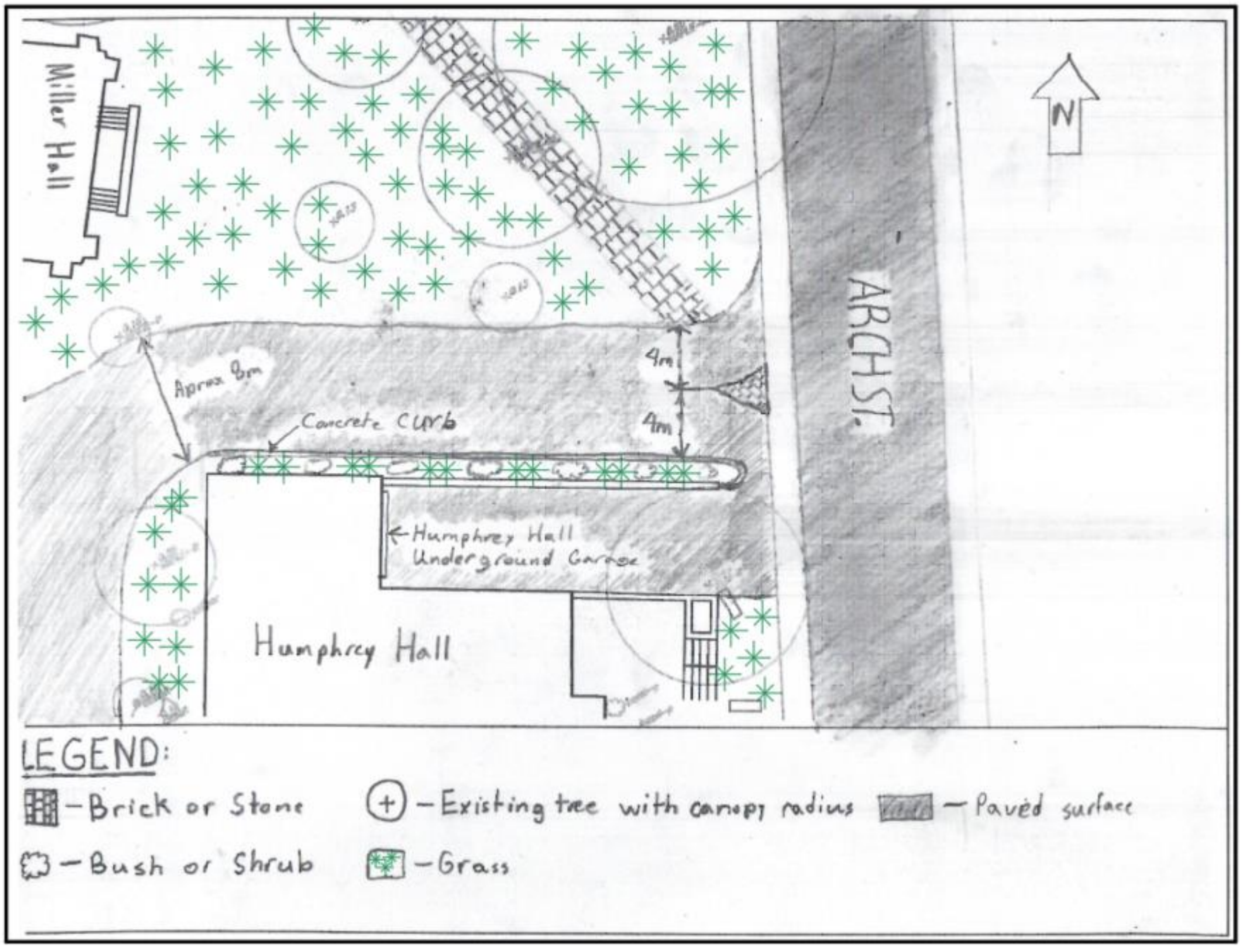


Figure 19: Proposed Arch Street Parking Lot Entrance

The new entrance features a direct path to Arch St. with a median island to delineate the lane directions. The current brick pathway will be shortened to accommodate the changes to the paved surfaces. The bricks removed from the current Humphrey Hall garage entrance will be repurposed to create the median island and extend the Union St. path. This would help cut down on costs and waste. Since Arch St. is a one-way street, both the entrance and exit lanes are curved to ensure any vehicle's maximum turning space. The Humphrey Hall underground garage area's entrance will now share a portion of the paved surface with the exit lane. A new concrete curb will also be installed on the south side of the entrance lanes along with Humphrey Hall and round off near Arch St.

8.0 Final Design

This section outlines the many different components of the final design. The aboveground layout of 5th Field Company Lane, the Arch St. parking lot access layout, the SWM system and the watermain system were all designed as part of this project. Additionally, a waste management plan was devised to service the redesigned area, and recommendations for sanitary sewer upgrades and hot water system are included. Limitations of the proposed design are also discussed within this section.

8.1 5th Field Company Lane

The 5th Field Company Lane site layout can be summarized into four parts. These are the laneway and parking layouts, free space use, alleyway repurposing, and turnaround point detailing.

8.1.1 Final Laneway and Parking

The new laneway will be composed of two separate 3.0 m wide lanes with a central 1.5 m wide boulevard. The central boulevard will also act as a bioswale and detain runoff, as further described in Section 8.3.3. The lanes will have a paved surface width of 3.0 m composed of concrete pavers. The minimum thickness of the pavers shall not be less than 80 mm to meet the requirements of OPSD 561.010. This is different than the first iteration, which called for stone pavers. This change was made because concrete pavers can be designed with different strengths depending on their use and offer a more consistent product, whereas the stone pavers may vary in quality from stone to stone. Concrete is also easier to form to custom shapes that may be required for this project's surfaces. Both lanes will be flanked, on both sides, by concrete barrier curbs. The boulevard curbs will follow the OPSD 600.080 at approximately every 20 m interval. There will be a 1.0 m section where the curb is tapered to allow water to flow into the bioswale. Design details of the boulevard curb sections can be found in Appendix D. For the outer sides of the lane, the curb will follow OPSD 600.110 and will be accompanied by 1.25 m wide sidewalks. Below, in Figure 20, is an example of the cross-section of the roadway.

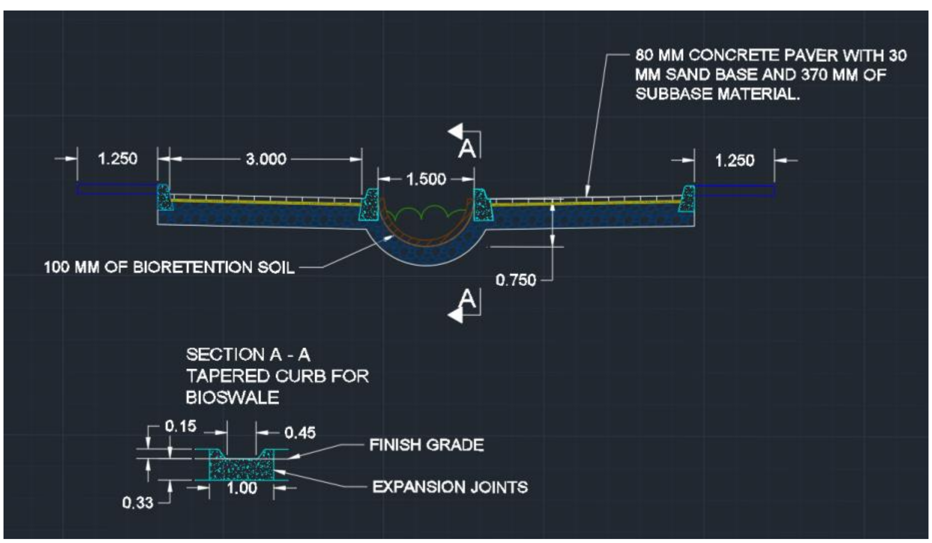


Figure 20: Typical Cross-section of the New Road Design

For the road by Clark Hall and Jackson Hall, the bioswale will discontinue providing adequate spacing for the delivery to maneuver into the loading dock at Clark Hall. The sidewalk on the west side fronting the Clark Hall loading dock will also be mountable to accommodate the delivery trucks.

The final iteration of the lane layout is different from the first. While the old layout of the roadway followed a relatively straight north-south path, the new layout has a slight bank towards the east then back towards the west, forming a shallow “V-shape” by Jackson Hall. This was done to maximize the space needed to accommodate the new wider laneway since the bioswale occupied the central boulevard. The full layout of the final design can be found in Appendix D.

The new layout also requires multiple changes from some surrounding buildings and existing green spaces to be correctly implemented. Bruce Wing of Miller Hall needed to have the western corner of its concrete staircase partially removed. Elevated planters/gardens similar to the ones between Ontario Hall and Grant Hall can be implemented in this provided space. Another change will be the removal and reinstallation of approximately 12 light posts along the existing lane. Because of the wider roadway, the new sidewalks would overlap with many of the existing light posts. Some of the light posts were removed because of their location in or near the new turnaround point.

Another major difference is the layout of the parking spaces in the Arch St. parking lot. Because the space between Bruce Wing and Jackson Hall will no longer provide a path for vehicular traffic, some of the space between the two buildings will be turned into greenspace, and the remaining space will be repaved. The repaved area will be repainted to host the six new disability parking spaces to meet the requirement of Queen’s University parking lot standards [Queen’s University 2019b]. The number of spaces in the existing lot will be reduced to 78 spaces. For lots between 76-100 spaces, six must be reserved for accessibility purposes. The repaved area between Bruce Wing and Jackson Hall will house two type A spots (for vans with mechanical lifts), two type B spots (for people who transfer out of their vehicle manually), and two type C spots (parking for people with limited mobility) as per the University’s accessibility standard. Below is Figure 21 showing the new layout of the accessibility spaces. Layout, cross-sections, and dimensional drawings for the lanes and parking spaces can be found in Appendix D.

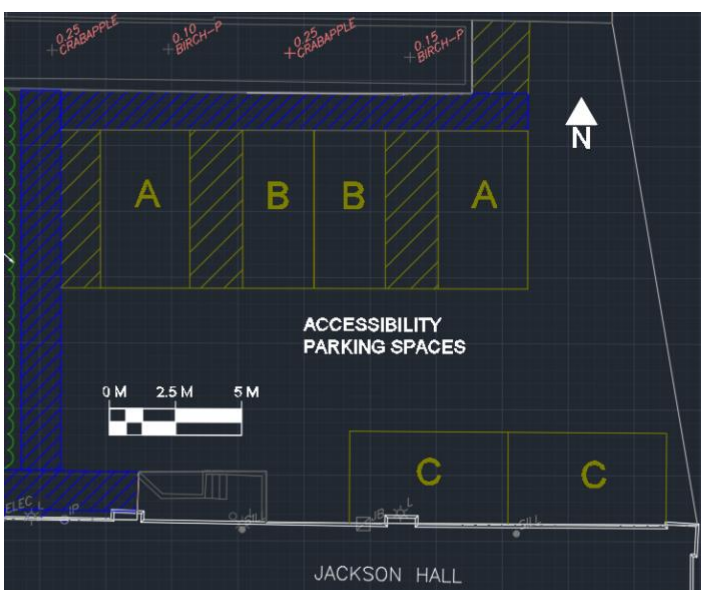


Figure 21: Finalized Accessibility Parking Spot Layout

8.1.2 Free Space

With one of the main project focuses being rejuvenating the laneway and its surrounding area, some previous hardscapes became useable spaces to implement the new social infrastructure. The final iteration did not deviate too much from the first iteration of the final design. The first open space redesign was the leftover free space between Bruce Wing and Jackson Hall beside the new accessibility parking lot. This area will be transformed into an area where students and staff can enjoy studying outdoors. There are six picnic tables laid out in two columns and three rows in this area, as shown in Figure 22.

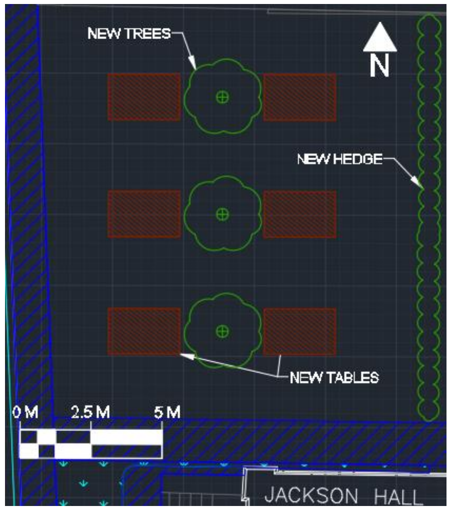


Figure 22: New Social Infrastructure

The number of tables and their orientation are the only difference between the two iterations. A tree for each row will also occupy the space between the columns of tables. Preferably the species of trees should be one native to the region and perhaps be different from each other for good tree diversity. Diversifying the tree species will prevent species-specific diseases from spreading from one tree to another.

The next area the team could turn into greenspace was the area between Carruthers Hall and Clark Hall. The area was paved to provide Queen's Campus Security and Postal Service vehicles with a route to the 5th Field Company Lane; however, these two services will move to a different campus location in the near future. The area no longer needs to be paved. A quarter-circle raised planter garden and a bench that follows the garden's inner curve is installed in this location. Located at the center of the garden's radius is a fully circular garden with a decorative tree. A Crab apple tree or another smaller tree species would be a good choice since they can remain small with regular pruning. The areas just west of the garden also provides a good spot for a new tree due to sunlight exposure for a good portion of the day from the east until noon. A similar garden/bench set up is also proposed for the space just west of Old Medical Building. This quarter circle garden will also have three circular tables place around the outside perimeter of the garden. The two quarter-circle gardens were added to the layout, because the first iteration of the final design had not yet been scaled to size, and the amount of space available was underestimated. Figure 23 and Figure 24 below show both locations of the quarter circle garden.

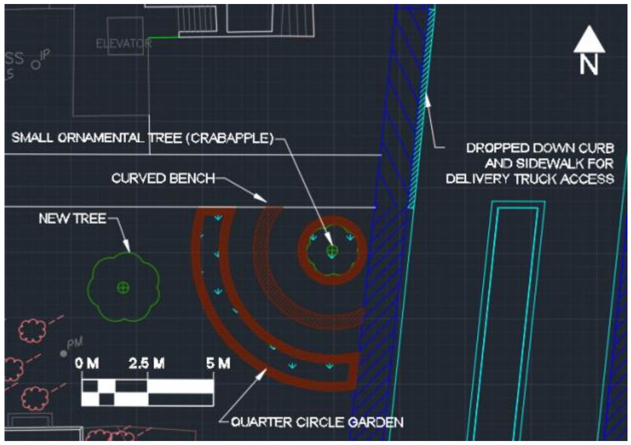


Figure 23: Quarter Circle Garden Design Detail Between Clark and Carruthers

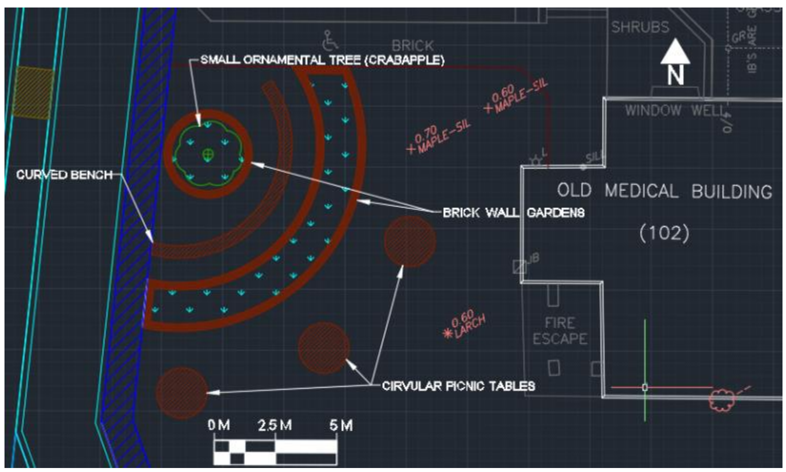


Figure 24: Quarter Circle Garden Design Detail west of Old Medical Building

8.1.3 Final Alleyways

The alleyways in the final design are slightly different than the first iteration. The first iteration called for native gardens along the walls of Clark Hall and Carruthers Hall with circular tables placed on concrete in the space that used to be asphalt, a bar table along the retaining wall of Carruthers Hall and a brick sidewalk in the center of the alleyway. The final design will have grass instead of concrete with a concrete sidewalk in the center instead of a brick one. The bar table was not included due to limited space. The circular tables were the only element that carried over since they would provide students with areas to socialize. Below is Figure 25, showing the new layout of the alleyway between Clark and Carruthers.

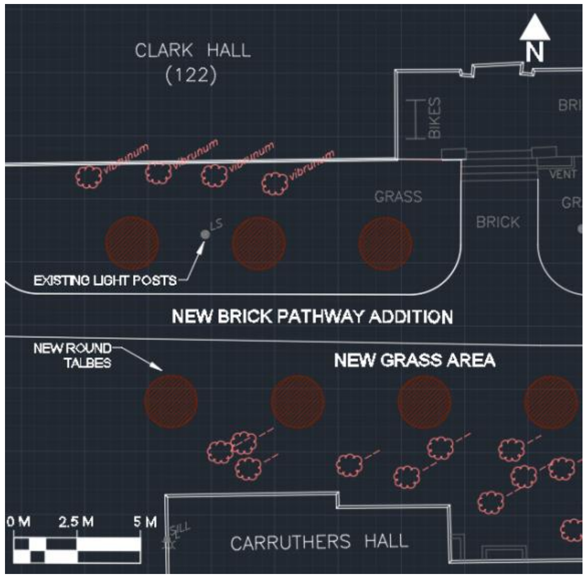


Figure 25: New Alleyway Design Between Clark and Carruthers

The other redesigned alleyway was located between Jackson Hall and Old Medical Building. The first iteration of the design consisted of a concrete path in the center of the alley flanked by greenery and benches. Instead, the final design kept the brick pathways along the sides of the buildings and turned the asphalt road surface into greenspace. Due to the lack of sunlight from the surrounding buildings' shadows, the team determined that only one tree can be planted in this area. This tree would be placed at the west end of the alley, and bushes and shrubs would occupy the rest of the center of the alleyway. Figure 26 shows the new layout of the alleyway between Jackson Hall and Old Medical Building.

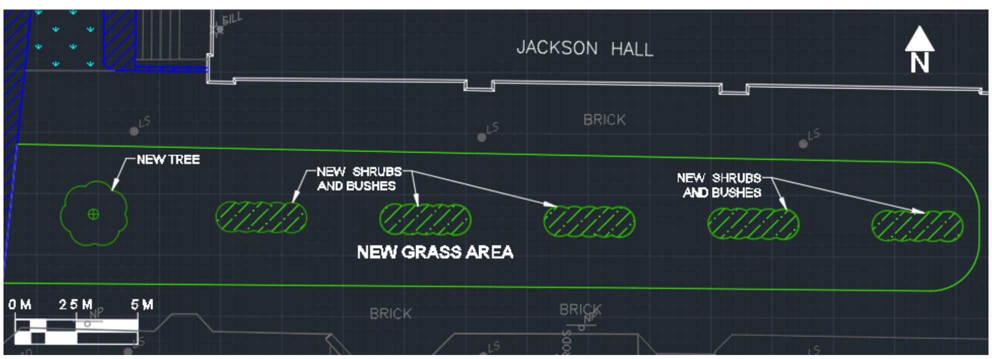


Figure 26: New Alleyway Design Between Jackson and Old Medical Building

8.1.4 Final Turnaround Point

The new turnaround point will be composed of a central tear drop shape garden, unlike the circular shape proposed in the first iteration of the design. The tail portion of the turnaround point was added to provide an easier approach for vehicles entering the circular portion of the lane. The lane's interior curbs will differ from the beginning of the curve from a simple barrier curb (OPSD 600.080) to a wider tangent mountable curb at the end, similar to that which is found in OPSD 600.030. The interior curb will also have two 600 mm x 600 mm catch basins, one on each curve's roadside. These catch basins will have a 100 mm PVC pipe going towards the retention ponds on the west and east sides' turnaround point. This method to divert water differs from the one used in the first iteration since the slope of the road in the final design is superelevated to have a low point on the road surface in the inner perimeter on the lane. The center of the tear drop is separated into two surface types. A brick paver plaza and a diamond-shaped greenspace stretching from the tail to the center of the arc.

The outside perimeter of the tear drop will have a barrier curb (OPSD 600.110) and sidewalk. The southwest portion of the outer perimeter will only have a superelevated mountable curb (OPSD 600.030) to provide access to the asphalt path heading to the west. The curb and sidewalk on the southeast side will be dropped and mountable to provide access to the waste bins next to Theological Hall. The outside radius of the arch portion of the teardrop is approximately 12.8 m. The required turning radius for most garbage trucks are below 11.6 m; however, the largest truck could require up to 13.7 m. The team decided to use a 12.8 m radius as a way to accommodate most trucks, and should a larger truck drive down the lane, the curbs are mountable to allow bigger trucks more room to maneuver. Another reason why the team did not go with a wider radius is that more trees would have to be removed, thus increasing the ecological impact of the project. It also should be noted that the existing road layout has the same turn radius of 12.8 m to access the bins. A detailed drawing of the teardrop area and its surroundings can be seen in Appendix D.

8.2 Final Arch St. Parking Lot Access Layout

The new Arch St. Parking entrance differs from the previous iteration in multiple ways. The first being that the final design no longer has a greenspace next to Humphrey Hall. It was decided that the amount of greenspace provided by the initial design would not be of any benefit because the area would be lost on the north side. Therefore, the team decided to keep a portion of the existing guard rail and expand it for the entire length of the separation wall for the Humphrey Hall underground garage. Along with the plan to extend the guardrail, a concrete curb with a narrow gutter following OPSD 600.100 will be installed below the rails to stop water from flowing beside the building walls and prevent pooling. This would reduce freeze-thaw damage to Humphrey Hall.

On the north side, the two iterations are the same, with both requiring the relocation of a retaining wall and installing a new concrete barrier curb (OPSD 600.110). The concrete wall currently exists as a curb with its height increased to serve as a retention wall. The height of the retained soil is estimated to vary from 0.3 m to 1.1 m. The new retaining wall will be built in the same fashion as the existing one and tapering downwards as the curb goes east.

The new Arch St. parking design also includes a new concrete pad behind Jackson Hall to support a new waste corral that will house one waste compactor and multiple recycling totes. Placing the compactor at the rear of Jackson Hall simplifies garbage truck maneuvers as the trucks will be entering the parking lot through the Arch St. entrance. The final Arch St. parking lot entrance redesign can be found as part of Appendix D below.

8.3 Storm Water Management

This section outlines the finalized detailed design for the SWM System for 5th Field Company Lane. As part of the design justification, modelling of the initial conditions and final components was completed on the Stormwater Management Model (SWMM) 5.0 to analyze its effectiveness.

8.3.1 SWMM 5.1 Modelling Overview

The client has requested that the SWM system aid in the redirection and control of runoff in a non-invasive manner. Specifically, the client has requested that the design controls runoff on-site rather than a traditional underground conveyance system. Reasons for this request include:

- ⇒ Limiting the disturbance of the infrastructure currently in place along the eastern site boundary
- ⇒ Limiting the need for a tie-in to stormwater trunk mains along Union St.
- ⇒ Limiting the need for a southern conveyance pipe extending beyond the site limits (past Theological Hall)
- ⇒ Providing potential for aesthetic and innovative improvement through the use of LID systems

The SWM system proposed in the following sections will promote the storage and infiltration of on-site rainwater to accommodate the client's request. By targeting an increase in storage and infiltration, the downstream load on the collection system present at the intersection between Union Street and 5th Field Company Lane will be limited. The goal of the SWMM modelling is to prove that there is a decrease in observed runoff between the initial and proposed conditions through the incorporation of LID technology.

Rainfall Data

SWMM 5.1 is a dynamic rainfall-runoff model that can be used for single-event or continuous simulation of the quantity and quality of runoff produced in urban drainage areas (Rossman 2015). SWMM 5.1 was chosen for the modelling of on-site conditions as it simulates the amount of runoff produced on-site through the use of rainfall data for the City of Kingston. To complete the modelling, hourly rainfall data over a 44-year period (spanning August 1960-November 2003) for the City of Kingston was provided by Dr. Yves Filion to compare the frequency of moderate, heavy, and very heavy-intensity storms in the City of Kingston. For the purposes of this modelling, the classification of these storms is as following:

- ⇒ **Moderate Intensity -** 2.5 - 10 mm/hr
- ⇒ **Heavy Intensity –** 10 - 50 mm/hr
- ⇒ **Very Heavy Intensity -** >50 mm/hr
- ⇒ **Moderate Storm Climate Change Effects –** 1.2x Peaking factor for the moderate storm

Climate change is an important consideration when evaluating runoff generated on-site. Since LID systems are only expected to decrease the runoff generated for smaller storms, climate change effects were considered for this model's moderate intensity storm. This was achieved by using a peaking factor of 1.2 on the historical data for the moderate storm. This represents a 20% increase in storm intensity for moderate storms for projected years, as commonly used in models completed for the CIVL 473 course (Filion 2021). Using this classification system, four time series were gathered from the 44-year data, allowing for an accurate representation of what the proposed system will be required to accommodate.

Table 9 below shows the three time-series input into the SWMM 5.1 model.

Table 9: Time Series Used for SWMM Modelling (Filion 2021)

Time [hr]	Storm 1 (Moderate Intensity) [mm]	Storm 2 (Heavy Intensity) [mm]	Storm 3 (Very Heavy Intensity) [mm]	Storm 4 (Moderate Storm Climate Change)
1	10	13	39	12
2	6	15	56	7.2
3	6	13	54	7.2
4	6	15	21	7.2
5	4	33	31	4.8
6	2	35	52	2.4
7	2	19	N/A	2.4
8	2	13	N/A	2.4

The four representative storms were used in the SWMM 5.1 to assess the decrease in runoff achieved by the proposed SWM system. Since 5th Field Company Lane has a small total area, light intensity storms were omitted from the modelling, as limited runoff would be produced within the site boundary.

8.3.2 Modelling of Existing Conditions

In order to complete an accurate model of the existing on-site conditions, a better understanding of the current overland runoff flow path was needed. Since there are no underground conveyance systems in place, runoff travels from a high point crossing 5th Field Company Lane in the east-west direction located approximately at the front entrance of Jackson Hall. This effectively separates the current system into two sub-watersheds carrying runoff towards Union St. and Theological Hall. Due to the catch-basins present at the Union St. intersection, water can be removed from the northern half of the site. However, there is currently no infrastructure in place to collect water at Theological Hall, thus causing the observed pooling in Section 3.2.

Once the flow path was determined, the next step in modelling was determining the distribution of pervious and impervious areas. Pervious areas currently in place include green spaces, while impervious areas were classified as asphalt and concrete. This was achieved on AutoCAD using the existing drawings provided by the client found in Appendix B. Table 10, below, summarizes the sub-area categorization as determined from the AutoCAD analysis.

Table 10: Existing Conditions Sub-Watershed Input Parameters

Watershed Characteristic	Northern Sub-watershed	Southern Sub-watershed
Impervious Area [m²]	2668.4	2822.7
Pervious Area [m²]	2192.1	2032.3
Percent Impervious Material [%]	54.9	58.1
Total Sub-watershed Area [m²]	4860.5	4855.0

The current area distribution shows that the site is currently dominated by impervious materials, which in turn drives the development of surface runoff within the site boundaries. Using the input parameters outlined in Table 10, a model was created in SWMM 5.1. Figure 27 shows a not-to-scale screenshot of the model layout used to analyze the current site runoff.

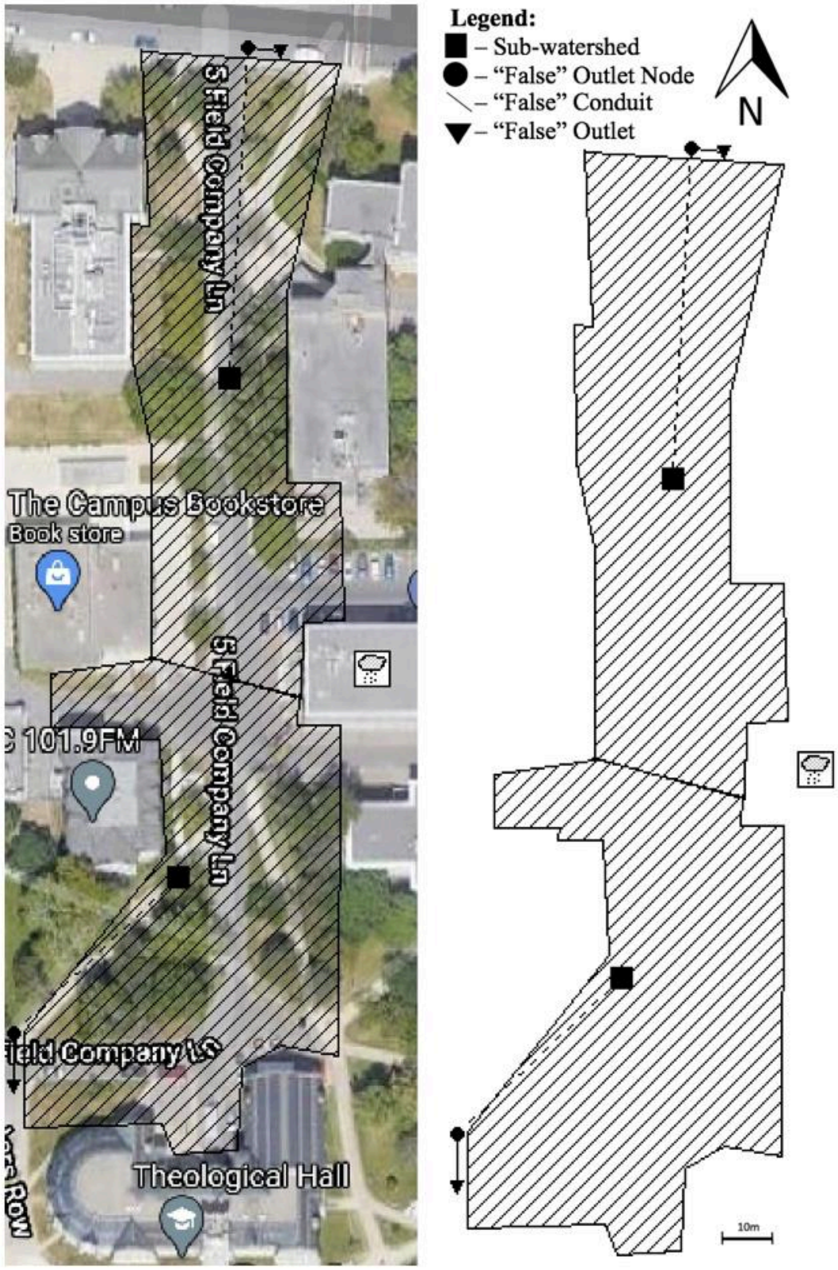


Figure 27: Model of Existing Conditions

This model uses a "False Collection System" to represent the point of drainage for each sub-watershed, as suggested by Dr. Filion in a consultation meeting (Filion 2021). These collection systems consist of one "False" collection node, such as a catch basin, that is connected to the "False" outlet by a 1 m long, 5 m diameter pipe (Filion 2021). This system's use has a negligible effect on the runoff generated as there are no friction effects by a conduit of such a small length and wide diameter (Filion 2021). However, this system's use is necessary on SWMM 5.1 to quantify the amount of rainfall produced on-site without the presence of a traditional underground conveyance system (Filion 2021). Table 11 below shows the outputs of the model for the three representative storms.

Table 11: Existing Conditions Modelling Results

Output	Storm 1 (Moderate Intensity) [mm]	Storm 2 (Heavy Intensity) [mm]	Storm 3 (Very Heavy Intensity) [mm]	Storm 4 (Moderate Storm Climate Change)
Total Precipitation [mm]	32.0	89.0	201.0	38.4
Underground Storage [mm]	1.7	6.6	6.4	1.9
Infiltration Loss [mm]	5.5	6.6	8.1	5.7
Total Runoff [mm]	25	77.0	187.8	30.9
Percent Stored/Infiltrated [%]	22.5	14.8	7.2	19.8

The existing model results show that as the storms worsen in severity, the direct runoff produced on-site increases. This trend is expected due to the large percentage of impervious material present on-site. The current storage rates on-site are meagre (1.7% - 6.6% of rainfall), leading to an increased load on the downstream collection system. This is further exemplified in Figure 28 below, which compares the runoff amount produced on-site during each storm under the initial conditions.

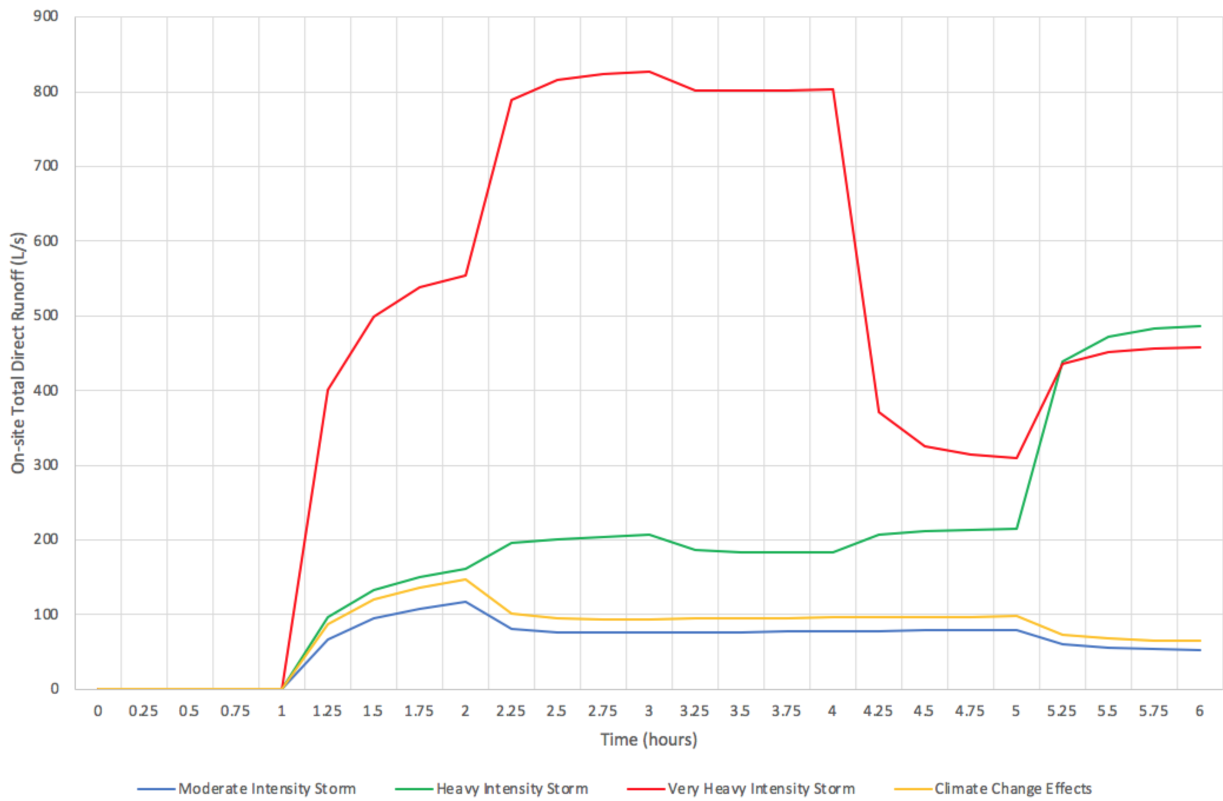


Figure 28: Runoff Produced on-site Under Initial Conditions

Additionally, infiltration rates on-site are low (4-17%) due to the small and separated green spaces within the site boundaries. One trend of importance is the decrease in storage/infiltration percentage as the storms worsen. As more intense rainfall is received on-site, current site drainage and impervious material promotes overland flow and leads to a decrease in time available for storage and infiltration. This suggests that the current on-site storage capacity is low, which is something that will be targeted for improvement in the final design.

8.3.3 Final SWM System Layout and Components

The final SWM layout can be found in the final layout drawing provided in Appendix D below. This system integrates innovative LID technology into the existing on-site drainage path to alleviate the downstream runoff load. As part of the design, permeable pavers, rain gardens, bioswales, and bioretention cells were used to increase rainwater storage and infiltration on-site. The design of each element described below was completed following the guidelines provided in the "*Low Impact Development Stormwater Management Planning and Design Guide*" created by the *Credit Valley Conservation Authorities (CVC*) in consultation with the *Ministry of Environment (MOE)*. Detailed cross-sections for each component can be found in the AutoCAD drawing in Appendix D.

Permeable Pavers

Figure 29 below provides the permeable pavers design assumptions, justification, dimensions, and materials.

Specific Design Requirements

- Central 5th Feild Company Laneway surrounding the central boulevard to be composed of permeable interlocking
- Concrete paver stones required to have depth of 80 mm to accomodate service vehicles (Credit Valley Conservation 2011)
- Minimum 10% surface area are gaps filled with well graded sand and gravel without fines [GW-SW] (Credit Valley Conservation 2011)
- 1% slope of permeable paver surface (Credit Valley Conservation 2011)
- 30 cm deep underlaying storage layer composed of ASTM C33 No. 57 Clear Stone (Credit Valley Conservation 2011)
- No underdrain in underlaying layer

Assumptions

- Unknown permeabilities (K), Manning's Number (n), and void ratio of materials were assumed using literature data for modelling:
- KGW-SW= 4 x 10-5 m/s (Geotech Data 2013)
- n_{paver} = 0.015 (Chow, 1959)
- Void ratio of 0.4 for Clear Stone (Credit Valley Conservation 2011)

Design Calculation(s)

- Equation 1 below was used to detemine the required depth of the underlaying storage layer
- $$d_{min} = \frac{(Q_c x R) + P - (ixT)}{V_r} \quad (1)$$
- Variables defined in design calculations provided in Appendix G below
- Minimum depth of storage was determined to be 25 cm (Appendix G)
- Design depth of 30 cm was used to accomodate potential clogging and future storm worsening due to climate change

Dimensions

- Total permeable paver area of 1524 m^2
- Total volume of underlaying storage material of 762 m^3
- Detailed cross-section provided in Appendix D (detailed design drawing)

Figure 29: Permeable Paver Design Breakdown

Rain Gardens

Figure 30 below provides the design assumptions, justification, dimensions, and materials for the proposed rain gardens.

Specific Design Requirements

- Bioretention Topsoil Depth of 23 cm (Natural Resources Conservation Service n.d.)
- Recommended plants: trees, phytoremediation plants, pollinator-friendly plants, wildlife-feeding plants and/or native ornamental plants as outlined in Section 2.5.4.

Assumptions

- Unknown porosity (ϕ), and Manning's Number (n) of materials were assumed using literature data for modelling:
- $\phi_{topsoil}$ = 0.5 (Natural Resources Conservation Service n.d.)
- $n_{vegetation}$ = 0.05 (Chow, 1959)

Dimensions

- Three rain garden areas:
- Fronting Clark Hall Pub (Large): Total Area of $89m^2$
- Fronting Clark Hall Pub (Small): Total Area of $53m^2$
- Adjacent Jackson Hall: Total Area of $29m^2$
- $V_{bioretentionsoil}$ = $40m^3$
- Detailed cross-section provided in Appendix D (detailed design drawing)

Figure 30: Rain Garden Design Breakdown

Not only does the use of larger rain gardens improve the aesthetics of the area, but it also aids in the separation of pathways and traffic direction in busy areas such as Clark Hall and Jackson Hall. Larger rain gardens provide the potential for diverse vegetation, such as that shown in the example rain garden from Figure 31 below.

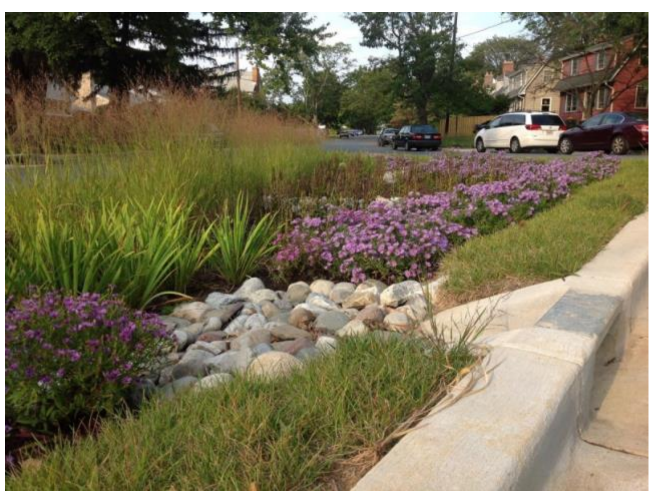


Figure 31: Example of Larger Rain Garden (Reed 2018)

Bioswales

Figure 32 below provides the design assumptions, justification, dimensions, and materials for the proposed bioswales.

Specific Design Requirements

- Bioretention Topsoil Depth of 10 cm
- 75% vegetation coverage
- Recommended plants: Native Grasses and/or Phytoremediation Plants as outlined in Section 2.5.4.
- 1% fall from high point at Jackson Hall for both northern and southern bioswale
- 1 % fall to central boulevard across permeable pavers surrounding bioswale
- 30 cm deep underlaying storage layer composed of ASTM C33 No. 57 clear stone (Credit Valley Conservation 2011)
- No underdrain in underlaying layer

Assumptions

- Unknown porosity (ϕ), Manning's Number (n), and void ratio of materials were assumed using literature data for modelling:
- $\phi_{topsoil}$ = 0.5 (Natural Resources Conservation Service n.d.)
- $n_{vegetation}$ = 0.05 (Chow, 1959)
- Void ratio of 0.4 for Clear Stone (Credit Valley Conservation 2011)

Dimensions

- Northern Bioswale: 105 m long x 1.5 m wide x 0.75 m deep
- Southern Bioswale: 43 m long x 1.5 m wide x 0.75 m deep
- Total aboveground storage capacity of 130 m^3
- Total uniform width of 1.5 m in the central boulevard
- Total uniform depth of 0.75 m to center of swale
- Uniform semi-circular cross section with radius of 0.75 m
- Curb-cutout inlet located every 20 m on either side of the bioswale
- Detailed cross-section provided in Appendix D (detailed design drawing)

Figure 32: Bioswale Design Breakdown

Having the central laneway sloped at 1% fall towards the central bioswale aids in runoff collection that cannot be stored in the permeable paver system. It is not expected that the bioswale has the capacity of extreme storms (similar to all LIDs). Rather, the bioswale is proven (Section 8.3.4) to aid in reducing surface runoff, while adequately fitting into the central boulevard, thus contributing to both the functionality of the SWM system and the aesthetic improvement of 5th Field Company Lane.

Bioretention Cells

Figure 33 below provides the design assumptions, justification, dimensions, and materials for the proposed bioretention cells.

Design Requirements

- Bioretention Topsoil Depth of 10 cm
- Recommended plants: Native Grasses and/or Phytoremediation Plants as outlined in Section 2.5.4.
- 75% vegetation coverage
- 30 cm deep underlaying storage layer composed of ASTM C33 No. 57 Clear Stone (Credit Valley Conservation 2011)
- No underdrain in underlaying layer

Assumptions

- Unknown permeabilities (K), Manning's Number (n), and void ratio of materials were assumed using literature data for modelling:
- $\phi_{topsoil}$ = 0.5 (Natural Resources Conservation Service n.d.)
- $n_{vegetation}$ = 0.05 (Chow, 1959)
- Void ratio of 0.5 for Clear Stone (Credit Valley Conservation 2011)

Design Calculation(s)

- Equation 2 below was used to detemine the required depth of the underlaying storage layer
- $$d_{cellMax} = \frac{i(t_s - \frac{d_p}{i})}{V_R} \quad (2)$$
- Variables defined in design calculations provided in Appendix G below
- Minimum depth of storage was determined to be 1.0 m (Appendix G)
- Design depth of 1.0 m was used to accomodate potential clogging of underlaying storage layer and future storm worsening due to climate change

Dimensions

- Eastern Bioretention Cell: 6 m long x 6 m wide x 1 m deep (rectangular)
- Western Bioretention Cell: 12 m base x 12 m height x 1 m depth (triangular)
- Side Slope of 1:1 supported by vegetation roots
- Total aboveground volume of 77 m^3 (accounting for area lost due to side slopes)
- Detailed cross-section provided in Appendix D (detailed design drawing)

Figure 33: Bioretention Cell Design Breakdown

8.3.4 Final Design Modelling

The same process for modelling as described in Section 8.3.2 was completed to determine the total runoff for the new SWM system to compare the two systems. However, modelling for the new system was more complex. The total site area had to be further categorized into smaller sub-watersheds to represent the LID controls within the system. Table 12 below shows the areas used to categorize each sub-watershed in the final model.

Table 12: New System Sub-Watershed Input Parameters

Watershed Characteristic	Northern Sub-watershed	Southern Sub-watershed
Impervious Area [m^2]	1862.0	1855.0
Pervious Area [m^2]	1906.0	2067.0
Permeable Paver Area [m^2]	792.0	732.0
Rain Garden Area [m^2]	142.5	29.0
Bioswale Area [m^2]	158.0	64.0
Bioretention Cell Area [m^2]	0.0	108.0
Percent Impervious Material [%]	38.3	38.2
Total Sub-watershed Area [m^2]	4860.5	4855.0

Before running any models, comparing Table 10 and Table 12 shows that the integration of LID technology and green spaces decreases the impervious area in the northern sub-watershed from 2664 m^2 to 1862 m^2 (30% decrease). Similarly, the impervious area in the southern sub-watershed is decreased from 2822.7 m^2 to 1855.0 m^2 (34% decrease). This will decrease runoff generation on hardscapes before the effects of LID controls are even considered. Using the input parameters outlined in Table 12, a second model was created in SWMM 5.1. Figure 34 shows a not-to-scale screenshot of the model layout used to analyze the runoff generated in the final SWM system.

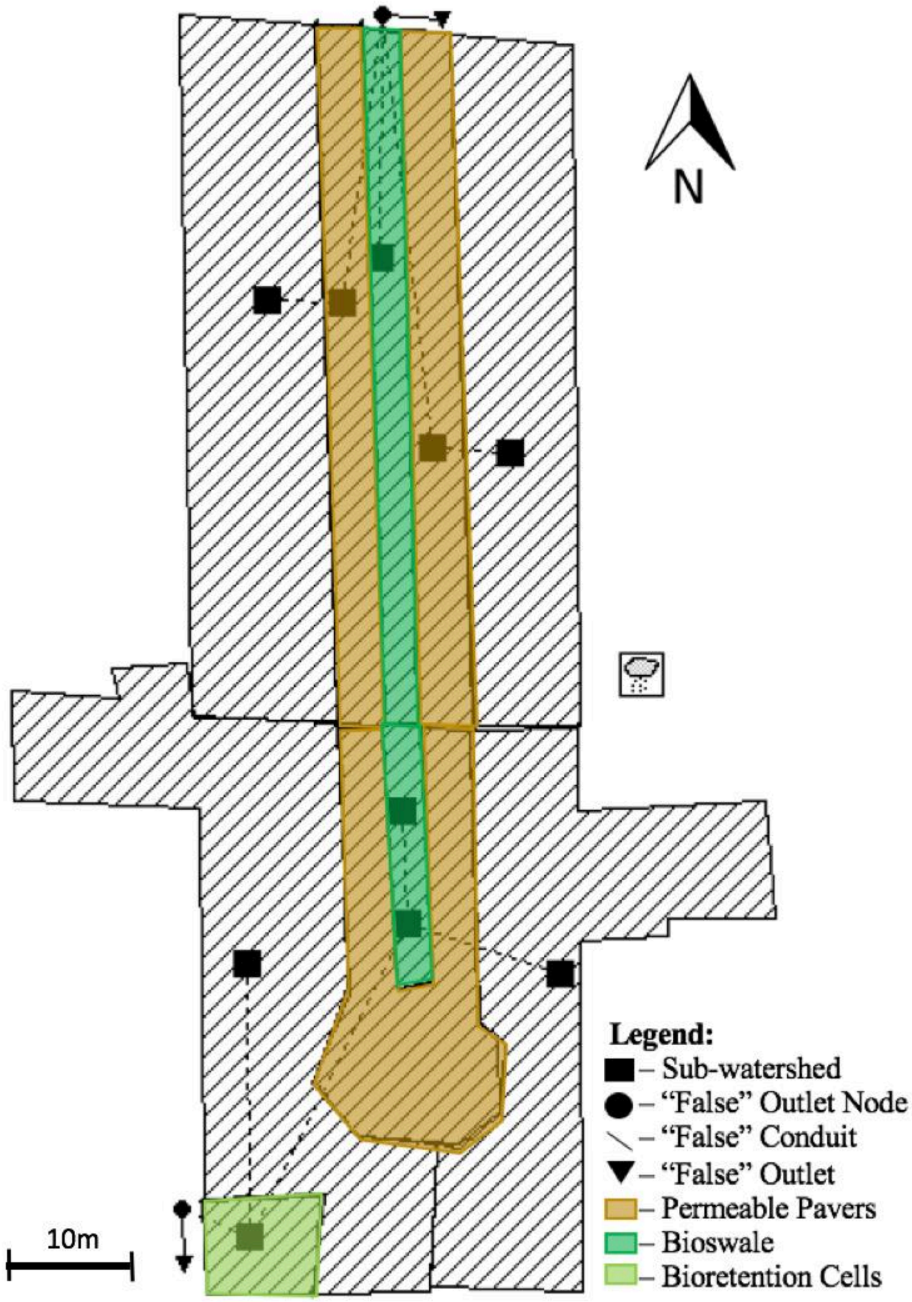


Figure 34: Model of Final SWM System

Similar to the procedure used in the initial model, a "False Collection System" was used to quantify the amount of runoff received by the site during the moderate, heavy, very heavy, and climate change storms for the Kingston Area (Filion 2021). However, in this model, the LID technology used in the final design was inputted in SWMM 5.1 using the permeable paver, bioretention, and rain garden LID controls. The design specifications, assumptions, and dimensions previously outlined in Section 8.3.3 were used as input parameters for the LID controls. Table 13 below shows the output for the final model.

Table 13: Final SWM System Modelling Results

Output	Storm 1 (Moderate Intensity) [mm]	Storm 2 (Heavy Intensity) [mm]	Storm 3 (Very Heavy Intensity) [mm]	Storm 4 (Moderate Storm Climate Change)
Total Precipitation [mm]	32.0	89.0	201.0	38.4
Underground Storage [mm]	22.4	28.5	31.2	23.1
Infiltration Loss [mm]	1.7	1.7	1.7	1.7
Total Runoff [mm]	8.4	57.3	166.8	14.3
Percent Stored/Infiltrated [%]	75.3	33.9	16.4	64.6

It can be observed in Table 13 that the implementation of LID technology helped reduce the amount of runoff produced within the site boundaries drastically. Runoff produced from the moderate storm decreased from 25 mm to 8.4 mm (66% decrease). Runoff produced from the heavy storm decreased from 77 mm to 57.3 mm (26% decrease). Runoff produced from the very heavy storm decreased from 187.8 mm to 166.8 mm (11% decrease). This is further exemplified in Figure 35 below, which compares the runoff amount produced on-site during each storm under the final conditions.

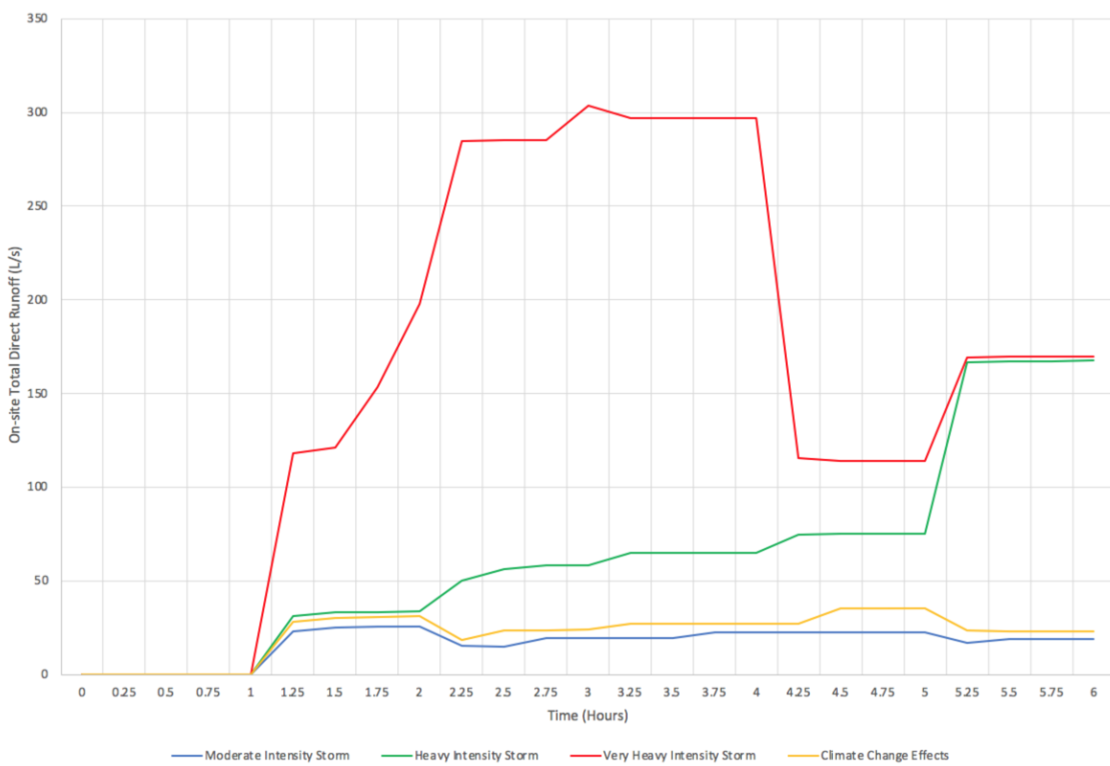


Figure 35: Runoff Produced on-site Under Final Conditions

Furthermore, the effects of climate change on runoff generation for moderate storms are partially mitigated by using LIDs as a decrease from 30.9 mm to 14.3 mm (46% decrease) was observed between the initial and final conditions. While this model shows the LIDs effectiveness in mitigating climate change, it is limited to moderate storms. As climate change continues, it is expected that the intensity of heavy and very heavy intensity storms will increase. Still, it is not expected that the LIDs in place control the runoff for these larger storms.

These results show that although it was not necessary for the LID systems to accommodate the larger storms, they could still assist in the reduction of runoff, thus decreasing the load on the receiving conveyance system. The goal of this system was achieved as on-site storage/infiltration capacities were improved. These values increased from 22. % to 75.3% for the moderate storm, as exemplified by Figure 36 below, which compares the runoff in the initial modelling to that in the final system.

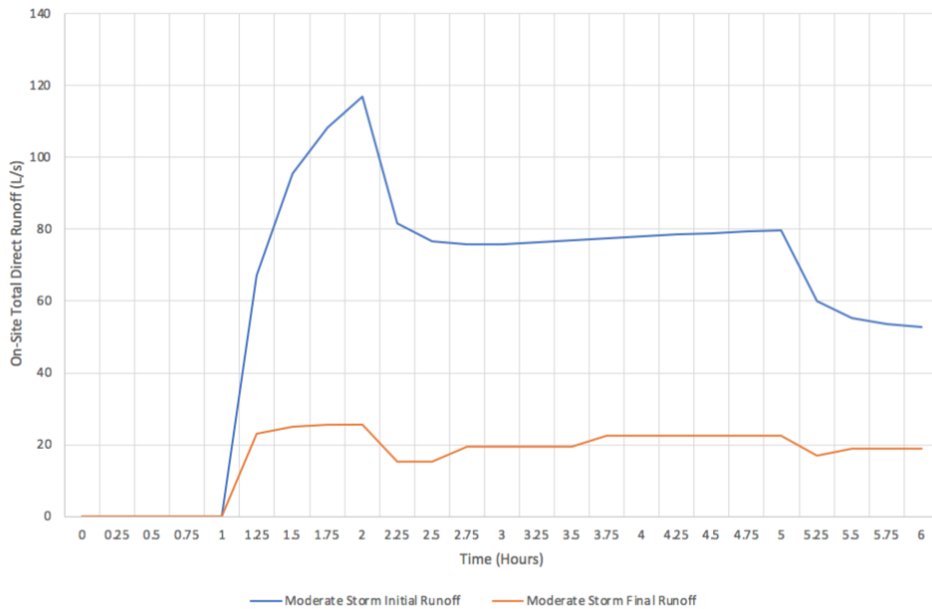


Figure 36: Comparison of Runoff Produced for Moderate Intensity Storms Under Initial and Final Conditions

Furthermore, storage/infiltration capacities were increased from 14.8% to 33.9% for heavy intensity storms, as exemplified by Figure 37 below.

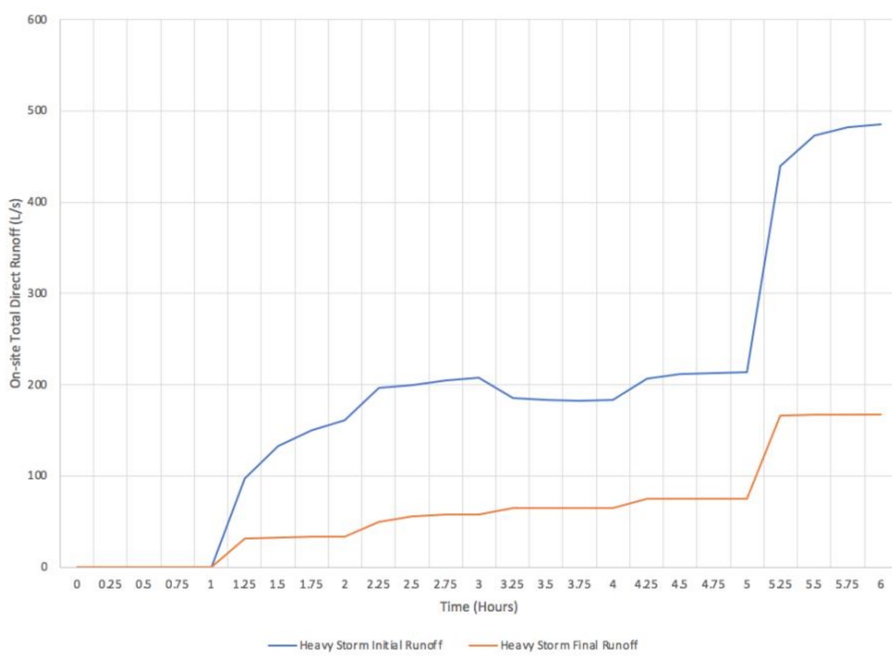


Figure 37: Comparison of Runoff Produced for Heavy Intensity Storms Under Initial and Final Conditions

Storage/infiltration capacities were increased from 7.2% to 16.4% for the very heavy storms, as further exemplified in Figure 38 below.

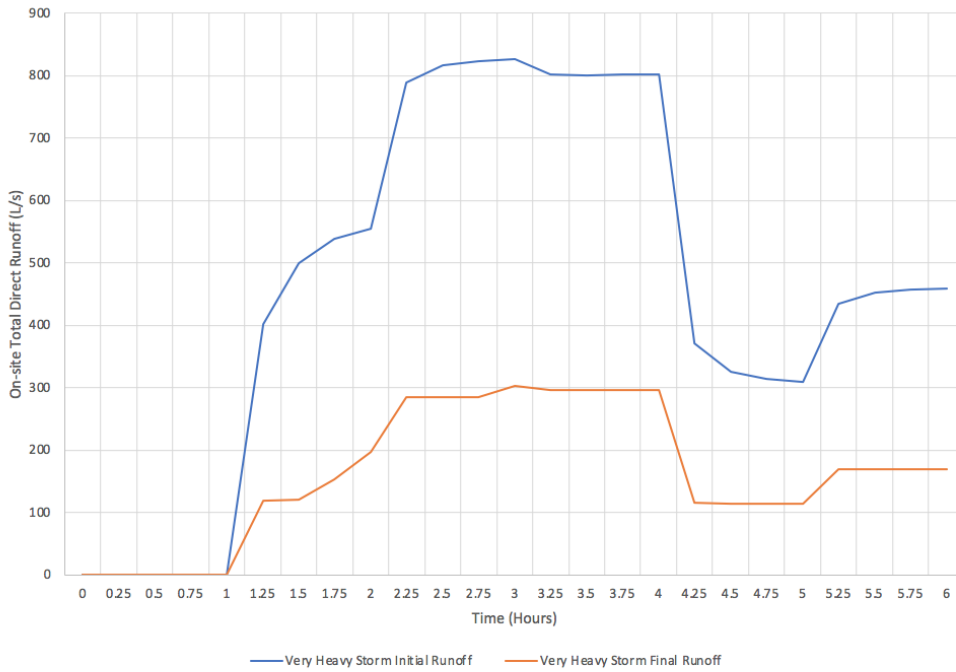


Figure 38: Comparison of Runoff Produced for Very Heavy Intensity Storms Under Initial and Final Conditions

Finally, storage/infiltration capacities were increased from 19.8% to 64.6% for the climate change storms, as further exemplified in Figure 39 below.

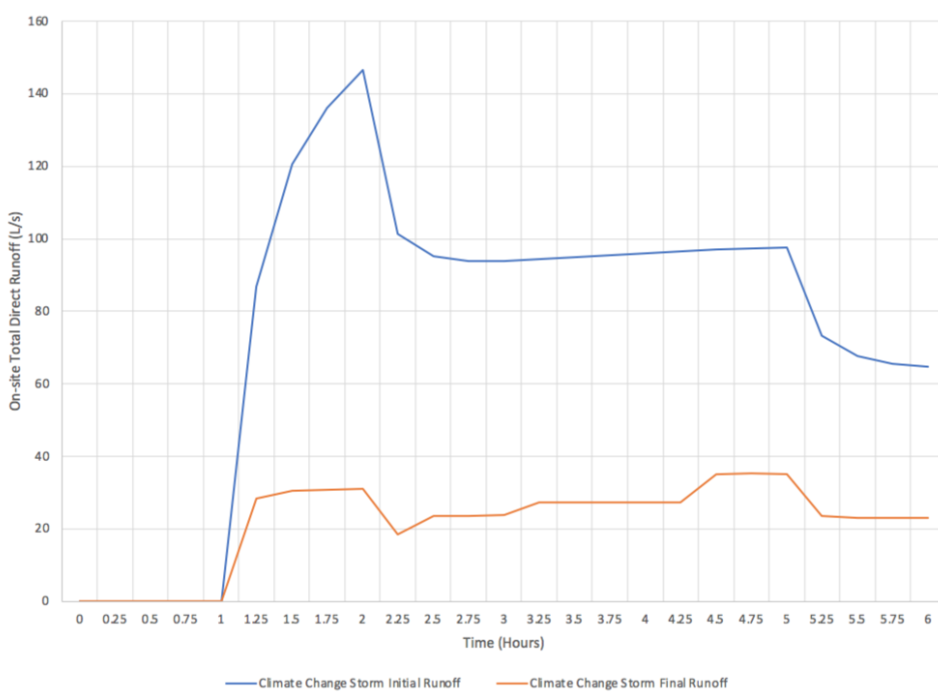


Figure 39: Comparison of Runoff Produced for Climate Change Storms Under Initial and Final Conditions

8.4 Watermain Design

This section outlines the changes made to the watermain extending to the south along 5th Field Company Lane. Design specifications, modelling, and justification will be included as part of this section. The current watermain conditions included two separate watermains under either side of the laneway. The first pipe on the watermain on the western side of the laneway was a 300 mm diameter PVC pipe, while the pipe on the eastern side of the lane had a diameter of 150 mm. This layout is extremely inefficient as both watermains service buildings on either side of the street, leading to multiple crossings. Sections of the pipes have also been abandoned over the years, leaving them plugged, such as the extension on the south side of Clark Hall. Both of the watermains are connected to the main network at Union St., and both loop within the Queen's University Campus system to help maintain pressure.

8.4.1 Proposed Design & EPANet Modelling

The clients requested a singular watermain to service 5th Field Company Lane and its surrounding buildings, as it will improve the system's efficiency and allow easier access for maintenance. The new design was analyzed using EPANet 2.2 using the following requirements and assumptions:

- ⇒ 350mm PVC DR18 pressure pipe for central watermain
- ⇒ 150mm PVC DR18 pressure pipe for water services
- ⇒ Functioning pressure range of 280 kPa and 700 kPa under standard flow conditions (City of Kingston 2014)
- ⇒ 60m constant head reservoir representing inflow from Union St. (Utilities Kingston 2017)
- ⇒ Looping mechanisms were represented using a pipe end with a 60m constant head.
- ⇒ Roughness coefficient for the PVC of 140 (Utilities Kingston 2017)
- ⇒ Standard depth of 1.7 m as required by the City of Kingston (City of Kingston 2014)

Each node represented either a water service to the many buildings (with required building demand) or a looping mechanism with a constant hydraulic head. Nodes that did not have the standard water demand of 1.03 L/s represented the maximum demand for each building from all of the data provided. At nodes where the extensions continued beyond the site boundaries to connect to the main network, a constant head reservoir with 60m of head was used to represent the continuous pressure provided by the main system's connections. These extensions include the southwest extension towards University Ave., the northwest extension towards University Ave., and the eastern extension towards Arch St.
Water Demand for Buildings

Table 39 shows the monthly water demands for each building on 5th Field Company Lane. The time series used in modelling was a 24-hr diurnal pattern, representing the fluctuations observed within the system with the peaks and minimums over a daily pattern. Figure 40 below shows the EPANet model of the new watermain layout, where nodes represent water service connections to the buildings with their associated water demands.

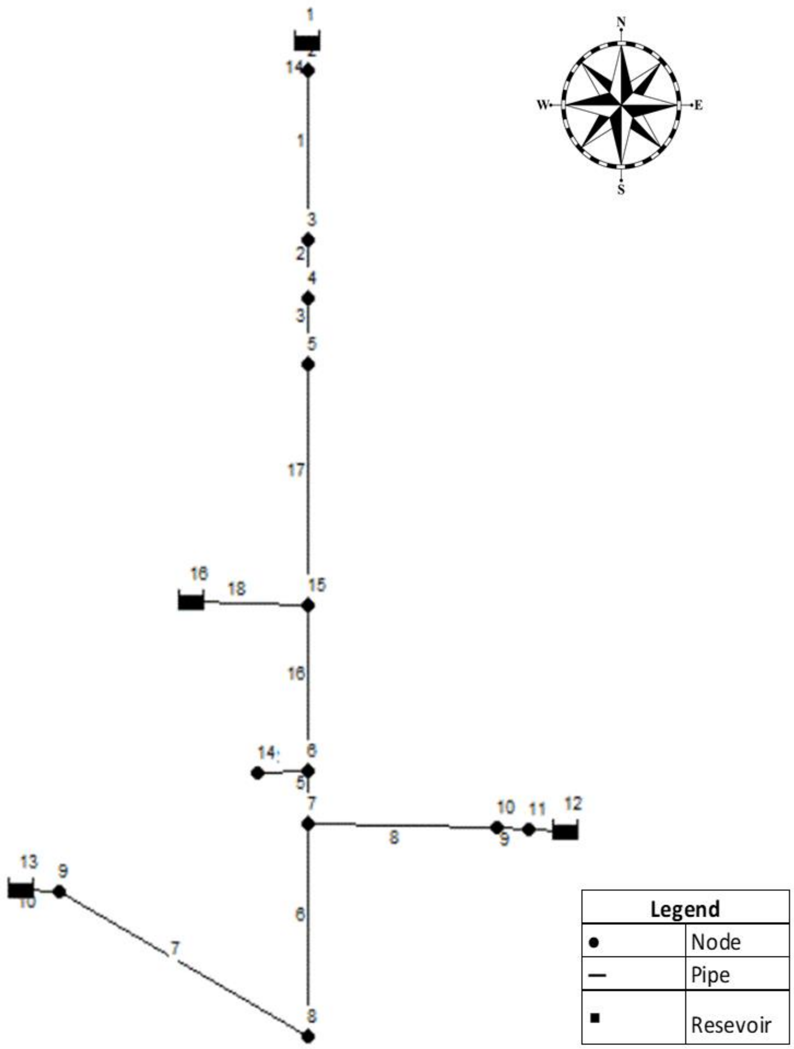


Figure 40: EPANet Network Map

The new watermain layout as prepared on AutoCAD can be found in Appendix D. Pipe lengths between each node were measured using AutoCAD and then drawn in EPANet using the coordinate system to ensure that the measured exact distances were implemented. All measured values can be seen in Table 14 below. PPS also provided data for each building's water demand and the maximum demand value for each building was used to ensure proper demand for each building was achieved. The water demand for each building can be seen in Appendix F.

Table 14: Pipe Lengths for New Watermain

<table>
<tr><th>Building</th><th>Distance Main (m)</th><th colspan="3">Distance to Building (m)</th></tr>
<tr><td>Nicol Hall</td><td>33.16</td><td colspan="3">17.53</td></tr>
<tr><td>Miller Hall</td><td>11.12</td><td colspan="3">18.51</td></tr>
<tr><td>Bruce Wing</td><td>13.13</td><td colspan="3">12.64</td></tr>
<tr><td>Clark Hall</td><td>79.02</td><td>24.67</td><td>90 Degree Bend</td><td>5.42</td></tr>
<tr><td rowspan="2">Jackson Hall & Old Medical Building</td><td>10.35</td><td>13.87</td><td>90 Degree Bend</td><td>4.16</td></tr>
<tr><td></td><td colspan="3">18.35</td></tr>
<tr><td>Theological Hall</td><td>41.28</td><td colspan="3">25.3</td></tr>
<tr><td>Carruthers Hall (Bend)</td><td>56.1</td><td colspan="3">13.43</td></tr>
</table>

The fire demands for the system were also modelled to ensure a functional system during a fire. If a fire hydrant is being used, the system must maintain a pressure of 140 kPa to avoid failure (City of Kingston 2014). The required fire flow can be determined using Equation 3:

$$F = 220C\sqrt{A} \quad \text{(3) (CGI Risk Management Services 1999)}$$

In Equation 3, variable "F" represents the required flow in m^3/s, "C" represents the building type coefficient (C = 1.0 for ordinary construction), and "A" represents the total floor area (in m^2) of the building. When modelling for fire flow, the largest building area was used (Theological Hall = $1330m^2$) to ensure that failure would not occur during the most extreme conditions. It was determined that the required flow for the fire hydrants was 133.7 L/s, as shown in the sample calculations provided in Appendix G below.

8.4.2 Watermain Modelling Results

The following results were attained using the previously described model, where Node 4 was the fire hydrant used to model fire flow.

Standard Flow Model

Using the maximum water demands for buildings, a 24-hr model was created on EPANet. It was found that the pressures were within the acceptable range, with a maximum value of 578.4 kPa and a minimum value of 489.9 KPa over the 24-hr period. Provided in Table 15 and Table 16 below are the results from hour one and hour twelve, which represent the peak and minimum flows, respectively.

Table 15: 1-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	578.4
3	0.33	578.4
4	1.03	578.4
5	1.03	578.4
6	1.03	578.4
7	1.03	578.4
8	0.04	578.4
9	0.05	578.4
10	0.22	578.4
11	0.13	578.4
12	1.03	578.4
13	1.03	578.4
14	0.25	578.4
15	1.03	578.4

Table 16: 12-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	558.8
3	0.33	494.7
4	1.03	473.3
5	1.03	473.5
6	1.03	489.9
7	1.03	490
8	0.04	490.3
9	0.05	574.3
10	0.22	575
11	0.13	491
12	1.03	578.2
13	1.03	578.3
14	0.25	485.3
15	1.03	492.6

The full results over the 24-hr diurnal period can be found in Appendix F below. The results did vary hour-by-hour as the ICI Pattern used by Utilities Kingston was used, as provided in Appendix F below (Utilities Kingston 2017).

Fire Flow Model

The system was modelled for a 3-hour fire using the largest building (Theological Hall) to put the system under the greatest strain possible. It was determined that the pressure stayed within the acceptable range throughout the entirety of the modelling and therefore was acceptable, as shown in Table 17 below.

Table 17: EPANet Fire Flow Pressure Head

Time (Hours)	Demand (LPS)	Pressure (kPa)
0	133.7	473.3
1	133.7	470.3
2	133.7	473.3
3	133.7	476.4

8.5 Recommendations for Sanitary Sewer Upgrades

Existing sanitary sewer conditions include a lack of sewer pipe down 5th Field Company Lane. Almost all of the buildings along 5th Field Company lane are serviced by external connections from trunk mains along Arch St. and University Ave. One of the main sanitary sewer pipes that do cross 5th Field Company Lane is a very old pipe that connects Clark Hall to Arch St. in the east-west direction. The buildings on the eastern side of the street connect to either University Ave. or Union St., almost all of these pipelines are likely in need of replacement due to their age. However, they are beyond the site boundaries thus are out of the scope of this project. Appendix B shows the AutoCAD drawing for the initial sanitary conditions.

8.5.1 Proposed Changes

An analysis of each pipe will need to be conducted to determine whether or replacement is necessary. This can be achieved using newer monitoring technologies, such as CCTV inspection. An ideal sewer pipe layout would consist of mainlines underneath streets/lanes only to simplify access for maintenance and monitoring. For example, a central mainline branching from the trunk main along Union St. can be installed along 5th Field Company Lane to service each building should the client want to include sanitary updates as part of the implementation of this project. The sanitary system changes should be made at the same time as changes are made to other underground systems, should this project go forward to implementation.

8.6 Waste Management Plan

Through consultation with Queen's PPS, it was determined that garbage collection would be centralized to two specific locations, where a series of garbage bins in corrals will be located. A new waste management plan is necessary for 5th Field Company Lane and its surrounding buildings. With the updated layout, it is no longer feasible to maintain the current locations for waste collection. This is partly from a desire to reduce the amount of vehicular traffic on 5th Field Company Lane, along with the current location lacking the required maneuverability that a garbage truck requires.

The first centralized bin location was at the eastern side of Jackson Hall, in the laneway connected to the Arch St. parking lot. The buildings that this location will service include Miller Hall, Bruce Wing, Nicol Hall, Clark Hall, Carruthers Hall, and Old Medical Building. It was determined that one compactor was required at this location. This location was selected because it is a centralized location that optimizes the PPS workers' walking distance. The required maximum distance for PPS workers to travel from the buildings to the garbage collection site was 80m, which is achieved using this location. This can help prevent fewer injuries in the winter due to less time travelled on surfaces that are potentially covered in ice. Placing a compactor within the parking lot makes it much simpler for garbage trucks to maneuver. It is recommended that garbage trucks enter the parking lot early in the morning or late in the evening to empty the waste bins to make it easier to maneuver within the parking lot due to the lack of cars in the parking lot during those times. Corrals will surround the waste collection site to improve the area's aesthetics, limit smells, and limit the potential for vandalism or damage from passers-by and animals. The area required to encompass the garbage bins and compactor was determined to be 55.63 m^2 and was calculated using AutoCAD, as shown in the layout drawing in Appendix D.

The second centralized location along the northeast side of Theological Hall. The garbage bins will be kept in the current location, and it was determined that three bins and one compactor were required in this location. Corrals will also surround this waste collection site, and the required area to be encompassed is determined to be 55.63 $m^{2,}$ as shown in the layout in Appendix D.

8.7 Recommendations for Hot Water Layout

It is recommended that the hot water pipes for the heating system use the same layout as the old steam ducts. However, a more in-depth analysis will be required to make a final decision. However, the most important areas of concern are the tunnels within the site boundaries located along Jackson Hall and stretch from the corner of the building to Fleming Hall. Depending on the tunnels' condition, they may have to be removed entirely, increasing labour costs, and requiring disposal. Another issue with the tunnels' existence is that if the tunnel is not buried deep enough, the new bioswale may intercept it. Another location that also crosses the laneway is the steam pipe layout from Nicol Hall to Miller Hall, which faces the same issues with the tunnels.

Another important consideration that should be accounted for the hot water heating design is the frost cover above the pipes. The risk of pipe freezing is minimal since the pipes carry a heated fluid; however, too little cover could cool the water, reducing the heating system's energy efficiency. This is especially concerning for pipes that will pass under the bioswale, where the frost depth will be lower.

8.8 Design Limitations

Although the proposed design is comprehensive, it still has its limitations. This section details the limitations of the layout design, stormwater management system, and watermain system.

8.8.1 Aboveground Layout Limitations

The final iteration of the design was created based on drawings that date back to when Frost Wing of Gordon Hall was still present on campus. Additionally, there were discrepancies between other drawings, and therefore multiple elements of the layout may need some minor modifications. To ensure that the latest iteration was as feasible as possible, the team used multiple satellite images of the area from different dates from Google Earth Pro.

Another limitation was the lack of access to surveying equipment like a total station and data collector, which could have provided crucial information like ground elevations, grades, and locations of elements absent on the client's CAD drawings. For example, the concrete pad that houses the HVAC of Theological Hall or the alternate entrance to the bookstore was not present on multiple drawings. The COVID-19 Pandemic also limited the number of site visits which could have provided the team with crucial information.

8.8.2 Storm Water Management System Limitations

While the proposed elements of the final SWM design are effective in decreasing the downstream runoff load, their performance is limited by certain considerations to be monitored if implemented. These considerations include:

- ⇒ Maintenance of vegetation to allow for adequate attenuation and infiltration
- ⇒ Maintenance of snow removal on permeable pavers in winter months
- ⇒ Propper snow removal along with curb entrances to the bioswale and bioretention cells
- ⇒ Monitoring of clogging of the underlaying storage layers
- ⇒ Freeze-thaw upheaving of permeable paver layer

The increase in maintenance required for the rejuvenated 5th Field Company Lane is a limitation of the innovative design. While runoff and drainage will be better controlled in the area, the required maintenance will increase Queen's University PPS's workload, thus increasing costs. Finally, the use of LID technology is beneficial for runoff decrease in smaller storms. It is uncommon that LIDs are designed to accommodate rainfall volumes experienced in large storms. The use of these minor systems still allows for the overland site drainage to the underground conveyance systems (at Union St.) currently in place for flood flows.

8.8.3 Watermain System Limitations

While the use of EPANet to model the prosed replacement design for the watermain is effective, it does have some limitations. The first modelling limitation is the constant head reservoir assumed to be 60 m of head at the northern inflow to the model. While this is a feasible assumption for this model, it is not entirely accurate as pressures within the main network that is providing water to the system may fluctuate rather than stay constant at the assumed 60 m of head. The second limitation is that it was assumed that the watermain was held at a constant depth, all as elevation data for the area was not available for use during the analysis. Therefore, changes in invert elevation that will occur along the watermain are not expressed in the model. Due to the addition of the other reservoirs, the velocities and water quality were not modelled due to the model not necessarily being representative of the real system.

9.0 Cost Analysis

Although no budget was put forth by the client, a cost estimation has been determined based on the unit prices for the materials, labour, and consulting work necessary to complete this project. The total cost of the project is $1,191,485.96, as summarized by Table 18 below.

Table 18: Cost Estimate Summary

Component	Cost
Materials	$692,441.96
Labor/Process	$390,544.00
Consulting Work	$108,500.00
Total	$1,191,485.96

A finalized design for the layout of 5th Field Company Lane, along with its SWM and watermain components, allows for a more accurate cost estimation compared to that proposed in the previous *Progress Report*. The final cost analysis shown in Appendix E, summarizes the materials necessary to implement the final design. The cost analysis is organized into six categories, with each broken down into its smaller components. These categories are the laneway, landscaping, social infrastructure, SWM system, watermains, and miscellaneous. Areas, lengths, and volumes were measured using CAD for increased accuracy.

Furthermore, labour analysis in Appendix E summarizes the labour costs associated with the implementation of the project. The costs outlined in this component of the estimation have been simplified based on average salaries and projected time of completion for each design component. While these costs are effective for a tentative estimation, these prices are subject to change based on the unit rates of different contractors. Finally, invoicing summary in Appendix E outlines the *JEMS Consulting Invoice* for works completed through this project's duration.

As part of the Queen's University Campus Master Plan, multiple rehabilitation projects have been completed on campus to date, with multiple projects planned for the future. One comparable project is the *Rehabilitation of Richardson Stadium and West Campus*, which was completed over 2015-2016. This project was completed at a price of $20.27 million and included the football stadium's rehabilitation and its surrounding infrastructure (Queen's Gazette 2014). While this project is much more expensive than the proposed cost for the *Rehabilitation of 5th Field Company Lane*, it shows that Queen's University is willing to spend money to provide updated facilities to improve student well-being. With 5th Field Company Lane being a central part of Main Campus and Richardson Stadium being located on West Campus, completing the *Rehabilitation of 5th Field Company Lane* at this price point is feasible as more students will frequent it daily.

10 Innovation

This section discusses how innovation was applied to the design and approach of the project and potential innovative applications in the future.

10.1 Design and Approach

Given the many stakeholder needs, project requirements, and project goals, there was no conventional or standard design solution readily available. To satisfy all needs, requirements and goals, innovative approaches were taken, and innovative design elements were incorporated into the overall design solution. Some of the innovative designs and approaches which were used to solve the design problem are summarized below.

Evaluation of Layout Design Options – To ensure the best design elements were incorporated into the final design, the three design options were evaluated on a component-by-component basis using an evaluation matrix and based on stakeholder feedback. Each component of each design was evaluated by each group member against the nine project criteria. The final scores were determined by averaging the scores assigned by each group member or by all group members agreeing to a particular score to ensure that all four members' opinions were reflected in the scores. This unconventional approach to formulating the final design resulted in a design that best reflects the stakeholder's needs and the thoughts and opinions of each group member.

Consulting Key Stakeholders – Instead of postulating each project stakeholder's needs, *JEMS Consulting* met with and/or corresponded with multiple key stakeholders to ask about their current and future needs. This is an unconventional approach to establishing stakeholder needs, and the team found it to be helpful when considering design ideas. Additionally, the team consulted a few stakeholders to get their feedback for the 5th Field Company Lane's preliminary aboveground layout. Typically, engineering consultants only ask for feedback from their clients. Still, *JEMS Consulting* decided to ask for the input of a few stakeholders to ensure the design will meet their needs as well.

Maximizing the Useability of the Space – In addition to updating the 5th Field Company Lane layout to serve its intended purpose as a pedestrian pathway, *JEMS Consulting* significantly increased the useability of the space by incorporating social infrastructure in key locations. For example, the alleyway between Clark Hall and Carruthers Hall could have been left as is or upgraded to a redesigned walking path. However, *JEMS Consulting* came up with a more innovative design which transformed the alleyway into a walking path with areas on either side for people to use the space to study, eat and drink, socialize and relax. By maximizing the useability of all areas within the project boundaries, *JEMS Consulting* was able to fulfill stakeholder needs at a much higher level.

Stormwater Management System – Instead of designing a traditional storm sewer system, *JEMS Consulting* created an innovative stormwater management system that uses LID technologies to handle direct runoff from moderate storms. The team's innovative system manages stormwater through the promotion of infiltration, evapotranspiration, and depression storage to reduce direct runoff instead of simply carrying all direct runoff away via gutters, catch basins, and sewers.

10.2 Future Opportunities

Due to the innovative design of the rehabilitated 5th Field Company Lane, there are many marketing, educational, and social opportunities. Figure 41 below highlights some of these opportunities.

Figure 41: Potential Marketing, Educational, and Social Opportunities made possible by the Innovation of the Design

Marketing

- Will be easier to market the project to potential donor due to the useability and aesthetic of the space
- The innovative, sustainable, and aesthetic aspects of the design will help establish the reputation of Queen's University as an environmental leader that fosters innovation.
- Some grants may be available to fund the project due to the sustainability aspects of the design
- This area of campus may sway prospective student to attend Queen's University due to the nice environment and the reflection of the values of the University, which were incorporated into the design

Educational

- Due to the use of LID technology, the design could be used for a field case study project for CIVL 473 Water Resources Systems
- Local schools could take a trip to the area to learn about sustainability, plants etc.
- Students from the School of Environmental Studies and the Biology Department could use the space for educational purposes as well if they would like to study the plants and wildlife
- Some of the gardens could be dedicated to Four Directions, and they could use the space to plant native plants to teach Indigenous students and community members about their culture

Social

- Queen's University clubs and organizations such as Queen's Urban Agriculture Club (SQASH) could use some of the garden spaces for their activities
- Due to the increased useability of the space, events such as live performances and socials could be held in this area of the Queen's Campus
- Due to the nice aesthetics, people may be more likely to take pictures or hold photoshoots in this area
- Having outdoor social infrastructure and grass areas where people can socialize and relax could improve the overall physical and mental health of people
- Clark Hall Pub, The Tea Room and other food outlets could use some garden space to grow fresh herbs, fruits, and vegetables

11.0 Project Management

This section discusses updates in terms of the project's development since the submission of the *Progress Report*. A project analysis that reflects on the progress of the project and the team dynamics is also included. A risk assessment was performed, and the findings are presented as well as some mitigation strategies. The next steps which should be taken by the client and other people who will be involved in the Rehabilitation of 5th Field Company Lane project are also outlined.

11.1 Project Updates

Since the *Progress Report's* submission on November 27th, the team has completed the project as per the scope of work. The required submissions for the project up until the submission of the *Draft Final Report* (as shown in Table 19 below).

Table 19: Key Dates for the Project

Date	Description
November 20th, 2020	Internal Deadline for *Progress Report*
November 27th, 2020	*Progress Report* Due
January 21st, 2020	Internal Deadline for Presentation Slides
January 22nd, 20201	Presentation
March 19th, 20201	Internal Deadline for *Draft Final Report*
March 26th, 2021	*Draft Final Report* Due
March 30th, 2021	Internal Deadline for Final Presentation Slides
March 31st, 2021	Final Presentation Slides Submitted
March 31st, 2021	Final Presentation
April 6th, 2021	Internal Deadline for *Final Report*
April 9th, 2021	Final Report Submitted

The black line separates the deadlines, the key dates from last semester (above the line) and the key dates from this semester (below the line). In terms of project management updates, the following changes have been made to the Work Breakdown Structure, Critical Path, and Gantt Chart.

- ⇒ The Design Creating and Design Optimization phases were combined to make one phase called *Design Modelling and Optimization*. It was found that creating the design was an iterative process that was performed simultaneously as the modelling.
- ⇒ Tasks that mentioned design calculations were updated to reflect the change in scope (no sanitary system design was proposed) to reflect the modelling performed to design and evaluate the watermain and stormwater management systems. These tasks were a big part of the project, so they were separated from one another in the updated *Design Modelling and Optimization* phase.

An updated Work Breakdown Structure, which reflects the changes listed above, can be seen in Appendix H, Figure 46. The significance of each box colour is, as indicated in the Work Breakdown Structure As can be seen, all phases of the project except for the *Design Completion* phase have been completed thus far. Only a few tasks under the *Design Completion* phase must be completed. An updated Critical Path can be seen below in Figure 42. The grey circles are tasks and deliverables which have been completed, the purple circles are tasks that have yet to be completed, and the orange circles are deliverables that have yet to be completed. The length of each arrow correlates to the amount of time the task at the base of the arrow should take.

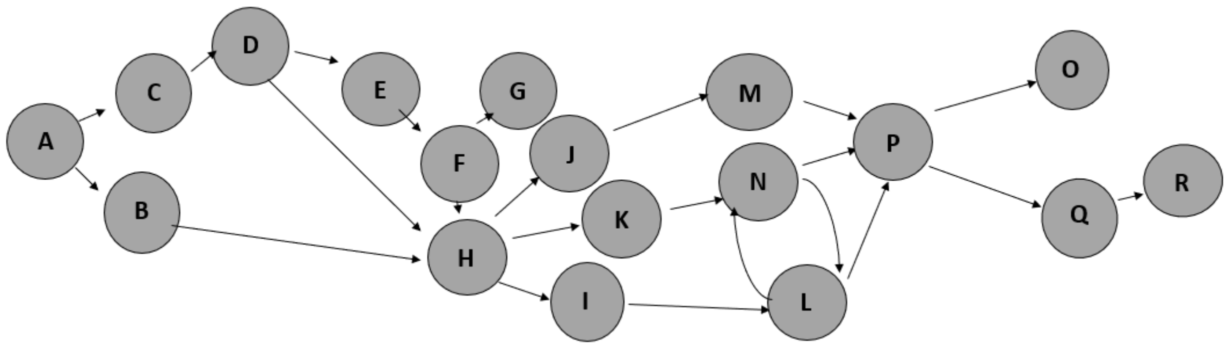


Figure 42: Critical Path of the Project. Deliverables are in Orange, and Tasks are in Purple

Table 20 below shows the tasks associated with each letter in the Critical Path.

Table 20: Tasks Assigned to Each Letter in the Critical Path

Letter	Task	Letter	Task
A	Work Plan	J	Complete watermain modelling and design
B	Speak with key stakeholders	**K**	Devise a plan for waste management
C	Conduct research	**L**	Create AutoCAD drawings for SWM
D	Create three possible design solutions and an approximate cost estimation for each	**M**	Create AutoCAD drawings for watermains
E	Choose design	**N**	Create AutoCAD drawings for layout
F	*Progress Report*	**O**	Final Presentation
G	Deliver presentation	**P**	*Draft Final Report*
H	Share initial design options and final design with the client, key stakeholders and TA and apply feedback to design	**Q**	Make changes to *Draft Final Report*
I	Complete SWM modelling and design	**R**	Submit *Final Report* to the client

The sequence of tasks that have already been completed was updated to reflect the order in which the tasks actually occurred. More arrows were added because the team realized that many tasks could be completed simultaneously. When possible, it is best for the team to be working on more than one task at a time in order to meet deadlines and to avoid schedule setbacks. The Gantt Chart has also been updated and shown in Appendix H.

The items which were completed before the submission of the *Progress Report* appear in first half of the Gantt Chart in Appendix H. The items that were completed after the *Progress Report* and before submitting this report appear in the second half of the Gantt Chart. This part of the Gantt Chart has been updated to reflect the schedule which was actually followed to date. No work was completed after submitting the *Progress Report* until the start of the new semester. Additionally, less work was completed at the beginning of the semester due to a few setbacks. *JEMS Consulting* required some information from the client, and it took a while for them to provide this information. This resulted in fewer days spent on the *Design Modelling and Optimization* and *Design Completion* phases. Furthermore, a few changes in the scope required the team to do additional background research to proceed with the modelling, design calculations, and drawings. The schedule for the remainder of this semester has been updated to reflect some of the changes in the course schedule.

11.2 Project Analysis

JEMS Consulting was successful in working cooperatively and efficiently with minimal conflict. Weekly meetings have continued for the entirety of the semester, with nearly daily discussions in the team group chat. Throughout the project's completion, iterations to the work approach have been made to best suit the stage of the design process. Figure 43 below outlines the typical stages of the engineering design process which were followed in this project.

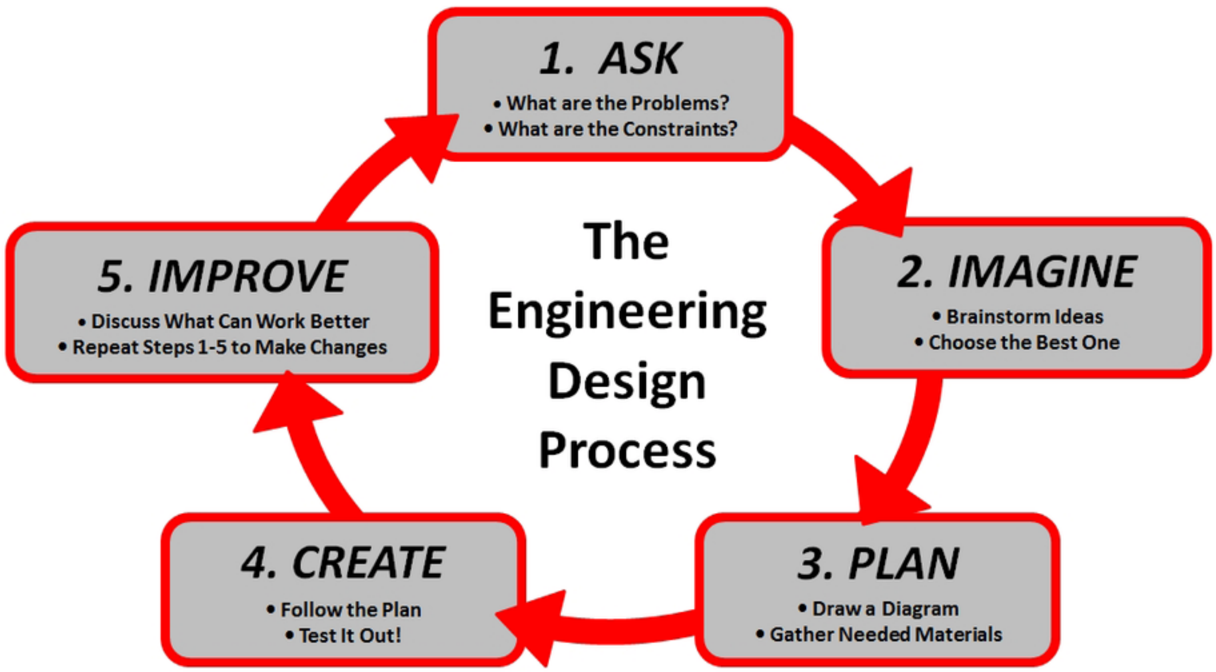


Figure 43: The Engineering Design Process (Queen's University, 2020)

To optimize team performance at each design stage, iterations of work distributions and collaboration were made. In the *Ask* and *Imagine* stages of the project, *JEMS Consulting* focused efforts on internal meetings, along with client and stakeholder meetings. Using the ideas put forth in these meetings, *JEMS Consulting* further distributed work to each individual during the *Plan* stage to enhance these ideas, build knowledge of the project requirements, and propose solutions for evaluation. For example, the three design ideas shown in Section 5 were proposed individually, so that idea generation was unaffected by other team members' bias. Combining the ideas generated in the *Plan* stage, *JEMS Consulting* came together once again to *Create* a final solution best suited for the project requirements. While a proposed design was decided upon, the design process did not stop. Constant iterations were made in the *Improve* stage combined with feedback from clients, stakeholders, TA's, and group members. Changes in SWM components, garbage bin locations, and material use are just a few examples of the improvements made throughout the project.

The current Covid-19 Pandemic limited the team's efficiency throughout the project since all work and meetings were conducted digitally. The team had to work with unreliable internet connections and limited cloud networking to share information. However, team leadership and communication were important contributors that allowed group success to be achieved in this project. Since the beginning of the project, group expectations have been appropriately communicated, and the importance of meeting deadlines was stressed to each member. Due to this, each deadline put forward in the Gantt Chart shown in Appendix H was met. Iterations to the Gantt Chart were made as outlined in Section 11.1 due to setbacks unforeseen by the team. However, the team was able to work past these setbacks and complete more work in the back half of the semester, meeting the final deadline. Overall, project progress was continuous, and *JEMS Consulting* was able to put time into the research and development of each component of interest for the design.

11.3 Risk Assessment

There are many risks associated with the implementation of this project, all with varying probabilities and severities. Nine categories of risks were identified, including safety, lack of funding, going over budget, the design being not well received, unforeseen circumstances, long construction time, design not functioning as intended, property damage and the project being shelved. A risk assessment matrix (as shown in Appendix H) was used to evaluate each risk category based on the probability and severity of each category's risks. Table 21 below shows the risk categories, the risk assessment classifications, specific risks, and some mitigation strategies.

Table 21: Risks Associated with the Project and Mitigation Strategies

Category & Classification	Risks	Mitigation Strategies
Safety – low medium to medium-high risk	• A worker could be injured while working on the job site. • If the job site is not secured correctly, a member of the public could be injured. • Some elements of the design could be unsafe.	• Follow all safety requirements related to personal protective equipment, processes and ensuring a secure and safe job site. • Thoroughly analyze all design elements to ensure there are little to no safety risks associated with them.
Lack of Funding – low medium to medium risk	• People may not be interested in donating money to the project. • Due to Covid-19, fewer people may have money to donate, and the University may have less money to spend on projects.	• Do an excellent job of marketing the project to get people and organizations to donate. • Add some elements which would motivate people to donate. For example, plaques with people's names on them. • Apply for funding and grants for sustainable and innovative projects.
Going over budget – low medium to medium-high risk	• Some materials or processes may cost more than initially estimated, especially if this project is implemented many years after this report is submitted.	• Do a thorough cost analysis so an accurate budget can be estimated in the first place. • Phase the project with the most important elements being implemented first so that if money does run out, most or all major.

	• Unforeseen circumstances or other delays could lead to additional costs.	elements of the design are already constructed. • Set aside additional funding as a buffer in case the project does go over budget.
Design is not well Received – low to medium risk	• The design may not be well received by the people who approve projects at Queen's University, and the public. • If part of the funding will come from student tuition fees, some students may be opposed to funding the project.	• Get feedback from the public and other stakeholders. • Make changes to the design where appropriate based on feedback from stakeholders and the public before an engineering consulting firm is hired. • Market the design to get people to see the value the project will bring to the Queen's University Campus.
Unforeseen Circumstances – low medium to high risk	• There could be several unforeseen circumstances related to the existing conditions, constructing the design and/or getting the required materials. For example, there could be some infrastructure in the ground that is not recorded on the drawings.	• Do thorough assessments of the existing conditions to avoid missing any unforeseen conditions. • Research into where a contractor could source some of the required materials before tendering the project. • Do some detailed feasibility studies to ensure all elements of the design can be feasibly constructed.
Long Construction Time – low medium to high risk	• Even if the project is phased, the construction of the design could take longer than planned due to setbacks caused by unforeseen issues. • Long construction time could inhibit the flow of traffic if the project runs into the semester.	• Be conservative when estimating how long certain phases of the construction will take and leave some time buffers where appropriate. • Ensure the contractor has a comprehensive, reasonable and detailed schedule before construction.
Design not Functioning as Intended – low medium to medium-high risk	• There are no standards for the design of LID technologies. • Some design elements may not work as intended due to the design itself as well as poor workmanship.	• Additional modelling must be performed to verify that all design elements will function as intended. Quality inspections should be performed to ensure good workmanship.
Property Damage – medium to medium-high risk	• During construction, some of the existing infrastructure, trees and or plants could be damaged due to poor workmanship and/or accidents. • Post-construction, there is a risk that some elements of the design could be damaged, vandalized and/or stolen.	• Ensure the contractor takes the necessary precautions to protect the existing infrastructure, plants and trees. • When tendering the project, ensure there are specifications related to the preservation of the existing infrastructure, trees and plants. • To minimize damage, vandalism and theft post-construction, Queen's University

		should ensure that adequate security measures are taken and that elements are adequately anchored (when appropriate) to prevent theft.
The Project is Shelved – low to medium risk	• If the University decided that this project is not needed, not urgent, too complicated, too expensive or if there is not enough funding, it might not be implemented.	• Make sure the project proposal is clear, thorough and broken down into manageable phases. • Market the project to the University and show them the value the project would bring to the campus and the University.

11.4 Next Steps

With the proposed design for the *Rehabilitation of 5th Field Company Lane Project*, many steps must be taken to move forward. There are four main areas that must now be focused on performing additional studies, addressing items outside of this project's scope of work, project planning, and marketing and fundraising for the project. Details of these next steps are provided in Figure 44 below.

Figure 44: Next Steps for Project

1

Additional Studies

- Properly survey the area to get elevation data
- Perform an Environmental Assessment (EA)
- Perform studies to see how the new design would impact traffic flow and the functionality of the area
- Redo EPANet modelling with a more realistic system and analyze water velocities and water quality
- Get additional stakeholder feedback
- Perform geotechnical studies of the ground conditions
- Perform SWMM modelling with back to back storms
- Assess the current condition of sanitary, gas, communication and electrical infrastructure

2

Addressing Items Outside of the Scope of Work

- Design the layout to manage higher return period storms
- Design an updated sanitary sewer system
- Design hot water system
- Upgrade gas, communication, and electrical infrastructure as needed
- Get feedback about the proposed design from students, faculty and community members
- Reach out to the City of Kingston to talk about potentially adding the laneway to the cycling network
- Students and faculty can perform studies for this project which were not done by *JEMS Consulting*

3

Project Planning

- Present this design to required people at the Queen's University Office of Planning and Budget
- If Approved, get a liscenced engineer/ engineering firm to create drawings and specs for the design
- Break up the project implementation into manageable phases
- Plan what statues, plaques, sculptures, learning tools, aknowledgements etc. will be included and where to include them
- Pick which specific plants and trees will be included
- Create a more detailed cost estimate, a budget and a funding plan
- Select social infrastructure pieces

4

Marketing and Fundraising

- Show everyone the value in taking on this project, especially students who may fund the project with some of their tuition, and potential donors
- Apply for project grants
- Ask for donations from Queen's Allumni and other organizations
- Reach out to some clubs and orgnaizations to see if they would be inerested in using some of the space for their activities

After completing these four steps, the project can be tendered, and construction can begin. It should be noted that it will likely take many years for all items listed in Figure 44 to be completed. Additionally, many items can be completed at the same time as others.

12.0 Conclusion

Although *JEMS Consulting* has completed the *Rehabilitation of 5th Field Company Lane Project* as per the defined scope of work, there is still work that needs to be done before the project can be implemented. *JEMS Consulting* has provided an innovative design for the area as set out in the problem definition. The design meets the project goals, criteria, and requirements as well as the stakeholder needs and CIVL 460 course requirements. It complies with design requirements and considers several different environmental, social and economic factors. The main design elements, along with a brief summary, are listed below.

- ⇒ **5th Field Company Layout:** The stakeholder needs were the main influencing factor of the aboveground layout. It has improved pathway connectivity, aesthetics, and useability due to the incorporation of better pathway layouts, green space, social infrastructure, and aesthetic elements.
- ⇒ **Arch St. Parking Lot Entrance:** Redesigned to be a functional entrance and exit to the parking lot.
- ⇒ **SWM System:** *JEMS Consulting* proposes an innovative way to manage stormwater through the use of LID technology. The modelling results from SWMM 5.1 showed that there was up to a 66% reduction in direct runoff with this system for the different storms modelled. The new SWM system design is effective in increasing storage and infiltration of runoff on-site, thus decreasing the loads on the downstream collection system.
- ⇒ **Watermain System:** A new centralized water main system to service the buildings along the lane was also designed to better serve the present and future domestic water needs. The modelling results for a 24-hour time period found that the proposed system showed acceptable pressures under both normal and fire flow conditions.
- ⇒ **Waste Collection Plan:** Eliminated the need for garbage trucks to use the redesigned laneway. There are two collection locations; one is to the east of Jackson Hall, and the other is on the north-east side of Theological Hall beside the turnaround point.
- ⇒ **Recommendations for Sanitary System Upgrades:** JEMS Consulting recommends that many pipes be replaced and relocated for a more modern, localized system. This would reduce the need for repairs in the future, and should repairs be required, they would be easier to complete.
- ⇒ **Hot Water System Layout:** *JEMS Consulting* recommends that a layout similar to the existing steam system be used.

The overall cost of the design is $1,191,485.96. Although the project did not go as planned from a project management perspective due to setbacks, working remotely, and changes to the scope of work, *JEMS Consulting* still worked cooperatively and efficiently on the project to produce an innovative design solution. Moving forward, *JEMS Consulting* will not be working on this project anymore, aside from delivering a final presentation as part of the CIVL 460 requirements. However, the team has proposed some next steps for the client as they continue to work on the project.

13.0 References

All Ontario. (2019). “11 Surprising Facts About Trillium.” <https://allontario.ca/11-surprising-facts-about-trillium/> (February 1, 2021).

Balogh, A. (n.d.). “The Best Perennials for Pollinators.” <https://www.gardendesign.com/perennials/pollinators.html> (February 1, 2021).

Barco Products Canada. (2019a). “Commercial Outdoor Benches & Park Benches for Sale.” <https://www.barcoproducts.ca/outdoor-furniture/tables-seating/park-benches> (Nov. 24, 2020).

Barco Products Canada. (2019b). “Commercial Outdoor Picnic Tables & Sets for Sale.” <https://www.barcoproducts.ca/outdoor-furniture/tables-seating/picnic-tables> (Nov. 20, 2020).

Bayridge Landscaping. (2021). “Landscaping Products.” <https://www.bayridgelandscaping.com/landscaping-products/> (Mar. 17, 2021).

CGI Risk Management Services. (1999). “Water Supply for Public Fire Protection - 1999 Edition.” *SCM-RMS*, CGI Risk Management Services, <http://www.scm-rms.ca/docs/Fire%20Underwriters%20Survey%20-%201999%20Water%20Supply%20for%20Public%20Fire%20Protection.pdf> (Mar. 21, 2021).

Chow, V. T. (1959). Open Channel Hydraulics, <https://heidarpour.iut.ac.ir/sites/heidarpour.iut.ac.ir/files/u32/open-chow.pdf> (Mar 3, 2021).

City of Kingston. (2014). “Subdivision Development Guidelines & Technical Standards - City of Kingston.” <https://www.cityofkingston.ca/documents/10180/26367/Subdivision+Development+Guidelines+Tech+Standards/cefab4e3-ff81-4866-803b-6e04145efd4d> (Nov. 20, 2020).

City of Kingston. (2018). “Kingston By-Law Number 2018-15.” <https://www.cityofkingston.ca/documents/10180/16904/Tree+Bylaw> (Nov. 20, 2020).

City of Kingston. (2021). “Walk ‘n’ Roll Technical Appendix H.” <https://www.cityofkingston.ca/city-hall/projects-construction/archived-projects/walk-roll-kingston/phases> (Nov. 23, 2021).

Climate Central. (2019). “POURING IT ON: How Climate Change Intensifies Heavy Rain Events” <https://www.climatecentral.org/news/report-pouring-it-on-climate-change-intensifies-heavy-rain-events> (Feb 1, 2021).

Concast Pipe. (2020). “2020 Concast Pipe Price List” <http://www.concastpipe.com/wp-content/uploads/2020/01/2020-Con-Cast-Pipe-Price-List-Complete.pdf> (March 23, 2021).

Connon Nurseries. (2020). “Plant & Product Pricing.” <https://connon.ca/plants-list/> (Mar. 17, 2020).

Credit Valley Conservation. (2011). “Low Impact Development Stormwater Management Planning and Design Guide.” <https://cvc.ca/low-impact-development/low-impact-development-support/stormwater-management-lid-guidance-documents/low-impact-development-stormwater-management-planning-and-design-guide/> (Mar 4, 2021).

Deeproot. (2010). “Deep Root’s Legacy Products: What Is A Root Barrier?” <https://www.deeproot.com/blog/blog-entries/deep-roots-legacy-products-what-is-a-root-barrier#:~:text=Root%20Barriers%20are%20patented%20mechanical,and%20beauty%20of%20mature%20trees.&text=They%20are%20used%20for%20linear,new%20plantings%20and%20existing%20trees.> (Mar. 22, 2021).

Dufferin Concrete. (2019). “2019 Price List Dufferin Concrete East District.” <https://www.dufferinconcrete.ca/wp-content/uploads/2020/02/DC-East-District-2019-price-list.pdf> (Nov. 23, 2020).

Earthco (G&L). (2019). “2019 Price List Earthco Soil Mixtures.” <https://www.earthcosoils.com/media/Earthco-Prices-2019.pdf> (Nov. 23, 2020).

Queen’s University. (2020). “CIVL 460 – Course Introduction – F2020 – Slides.” <https://onq.queensu.ca/d2l/le/content/433781/viewContent/2613590/View> (March 20, 2021).

Farrington, D. P., and Welsh, B. C. (2002). “Effects of improved street lighting on crime: a systematic review.” 61.

Filion, Y. (2021). ‘In-Person Interview.’

Gardenia. (n.d.). “White Oak.” <https://www.gardenia.net/plant/quercus-alba> (February 1, 2021).

Geotech Data. (2013). “Soil Permeability Coefficient.” <https://www.geotechdata.info/parameter/permeability> (Mar 4, 2021).

Global Trash Solutions. (2021). “Trash Compactor.” <https://globaltrashsolutions.com/product-category/compactor/?campaign=764855517&keyword=%2Bwaste%20%2Bmanagement%20%2Bcompactor&gclid=CjwKCAjw9MuCBhBUEiwAbDZ-7kPtP8TW3Qkb1olzHpebz-_lkfLcAzkMQ856iw0DQuRGUi3g8nttNBoCpW4QAvD_BwE&fbclid=IwAR2oB3a0cM2DWf8nQgJE4V905_V4xVrm5XjMXs1tyfCPELXkdqSiROawP2w> (March 23, 2021).

Google Maps. (2021). “5th Field Company Lane.” <https://www.google.com/maps/place/5+Field+Company+Ln,+Kingston,+ON/@44.2268475,-76.4969439,540m/data=!3m2!1e3!4b1!4m5!3m4!1s0x4cd2ab03791d06f7:0xd99282a98f59f63e!8m2!3d44.2268475!4d-76.4947552> (March 1, 2021).

Government of Ontario. (2014). “O. Reg 413/12.” *Ontario.ca*, <https://www.ontario.ca/laws/view> (Nov. 20, 2020).
HGTV. (n.d.). “The importance of Pollination.”

<https://www.hgtv.ca/outdoors/photos/10-gorgeous-pollinator-friendly-flowers-for-your-garden-1918772/#currentSlide=1> (February 1, 2021).

Government of Ontario. (2021). “The Tree Atlas.” <https://www.ontario.ca/environment-and-energy/tree-atlas/ontario-southeast/6E-15/6E-15> (February 1, 2021).

Homeguide. (2020). “2020 Driveway Paving Cost Guide (Concrete, Asphalt, Gravel, Heated...).” <https://homeguide.com/costs/driveway-paving-cost> (Nov. 23, 2020).

Indeed. (2021). “How much does a Pipelayer in Ontario Make?” <https://ca.indeed.com/career/pipelayer/salaries/Ontario> (Mar 17, 2021).

Ingebrigsten, M. Nimmrichter, P. (2017). “Planning for Extreme Precipitation.” <http://www.climateontario.ca/doc/RACIII/OCCIAR_Webinar_2017March22.pdf> (Mar 23, 2021).

Lui, J., Xin, X., and Zhou, Q. (2018). “Phytoremediation of contaminated soils using ornamental plants.” *Environmental Reviews,* 26(1).

Manotick Gardens & Landscaping Supplies. (2020). “Landscape Construction Ottawa | Gravel & Sand | Manotick Gardens & Landscaping Supplies.” <https://www.manotickgardens.com/landscaping-supplies--prices/gravel--sand> (Nov. 23, 2020).

Master Gardeners of Northern Virginia. (2018). “Little Bluestem.” <https://mgnv.org/plants/grasses/bluestem/schizachyrium_scoparium_in_landscape-3_aug-elm/> (February 1, 2021).

Ministry of Transportation of Ontario. (2000). “OTM-Book-5.pdf.” <https://inps.net/graphics/sites/default/files/pdf/MTO-Book-5.pdf> (Nov. 20, 2020).

Moeur, R. C. (2021). “Costs of Traffic Signs.” <http://www.trafficsign.us/signcost.html> (Mar. 17, 2021).

Municipality of Smiths Falls. (2019). “Smith’s Falls RFQ Supply of Asphalt Patching Services Contract # 19-PW-003.” <https://www.smithsfalls.ca/media/2019/03/Summary-Sheet-19-PW-003.pdf> (Nov. 20, 2020).

Natural Resources Conservation Service. (n.d.). “Rain Gardens.” <https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_007154.pdf> (Mar 5, 2021).

Natural Resources Conservation Service. (n.d.). “Soil Infiltration.” <https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053268.pdf> (Mar 5, 2021).

Not So Hollow Farm. (n.d.) “Five Native Berry-Producing Trees and Shrubs for Birds.” <https://notsohollowfarm.ca/five-native-berry-producing-trees-shrubs-birds/> (February 1, 2021).

Ontario Contractors. (2020). “Renovation and Building Costs.” <http://www.ontariocontractors.com/costs.htm> (Nov. 23, 2020).

Ontario Native Plants. (2021). “Wildflowers.”
<https://onplants.ca/product-category/wildflowers/> (February 1, 2021).

Ontario Society of Professional Engineers (2012). “Fee Guideline.”
<https://www.ospe.on.ca/public/documents/general/2012-fee-guideline.pdf> (Mar. 17, 2021).

Payscale. (2020a). “Masonry Contractor Hourly Rate in Canada.”
<https://www.payscale.com/research/CA/Industry=Masonry_Contractor/Hourly_Rate> (Nov. 24, 2020).

Payscale. (2020b). “Asphalt Paver Operator Hourly Pay.”
<https://www.payscale.com/research/US/Job=Asphalt_Paver_Operator/Hourly_Rate> (Nov. 24, 2020).

Purdue University. (2000). “Television and Fiber Optics.”
<https://engineering.purdue.edu/Intsect/carmel_ints/pa_116/tv_fo1.htm> (Nov. 23, 2020).

Queen’s Gazzette. (2014). “Board Approves Stadium Revitalization.”
<https://www.queensu.ca/gazette/stories/board-approves-stadium-revitalization#:~:text=Queen's%20Board%20of%20Trustees%20has,a%20cost%20of%20%2420.27%20million.> (March 24, 2021).

Queen’s Journal. (2012). “Engineering jacket slam 2012.” *The Journal*,
<https://www.queensjournal.ca/gallery/2012-12-14/jacketslam2012/> (Nov. 25, 2020).

Queen’s PPS. (2017). “Main West Campus Sanitary Storm Final Submission.”
Report # 208-1-13_2017-04-24.

Queen’s University. (2010). “Historic Streets of Queen’s.”
<https://www.queensu.ca/campusmap/sites/default/files/assets/campusmap/QU_map_historicstreets.pdf> (October 1, 2020).

Queen’s University. (2016). “Queen’s University Climate Action Plan.”
<https://www.queensu.ca/principal/sites/webpublish.queensu.ca.opvcwww/files/files/15-0406%20Climate%20Action%20Plan_accessible.pdf> (Sep. 28, 2020).

Queen’s University. (2017). “Main West Campus Sanitary Storm Final Submission.”

Queen’s University. (2019a). “Division 26 00 00 Electrical - Queen’s University Standards.”
<https://www.queensu.ca/pps/sites/webpublish.queensu.ca.ppswww/files/files/1-%2026%2050%2000%20Lighting%20Final%2004-24-19.pdf> (Nov. 20, 2020).

Queen’s University. (2019b). “Queen’s University Facilities Accessibility Design Standards.”
<https://www.queensu.ca/pps/sites/webpublish.queensu.ca.ppswww/files/files/QFADS%20Final%2004-09-2019.pdf> (February 10, 2021).

Queen’s University. (2020). “Theological Hall | Queen’s Encyclopedia.”
<https://www.queensu.ca/encyclopedia/t/theological-hall> (Sep. 28, 2020).

Quinlan, C. (2005). “A Landowners Guide to Tallgrass Prairie and Savannah Management in Ontario.” < https://tallgrassontario.org/wp-site/wp-content/uploads/2018/07/LandownersGuide2005.pdf> (February 1, 2021).

Reed, D. (2018). “Montgomery Residents are Fighting Plans to Build Rain Gardens.” <https://ggwash.org/view/67222/montgomery-residents-are-fighting-plans-to-build-rain-gardens> (Mar 8, 2021).

Roach, B. (n.d.). “Efficient by Design.” <http://ccag-eh.ucanr.edu/files/241439.pdf> (February 1, 2021).

Road Authority. (2016). “OPSS MUNI 353 Concrete Curb and Gutter Systems.” <http://www.roadauthority.com/Standards/?id=5f3fd08c-5543-4f2b-a531-63d0351bbf35> (Nov. 25, 2020).

Road Authority. (2017a). “OPSS 3423 Steel Poles, Base Mounting.” *Standards*, <http://www.roadauthority.com/Standards/?id=7515a241-7ed9-4b5b-b9d2-691a176fa6c9> (Nov. 20, 2020).

Road Authority. (2017b). “OPSS 310 Hot Mix Asphalt.” <http://www.roadauthority.com/Standards/?id=5f3fd08c-5543-4f2b-a531-63d0351bbf35> (Nov. 20, 2020).

Road Authority. (2019). “OPSS 351 Concrete Sidewalk.” <http://www.roadauthority.com/Standards/?id=34367b22-5a9e-4936-8209-fba892bbd539> (Nov. 20, 2020).

Rossman, L. A. (2015). “Storm Water Management Model User’s Manual Version 5.” <https://www.epa.gov/sites/production/files/2019-02/documents/epaswmm5_1_manual_master_8-2-15.pdf> (Mar 3, 2021).

Seneviratne, S. I., Nicholls, N., Easterling, D., Goodess, C. M., Kanae, S., Kossin, J., Luo, Y., Marengo, J., McInnes, K., Rahimi, M., Reichstein, M., Sorteberg, A., Vera, C., Zhang, X., Rusticucci, M., Semenov, V., Alexander, L. V., Allen, S., Benito, G., Cavazos, T., Clague, J., Conway, D., Della-Marta, P. M., Gerber, M., Gong, S., Goswami, B. N., Hemer, M., Huggel, C., van den Hurk, B., Kharin, V. V., Kitoh, A., Tank, A. M. G. K., Li, G., Mason, S., McGuire, W., van Oldenborgh, G. J., Orlowsky, B., Smith, S., Thiaw, W., Velegrakis, A., Yiou, P., Zhang, T., Zhou, T., and Zwiers, F. W. (2012). “Changes in Climate Extremes and their Impacts on the Natural Physical Environment.” *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, C. B. Field, V. Barros, T. F. Stocker, and Q. Dahe, eds., Cambridge University Press, Cambridge, 109–230.

Stantec. (2017). “Square One Drive Extension Municipal Class Environmental Assessment.” <http://www7.mississauga.ca/documents/TW/sqone-dr-ea/Appendix_N_Cost_Estimate.pdf> (Mar. 17, 2021).

Sustainable Technologies Evaluation Program. (2016). “University of Toronto Scarborough Campus Case Study.” <https://sustainabletechnologies.ca/app/uploads/2015/07/U-of-T-Scarborough.pdf> (Feb 1, 2021).

TIP of the MITT Watershed Council. (n.d.). “Bioswale.”
<https://www.watershedcouncil.org/bioswale.html> (Feb 1, 2021).

Toronto and Region Conservation Authority. (2020). “Low Impact Development.”
<https://trca.ca/conservation/restoration/low-impact-development/> (Feb 1, 2021).

Urban Strategies Inc. (2014). “Queens CMP Executive Summary.”
<https://www.queensu.ca/sites/default/files/assets/pages/strategicframework/cmp/Queens-CMP-Executive-Summary.pdf> (Sep. 29, 2020).

Utilities Kingston. (2017). “City of Kingston Water Master Plan Updates.”
<https://utilitieskingston.com/Cms_Data/Contents/UtilitiesKingston/Media/Documents/Projects/MasterPlans2015/FinalDocuments/Appendix-J-Water-Model-Calibration-Report.pdf> (March 1, 2021).

Wikimedia Commons. (2020). “Malabar Melastome.”
<https://commons.wikimedia.org/wiki/File:Malabar_Melastome_(Melastoma_malabathricum)_(15706435289).jpg> (February 1, 2021).

1800 Sweeper. (n.d.). “BMPs for cleaning Porous Pavement.”
<https://www.1800sweeper.com/sweeper-blog/porous-pavement-cleaning/bmps-for-cleaning-porous-pavement> (Feb 1, 2021).

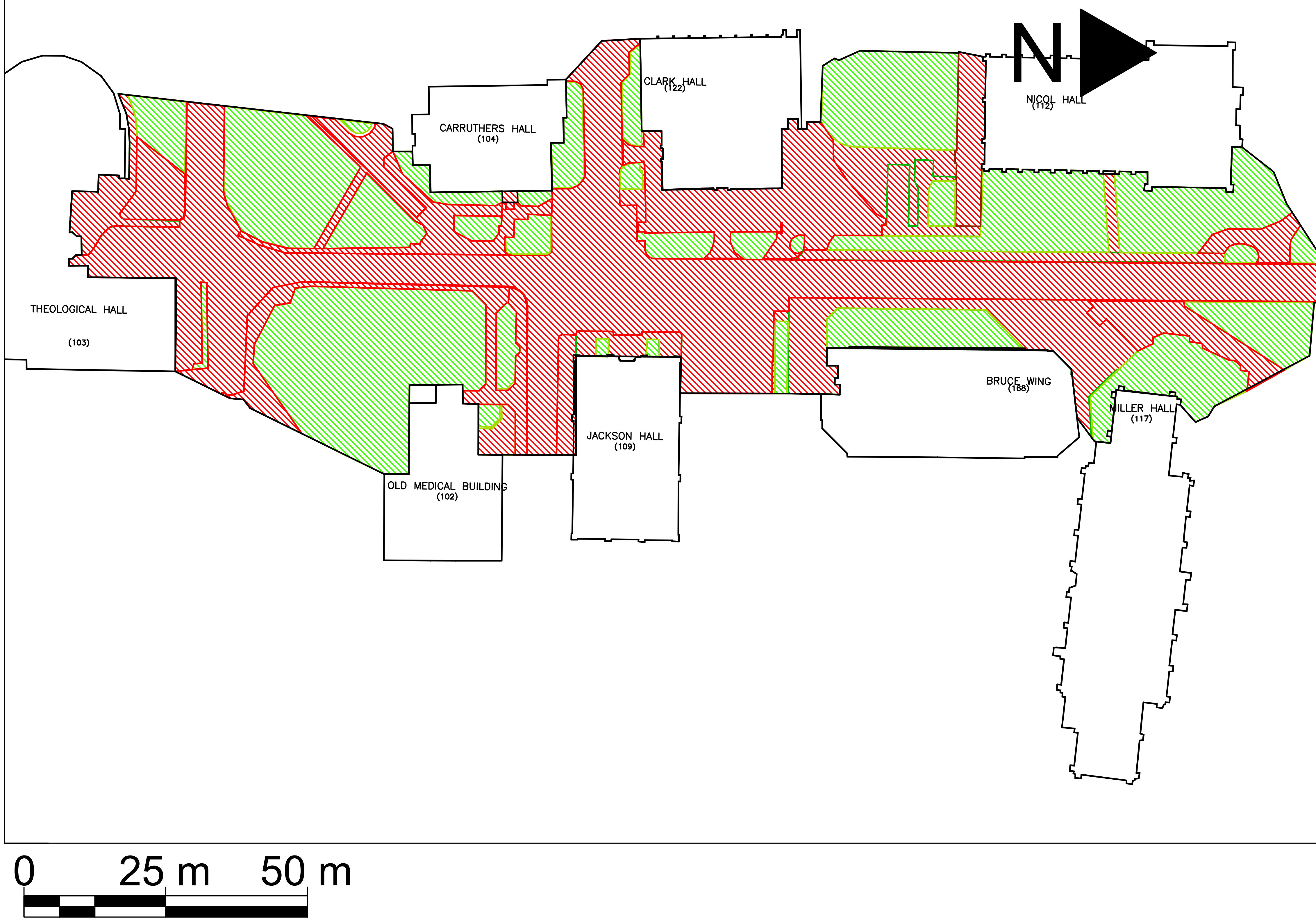
Appendix A – Design Drawing Summary

The following table summarizes the drawings attached within the appendices of this report.

Drawing Number	Description
1	SWMM Analysis Layer Delineation: Existing Conditions
2	Existing Watermain Pipes to be Removed
3	General Layout of the New Lane
4	Miller Hall Free Space
5	Jackson Hall Free Space
6	Clark Hall Free Space
7	Clark Hall Alleyway
8	Arch St. Parking Lot
9	Jackson Hall Alleyway
10	Old Medical Building Free Space
11	Turnaround Point
12	Road Section of Union St. Entrance
13	Midway Road Section
14	Road Section at Turnaround Point
15	Typical Road Cross-section (1)
16	Typical Road Cross-section (2)
17	Arch St. Parking Lot Entrance
18	Arch St. Parking Lot Entrance Details
19	Waste Bin Corral Details
20	Parking Dimensions for Accessibility Spaces
21	SWMM Analysis Layer Delineation: Final Conditions
22	SWMM Analysis Layer Delineation (1)
23	SWMM Analysis Layer Delineation (2)
24	SWMM Analysis Layer Delineation (3)
25	SWMM Analysis Layer Delineation (4)
26	SWMM Analysis Layer Delineation (5)
27	SWMM Analysis Layer Delineation (6)
28	SWMM Analysis Elements Detail Drawing
29	Drainage Layout for Catch-basins in Turnaround Point
30	New Watermain Layout

Appendix B – Existing Conditions CAD Drawing

PROJECT: 5TH FIELD COMPANY LANE REDESIGN



LEGEND:

- INFILTRATION REGIONS:
- IMPERVIOUS REGIONS:
- BIOSWALE OR POND:
- PAVERS:
- SWMM ANALYSIS BOUNDARY:

DRAWING: 1

SWMM ANALYSIS LAYER DELINEATION: WHOLE SITE OF EXISTING CONDITIONS

DRAFTER(S):

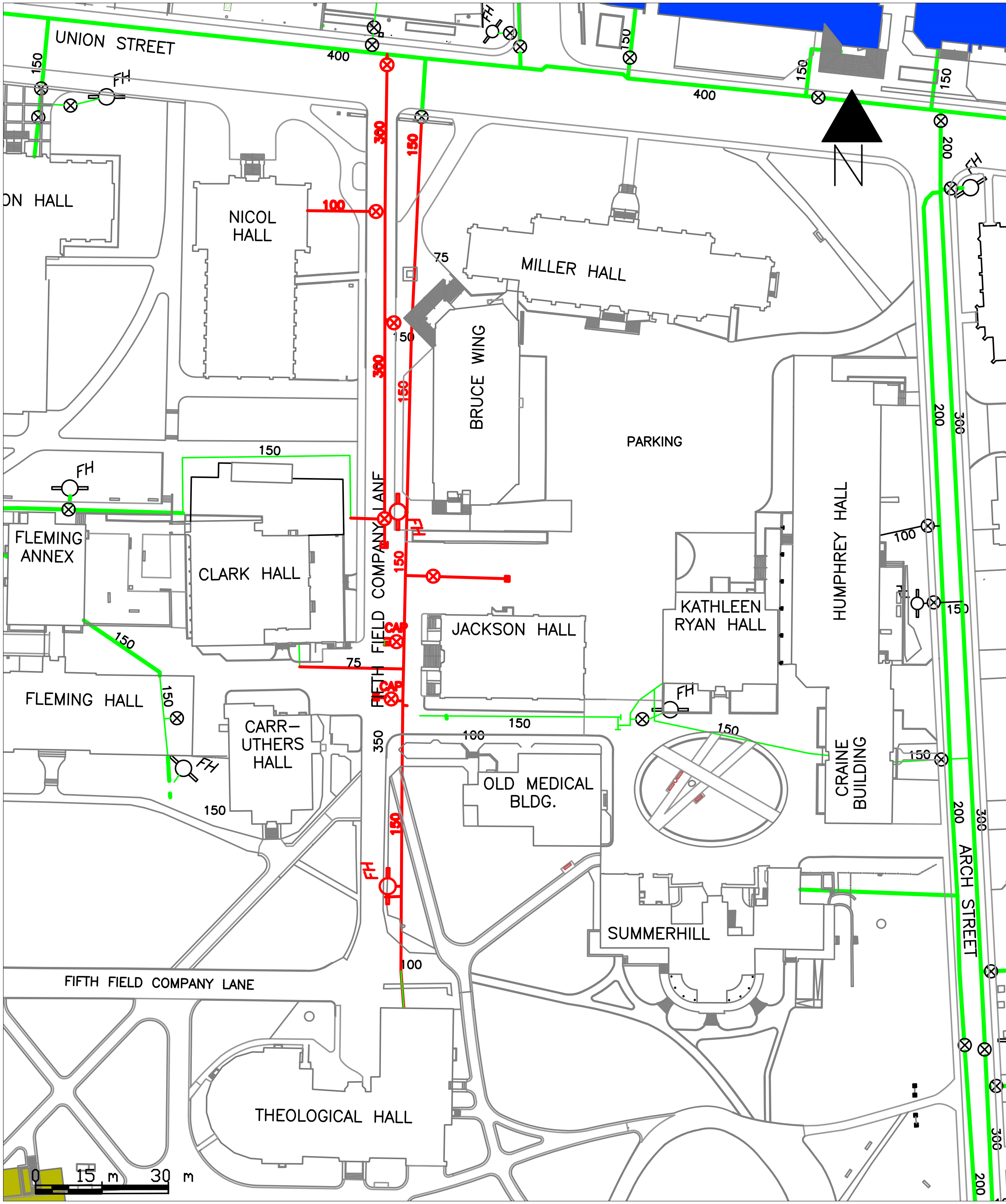
- JEAN-SEBASTIEN YOUNG

SCALE: NOT TO SCALE

NOTES:

THESE DRAWINGS ARE ONLY FOR DELINEATING DIFFERENT REGIONS ANALYZED BY THE SWMM MODELING SOFTWARE

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND

⊗	WATER VALVE
FH	FIRE HYDRANT
⊗	NEW WATER VALVE
FH	NEW FIRE HYDRANT
⊕ WM	WATER METER
△ STP	SIAMESE CONNECTION (STAND PIPE)
▲ SPR	SIAMESE CONNECTION (SPRINKLER)
	WATER MAIN
	WATER MAIN ABANDONED
	NEW WATER MAIN
	PIPE FOR REMOVAL
⊗	WATER VALVE FOR REMOVAL
FH	FIRE HYDRANT FOR REMOVAL

DRAWING: 2

EXISTING PIPES TO BE REMOVED

DRAFTER(S):
- PPS STAFF

MODIFIED BY
- JEAN-SEBASTIEN YOUNG

SCALE: NOT TO SCALE

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS

Appendix C – Design Evaluation

Table 22: Evaluation Rubric Used in the Analysis of the Design Options.

Criteria	1	2	3	4	5
Stakeholder Needs	The design satisfies little to none of the stakeholder needs.	The design satisfies some of the stakeholder needs.	The design satisfies many of the stakeholder needs.	The design satisfies most of the stakeholder needs.	The design fully satisfies the stakeholder needs
Sustainability	The design is not at all sustainable. No sustainable options were considered.	The design is somewhat sustainable. Sustainable alternatives were used a few times.	The design is sustainable. Sustainable alternatives were used many times.	The design is very sustainable. Sustainable alternatives were used most of the time.	The design is highly sustainable. Sustainable alternatives were used whenever possible.
Aesthetics	The design is not at all aesthetic and does not match the rest of the campus.	The design is not aesthetic but matches the rest of the campus or vice versa.	The design is somewhat aesthetic and matches the rest of the campus	The design is aesthetic and matches the rest of the campus.	The design is very aesthetic and flows perfectly with the rest of the campus.
Innovation	The design is not innovative at all.	The design is not really innovative.	The design is somewhat innovative.	The design is innovative.	The design is very innovative and is unlike anything seen before.
Social Infrastructure	Little to no social infrastructure was incorporated into the design.	A few pieces of social infrastructure were incorporated into the design.	Some social infrastructure was incorporated into the design.	Much social infrastructure was incorporated into the design.	A great deal of social infrastructure was incorporated into the design.
Maintenance	The design will require a great deal of maintenance, and components are not easily fixed nor replaced.	The design will require a lot of maintenance, but components can be fixed or replaced with some ease.	The design will require some maintenance, but components can be fixed or replaced with some ease.	The design will not require much maintenance and components can easily be fixed or replaced.	The design will require little to no maintenance and components can easily be fixed or replaced.
Cost	Too expensive. The design is not economically feasible, and most costs are not justifiable.	Costly. The design is somewhat economically feasible, but many costs are still not justifiable.	Economic. The design has a reasonable cost, and most costs are justifiable.	More economic. The design has a reasonable cost and almost all costs are justifiable.	Very economic. The design is affordable, and all costs are justifiable.
Feasibility	It is not possible to actually implement this design.	This design will be difficult to implement and there will likely be a number of issues	There are a few difficulties with implementing this design and a few other issues may also arise.	This design should be fairly easy to implement but there still may be a few difficulties.	This design will be easy to implement and there should be no issues.
Time of Construction	The project will take a very long time to implement (several years) and access cannot be provided to the area during the school year nor can the project be easily phased.	The project will take a long time (a few years) and access to the area cannot be easily provided during the school year nor can the project be easily phased.	The project will take a while to complete (1-2 years) but access to the area can be provided during the school year or the project can be phased.	The project will take 6 months to a year to complete but the project can be phased over the summer or construction can continue during the school year with access through the area.	The project can be completed over one summer (4 months), and if the project is delayed access through the area can be easily arranged.

Table 23: Weighted Evaluation Matrix for Design of Lane

Lane							
		Design 1		**Design 2**		**Design 3**	
Criteria	**Weight**	**Score**	**Weighted**	**Score**	**Weighted**	**Score**	**Weighted**
Stakeholder Needs	5	3	15	5	25	5	25
Sustainability	5	5	25	3	15	2	10
Aesthetics	4	5	20	4	16	2	8
Innovation	4	4	16	2.5	10	1.5	6
Social Infrastructure	4	4.5	18	1	4	1	4
Maintenance	3	3	9	5	15	5	15
Cost	3	2	6	4	12	5	15
Feasibility	2	2.5	5	5	10	5	10
Time of Construction	2	1	2	4	8	5	10
Total			**116**		115		103

Table 24: Weighted Evaluation Matrix for Design of Free Space

Free Space							
		Design 1		**Design 2**		**Design 3**	
Criteria	**Weight**	**Score**	**Weighted**	**Score**	**Weighted**	**Score**	**Weighted**
Stakeholder Needs	5	4.5	22.5	5	25	1	5
Sustainability	5	5	25	4	20	3	15
Aesthetics	4	4.5	18	4.5	18	2	8
Innovation	4	4	16	3	12	2	8
Social Infrastructure	4	5	20	4	16	2	8
Maintenance	3	3	9	5	15	4	12
Cost	3	3.5	10.5	4	12	5	15
Feasibility	2	4	8	5	10	5	10
Time of Construction	2	3	6	4	8	5	10
Total			135		**136**		91

Table 25: Weighted Evaluation Matrix for Design of Alleyways

Alleyways							
		Design 1		Design 2		Design 3	
Criteria	**Weight**	**Score**	**Weighted**	**Score**	**Weighted**	**Score**	**Weighted**
Stakeholder Needs	5	5	25	5	25	3.5	17.5
Sustainability	5	3	15	3	15	2	10
Aesthetics	4	5	20	4	16	3.5	14
Innovation	4	3	12	3	12	1	4
Social Infrastructure	4	5	20	2.5	10	2	8
Maintenance	3	4	12	5	15	4.5	13.5
Cost	3	3	9	4.5	13.5	4.5	13.5
Feasibility	2	4	8	5	10	5	10
Time of Construction	2	3	6	4.5	9	5	10
Total			**127**		125.5		100.5

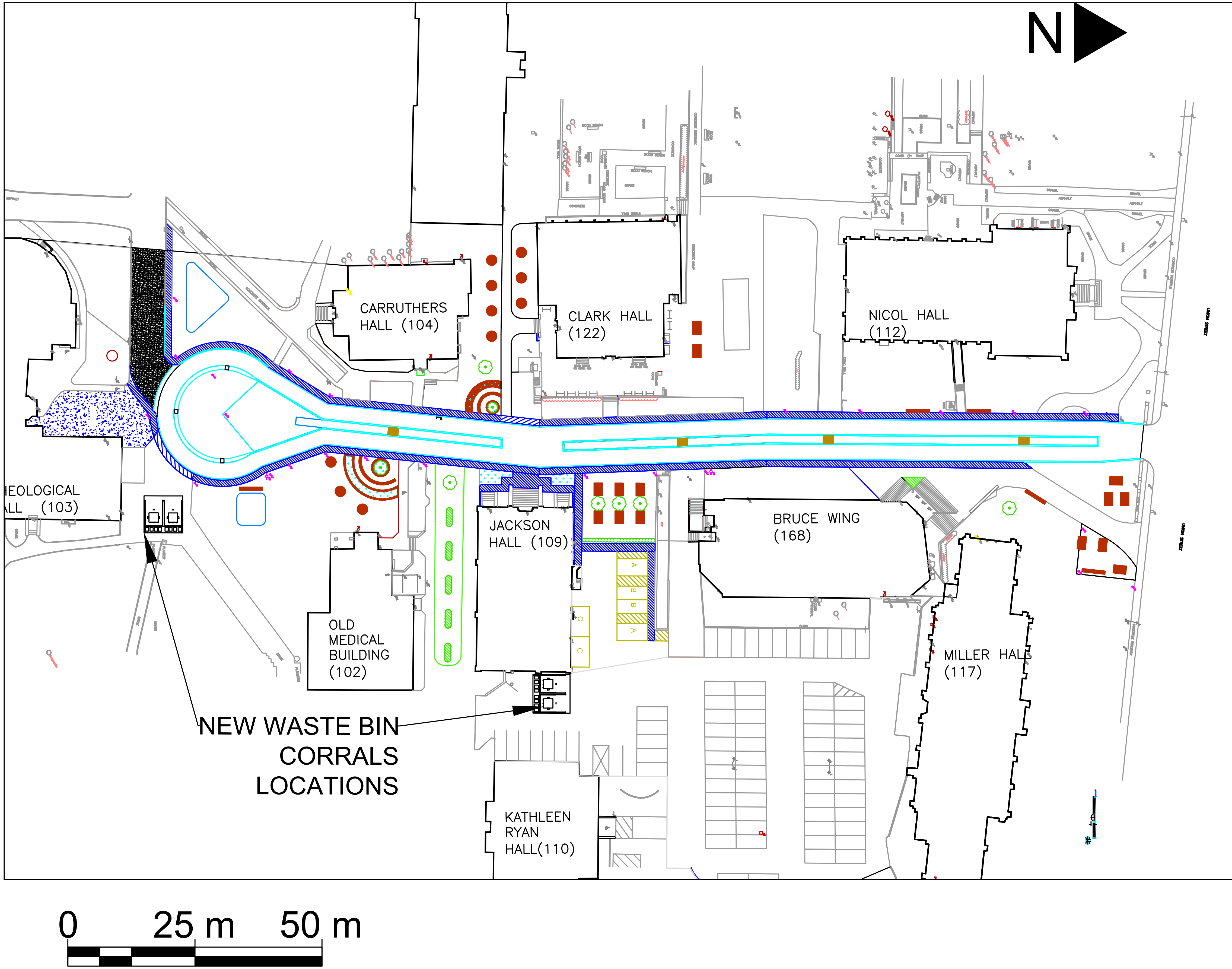
Table 26: Weighted Evaluation Matrix for Design of Turnaround Point

Turnaround Point							
		Design 1		Design 2		Design 3	
Criteria	**Weight**	**Score**	**Weighted**	**Score**	**Weighted**	**Score**	**Weighted**
Stakeholder Needs	5	5	25	4.5	22.5	5	25
Sustainability	5	4	20	3	15	2.5	12.5
Aesthetics	4	4	16	4.5	18	2.5	10
Innovation	4	3	12	3	12	2.5	10
Social Infrastructure	4	3	12	2	8	1.5	6
Maintenance	3	3.5	10.5	4.5	12	5	15
Cost	3	3	9	5	15	4.5	13.5
Feasibility	2	5	10	5	10	5	10
Time of Construction	2	3	6	4	8	4.5	9
Total			**120.5**		**120.5**		111

Table 27: Modified Weighted Evaluation Matrix for First Iteration of Final Design

First Iteration of Final Design									
Criteria	**Weight**	**Lane**		**Free Space**		**Alleyways**		**Turnaround Point**	
		Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Stakeholder Needs	5	5	25	5	25	5	25	5	25
Sustainability	5	5	25	4.5	22.5	4	20	4	20
Aesthetic	4	5	20	4.5	18	5	20	4.5	18
Innovation	4	5	20	3	12	3	12	3	12
Social Infrastructure	4	1	4	5	20	4.5	18	4	16
Maintenance	3	4	12	4	12	4	12	4	12
Cost	3	3.5	10.5	4	12	4	12	4	12
Feasibility	2	3	6	5	10	4.5	9	4.5	9
Time of Construction	2	3	6	4	8	3.5	7	4	8
Total			**128.5**		**139.5**		**135**		**132**

Appendix D – Final CAD Drawing



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- EXISTING ELEMENTS
- NEW RETENTION POND
- NEW BIOSWALE CROSSING POINT
- NEW CURB
- NEW SIDEWALK OR CONCRETE STRUCTURE (I.G. CATCH BASIN OR PAD
- NEW TREES OR GRASSY AREAS
- SOCIAL INFRASTRUCTURE (BENCH, TABLES, GARDEN WALLS, ETC.)
- NEW LIGHT POST OR FIRE HYDRANT
- NEW ACCESSIBILITY PARKING

DRAWING: 3

GENERAL LAYOUT OF THE NEW LANE

DRAFTER(S):

- JEAN-SEBASTIEN YOUNG

SCALE: NOT TO SCALE

NOTES:

THE PURPOSE OF THIS DRAWING IS TO SHOW THE GENERAL LAYOUT OF THE NEW LANEWAY WITH RESPECT TO THE LOCATION OF THE BUILDINGS

PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- EXISTING TREE OR PLANT
- EXISTING LIGHT POST
- NEW LIGHT POST
- NEW PICNIC TABLE
- NEW CURB

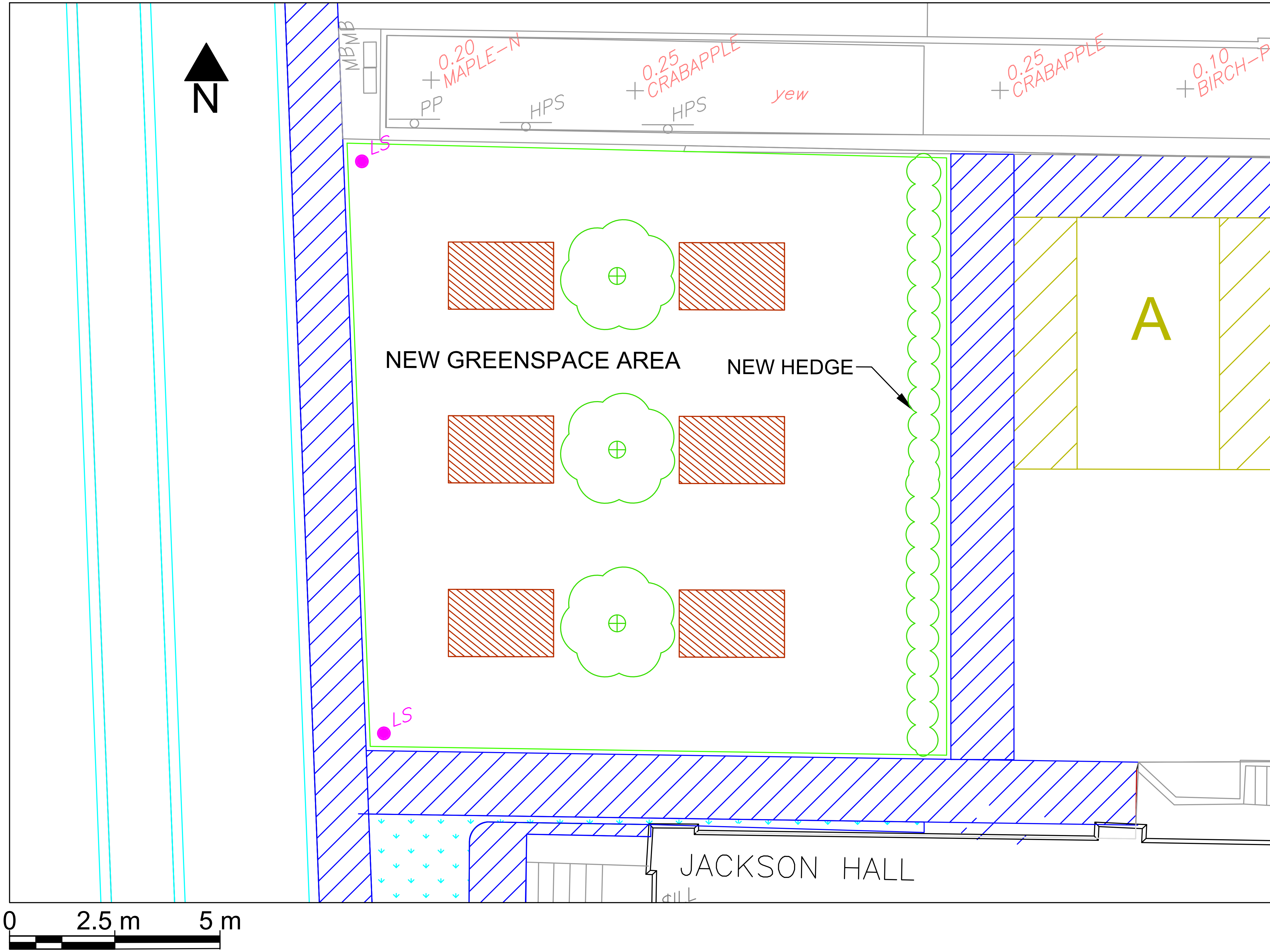
DRAWING: 4
FREE SPACE: JUST NORTH OF MILLER HALL, EAST OF 5TH FIELD COMPANY LANE

DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: 1:100

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- EXISTING TREE OR PLANT
- EXISTING LIGHT POST
- NEW LIGHT POST
- NEW PICNIC TABLE
- NEW CURB
- NEW TREES
- NEW CONCRETE SIDEWALK

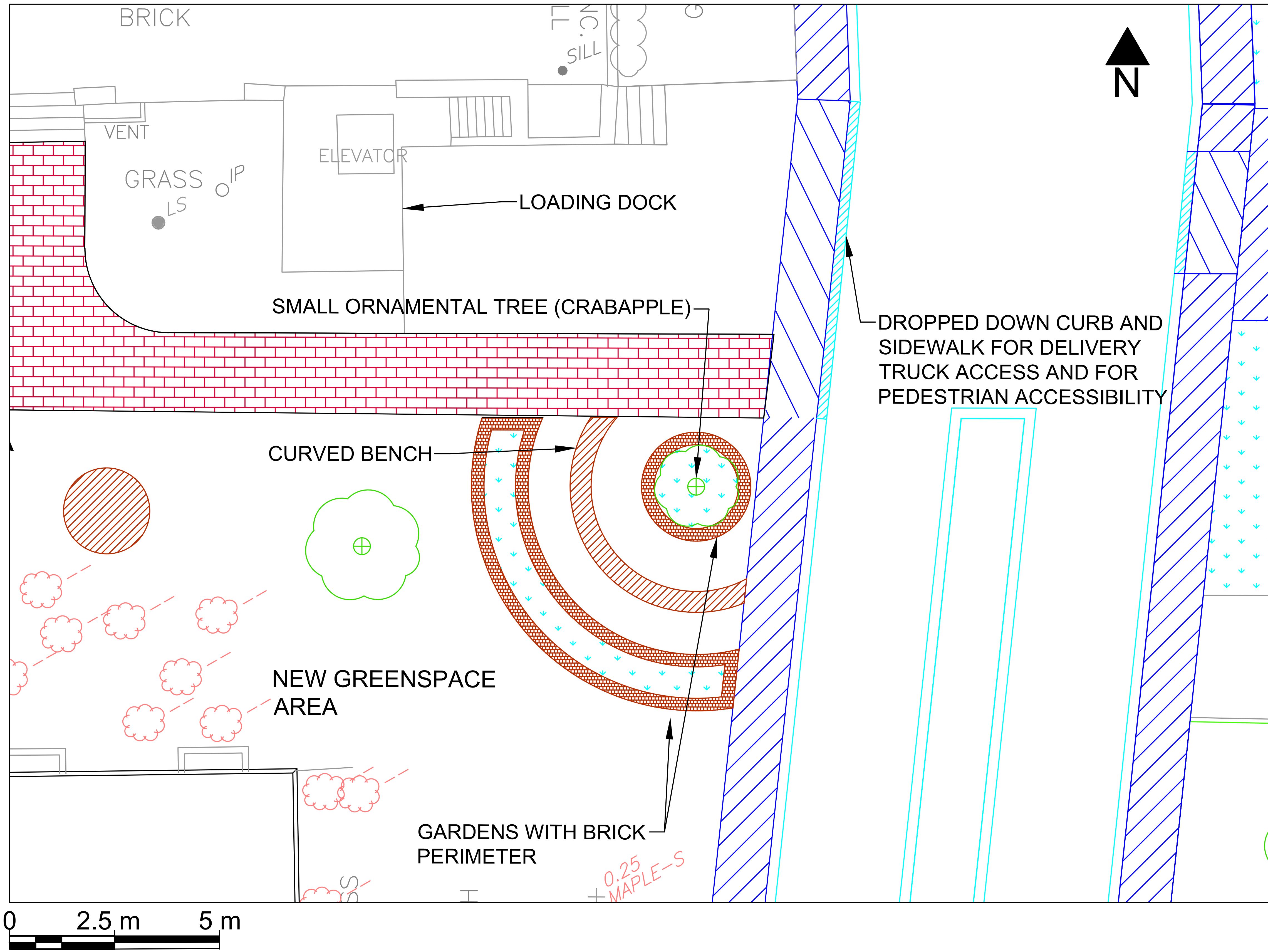
DRAWING: 5
FREE SPACE: BETWEEN BRUCE WING AND JACKSON HALL

DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: 1:100

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- EXISTING TREE OR PLANT
- EXISTING LIGHT POST
- NEW LIGHT POST
- NEW PICNIC TABLE
- NEW CURB
- NEW TREES
- EXISTING SHRUB
- NEW CONCRETE SIDEWALK
- NEW BRICK PATHWAY
- NEW GARDEN

DRAWING: 6

FREE SPACE: QUARTER CIRCLE GARDEN BETWEEN BRUCE WING AND JACKSON HALL

DRAFTER(S):

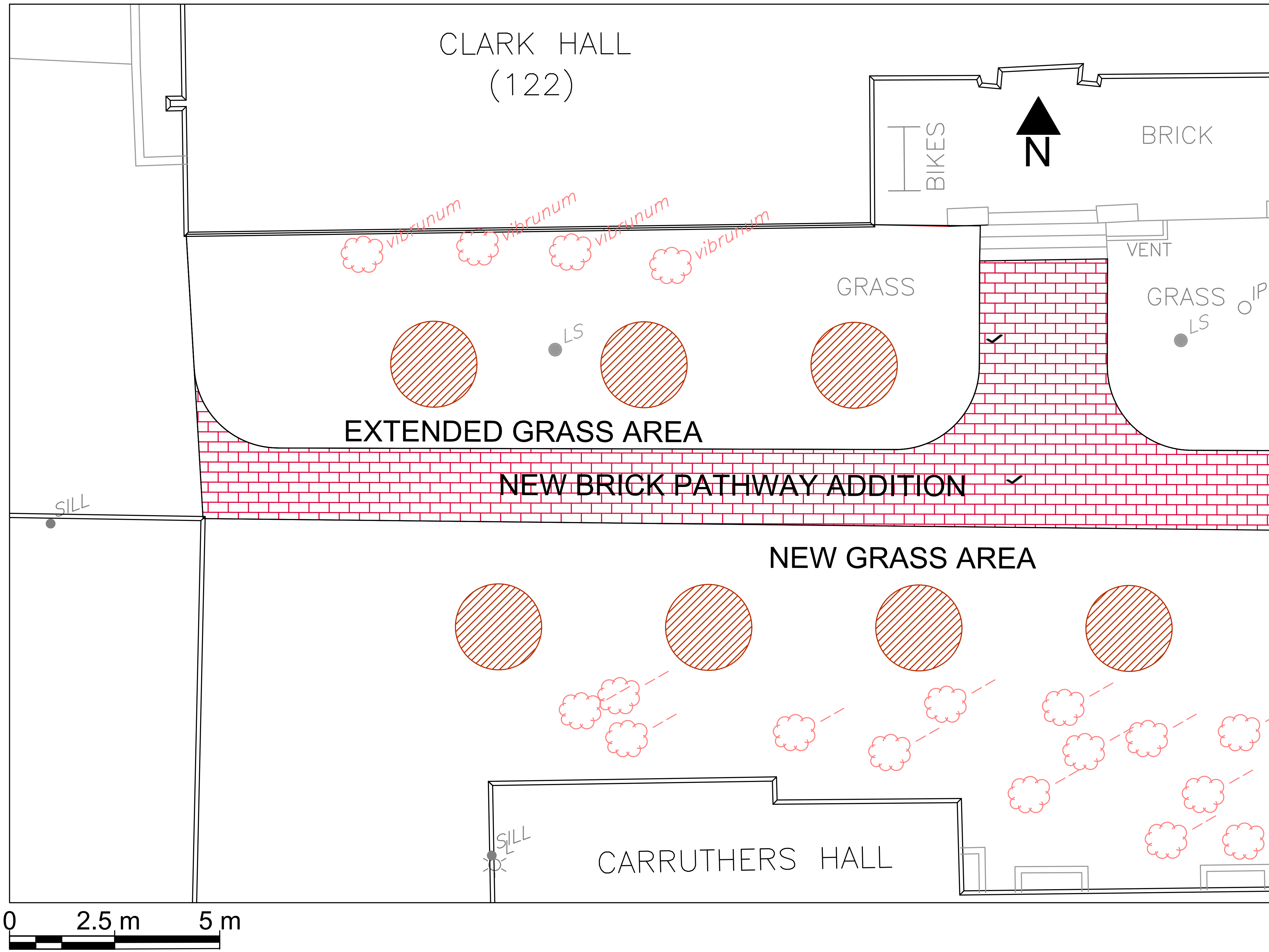
- JEAN-SEBASTIEN YOUNG

SCALE: 1:100

NOTES:

ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- EXISTING TREE OR PLANT
- EXISTING LIGHT POST
- NEW LIGHT POST
- NEW PICNIC TABLE
- NEW CURB
- NEW TREES
- EXISTING SHRUB
- NEW CONCRETE SIDEWALK
- NEW BRICK PATHWAY
- NEW GARDEN

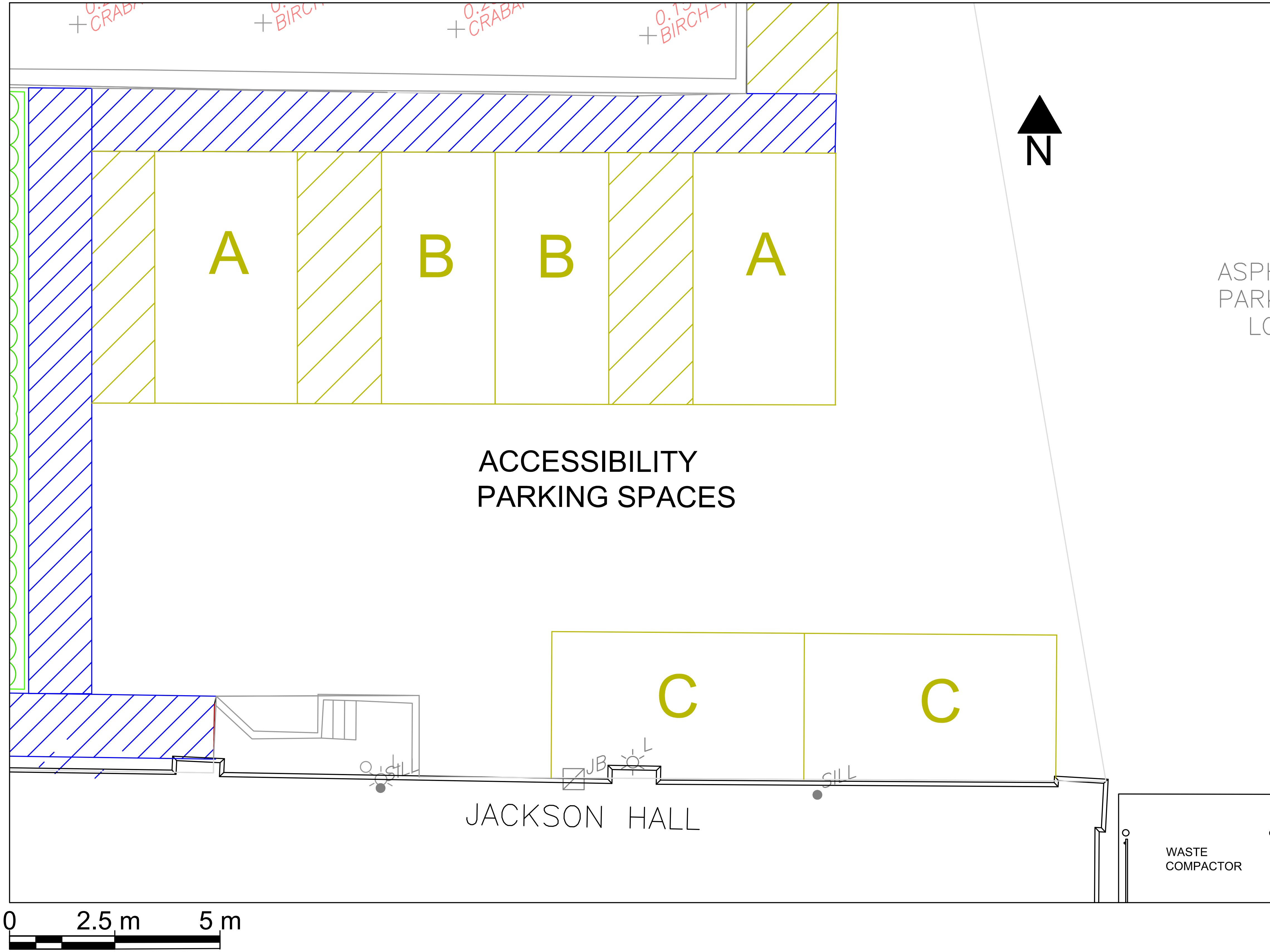
DRAWING: 7
ALLEYWAY: BETWEEN CLARK HALL AND CARRUTHERS HALL

DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: 1:100

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- EXISTING TREE OR PLANT
- NEW CONCRETE SIDEWALK
- NEW HATCH LINE PAINT FOR SPACING
- NEW PARKING LINE PAINT

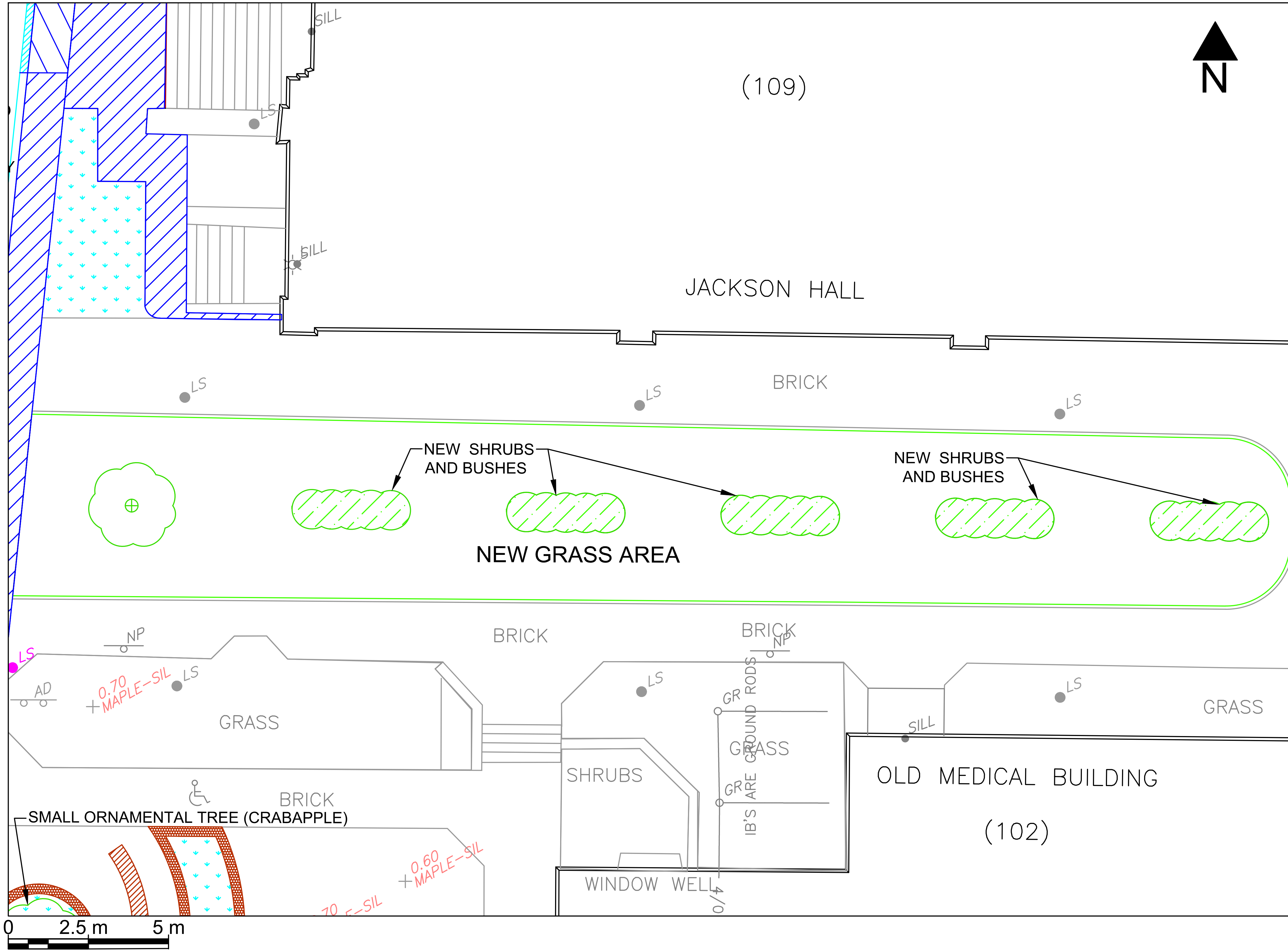
DRAWING: 8
ALLEYWAY: BETWEEN CLARK HALL AND CARRUTHERS HALL

DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: 1:100

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED OTHERWISE

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:
- EXISTING TREE OR PLANT
- EXISTING LIGHT POST
- NEW LIGHT POST
- NEW PICNIC TABLE
- NEW CURB
- NEW TREES
- EXISTING SHRUB
- NEW CONCRETE SIDEWALK
- NEW GARDEN

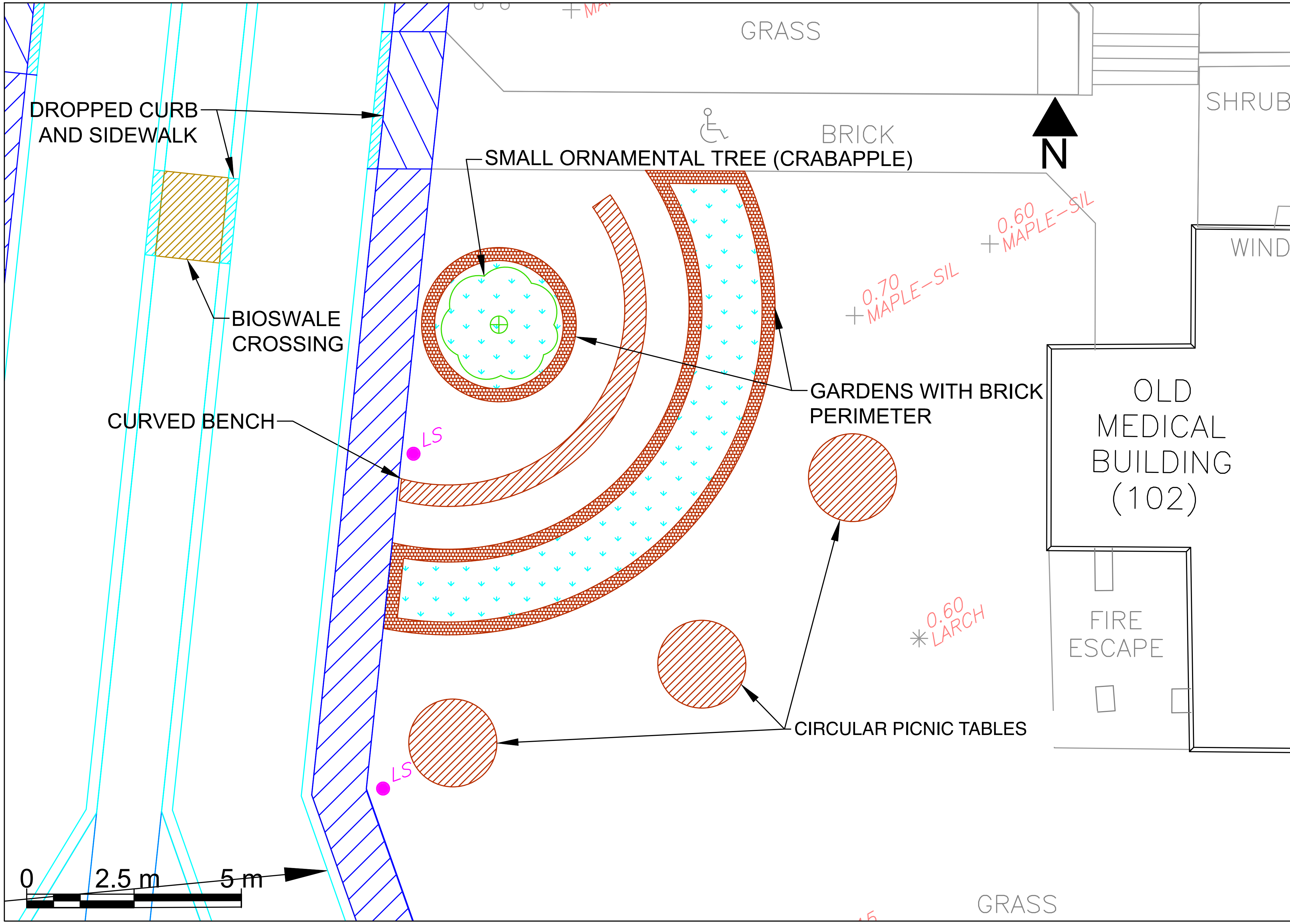
DRAWING: 9
ALLEYWAY: BETWEEN JACKSON HALL AND OLD MEDICAL BUILDING

DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: 1:125

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- EXISTING TREE OR PLANT
- EXISTING LIGHT POST
- NEW LIGHT POST
- NEW PICNIC TABLE
- NEW CURB
- NEW TREES
- EXISTING SHRUB
- NEW CONCRETE SIDEWALK
- NEW GARDEN

DRAWING: 10

ALLEYWAY: QUARTER CIRCLE GARDEN JUST WEST OF OLD MEDICAL BUILDING

DRAFTER(S):

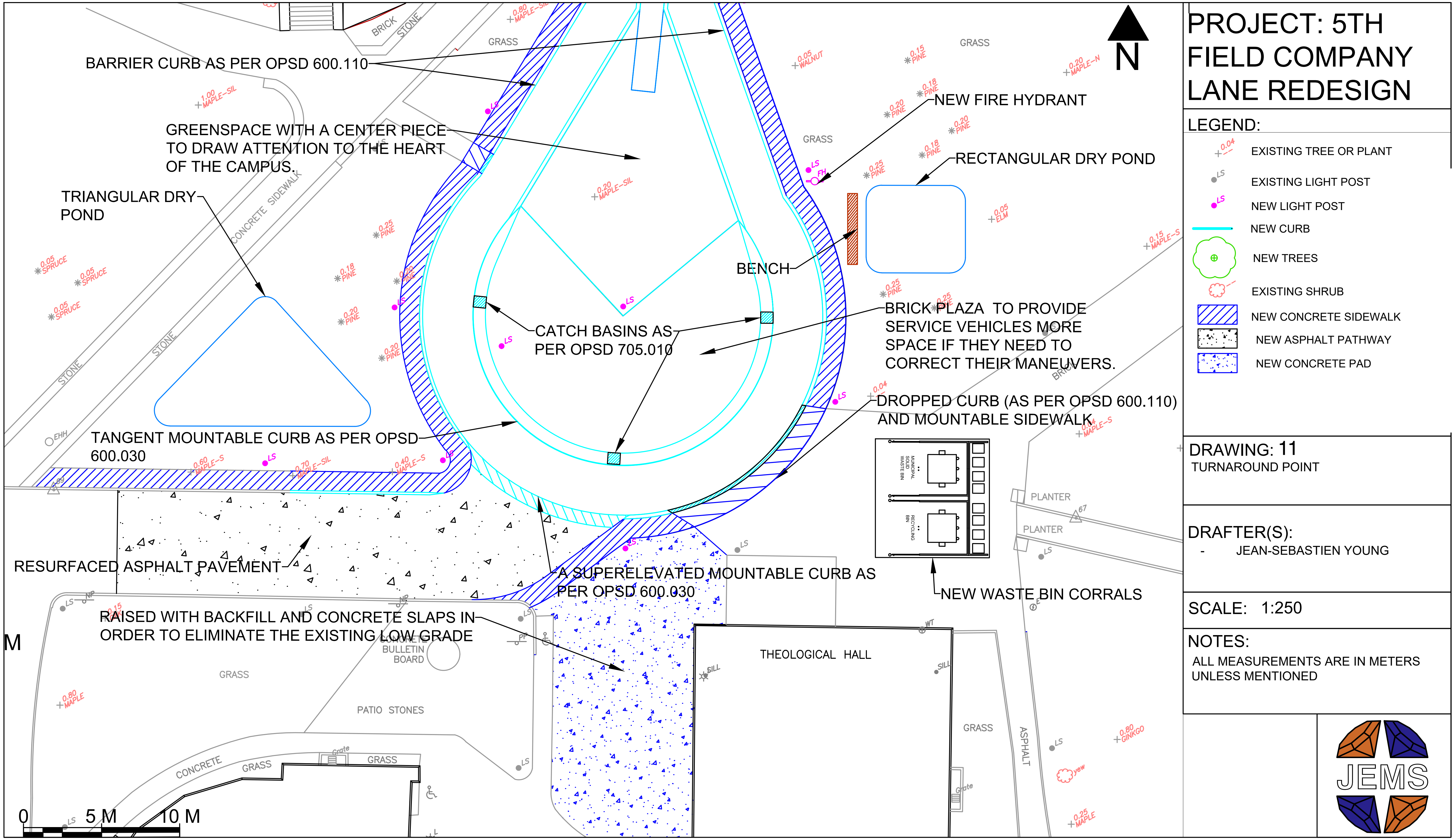
- JEAN-SEBASTIEN YOUNG

SCALE: 1:100

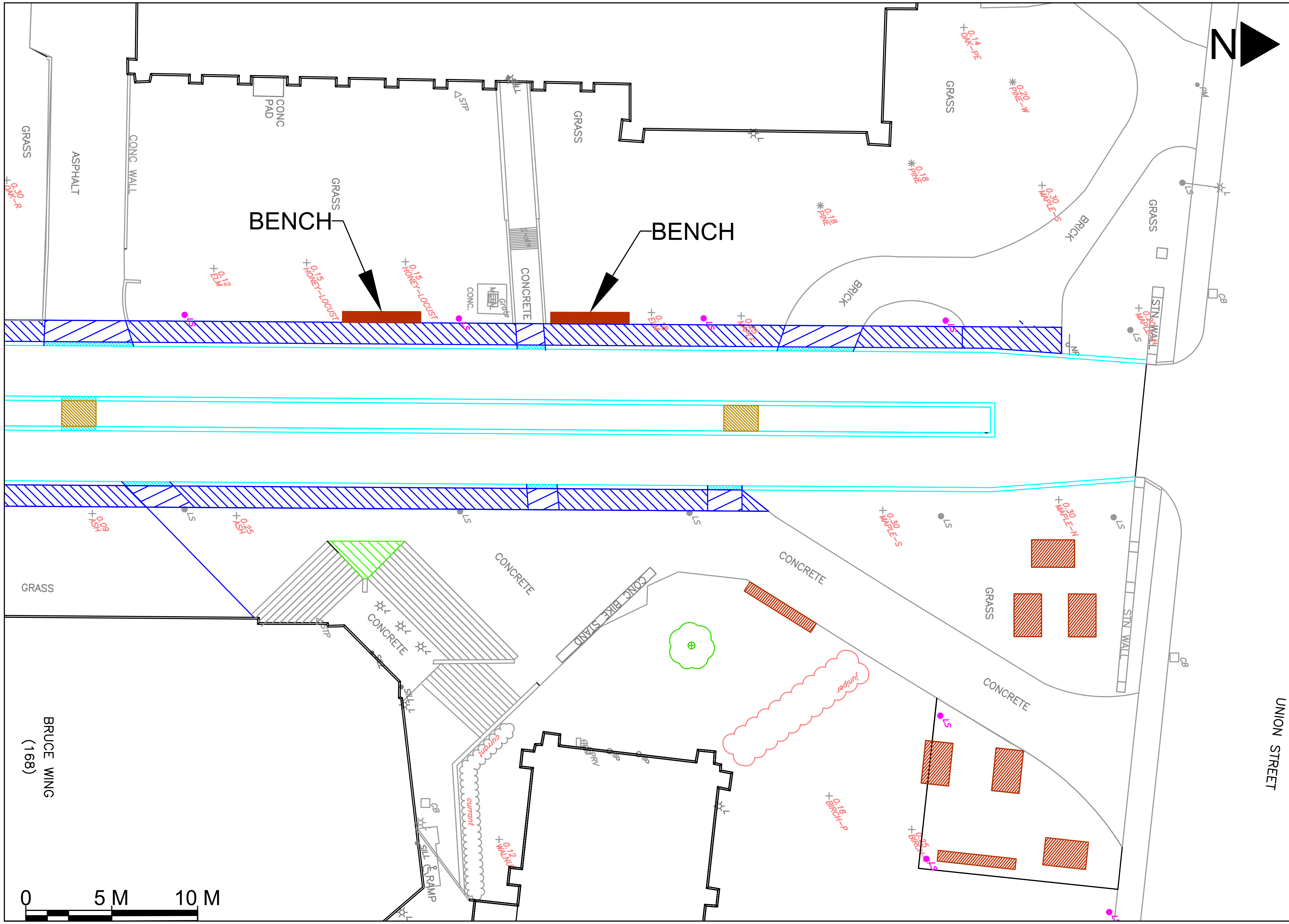
NOTES:

ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN
LEGEND:
EXISTING TREE OR PLANT
EXISTING LIGHT POST
NEW LIGHT POST
NEW CURB
NEW TREES
EXISTING SHRUB
NEW CONCRETE SIDEWALK
NEW ASPHALT PATHWAY
NEW CONCRETE PAD
DRAWING: 11
TURNAROUND POINT
DRAFTER(S):
- JEAN-SEBASTIEN YOUNG
SCALE: 1:250
NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED
JEMS
N
BARRIER CURB AS PER OPSD 600.110
GREENSPACE WITH A CENTER PIECE TO DRAW ATTENTION TO THE HEART OF THE CAMPUS.
TRIANGULAR DRY POND
NEW FIRE HYDRANT
RECTANGULAR DRY POND
BENCH
CATCH BASINS AS PER OPSD 705.010
BRICK PLAZA TO PROVIDE SERVICE VEHICLES MORE SPACE IF THEY NEED TO CORRECT THEIR MANEUVERS.
DROPPED CURB (AS PER OPSD 600.110) AND MOUNTABLE SIDEWALK
TANGENT MOUNTABLE CURB AS PER OPSD 600.030
RESURFACED ASPHALT PAVEMENT
A SUPERELEVATED MOUNTABLE CURB AS PER OPSD 600.030
NEW WASTE BIN CORRALS
RAISED WITH BACKFILL AND CONCRETE SLAPS IN ORDER TO ELIMINATE THE EXISTING LOW GRADE
THEOLOGICAL HALL
GRASS
PATIO STONES
CONCRETE
ASPHALT
PLANTER
CONCRETE SIDEWALK
STONE
BRICK
0
5 M
10 M



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- EXISTING TREE OR PLANT
- EXISTING LIGHT POST
- NEW LIGHT POST
- NEW CURB
- NEW TREES
- EXISTING SHRUB
- NEW CONCRETE SIDEWALK
- DROPPED SIDEWALK AND CURB
- BIOSWALE CROSSING
- TABLES

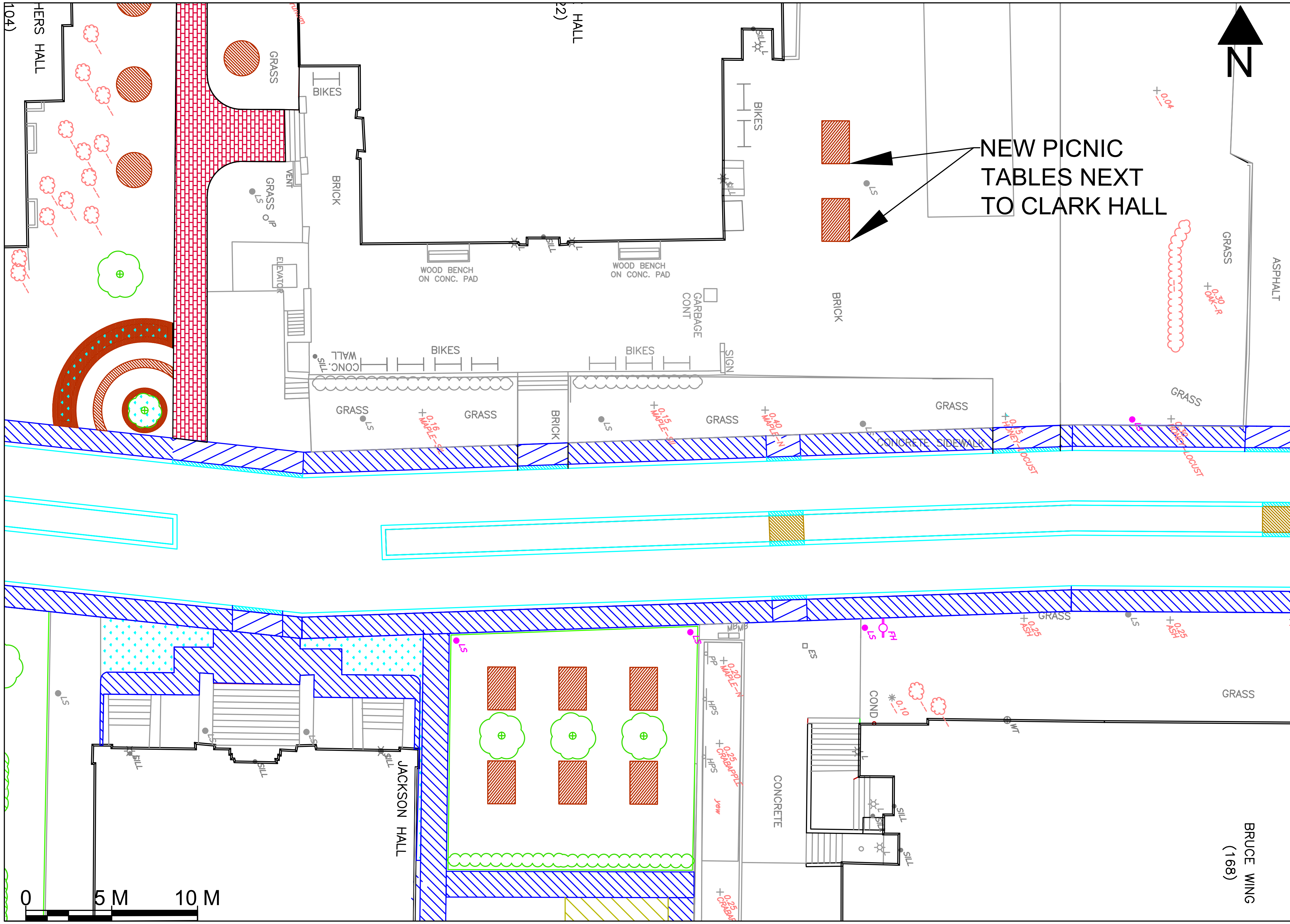
DRAWING: 12
ROAD SECTION OF UNION ST. ENTRANCE

DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: 1:250

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- EXISTING TREE OR PLANT
- EXISTING LIGHT POST
- NEW LIGHT POST
- NEW CURB
- NEW TREES
- EXISTING SHRUB
- NEW CONCRETE SIDEWALK
- DROPPED SIDEWALK AND CURB
- BIOSWALE CROSSING
- TABLES

DRAWING: 13

ROAD SECTION MIDWAY

DRAFTER(S):

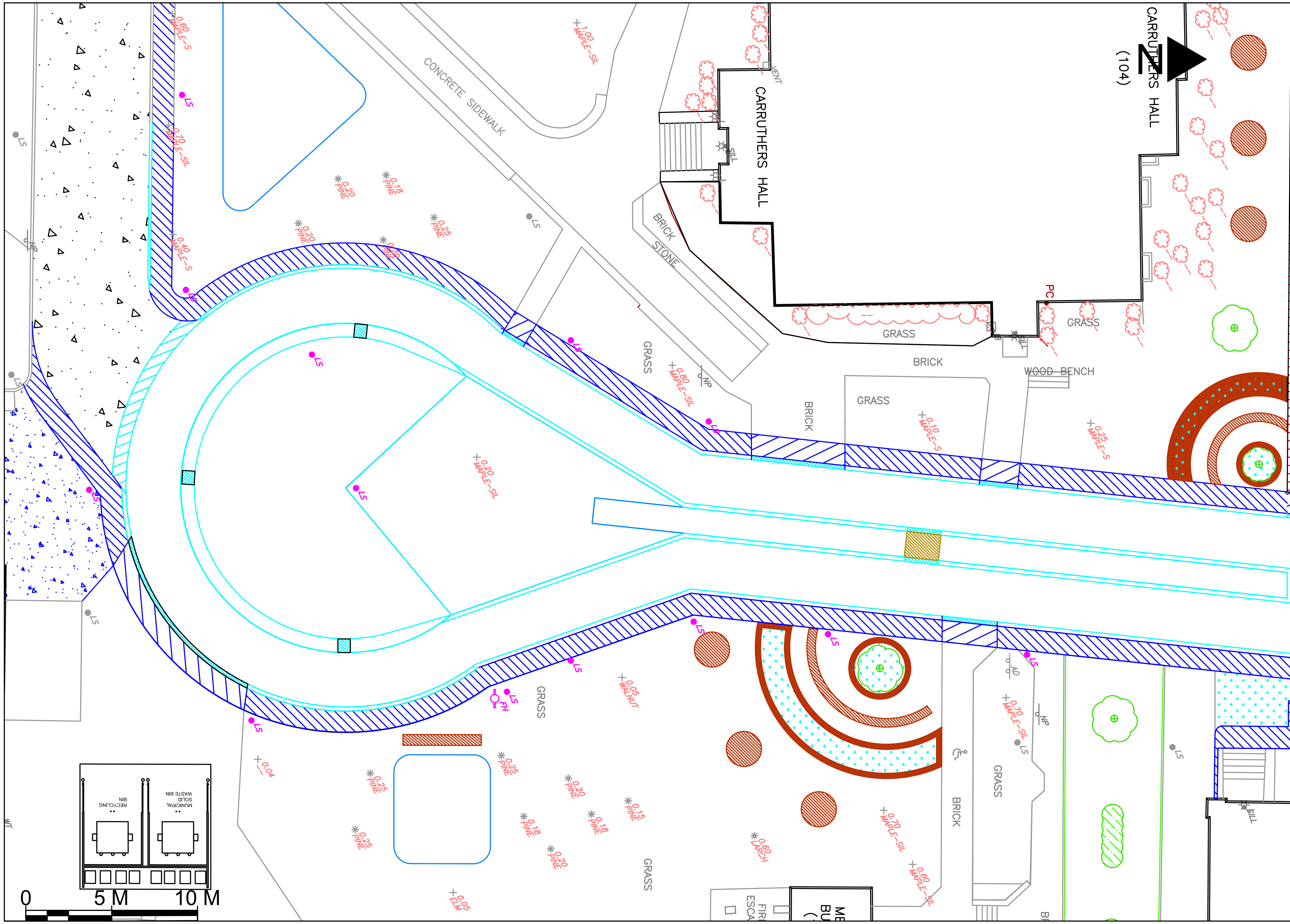
- JEAN-SEBASTIEN YOUNG

SCALE: 1:250

NOTES:

ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- EXISTING TREE OR PLANT
- EXISTING LIGHT POST
- NEW LIGHT POST
- NEW CURB
- NEW TREES
- EXISTING SHRUB
- NEW CONCRETE SIDEWALK
- DROPPED SIDEWALK AND CURB
- BIOSWALE CROSSING
- TABLES

DRAWING: 14
ROAD SECTION AT TURNAROUND POINT

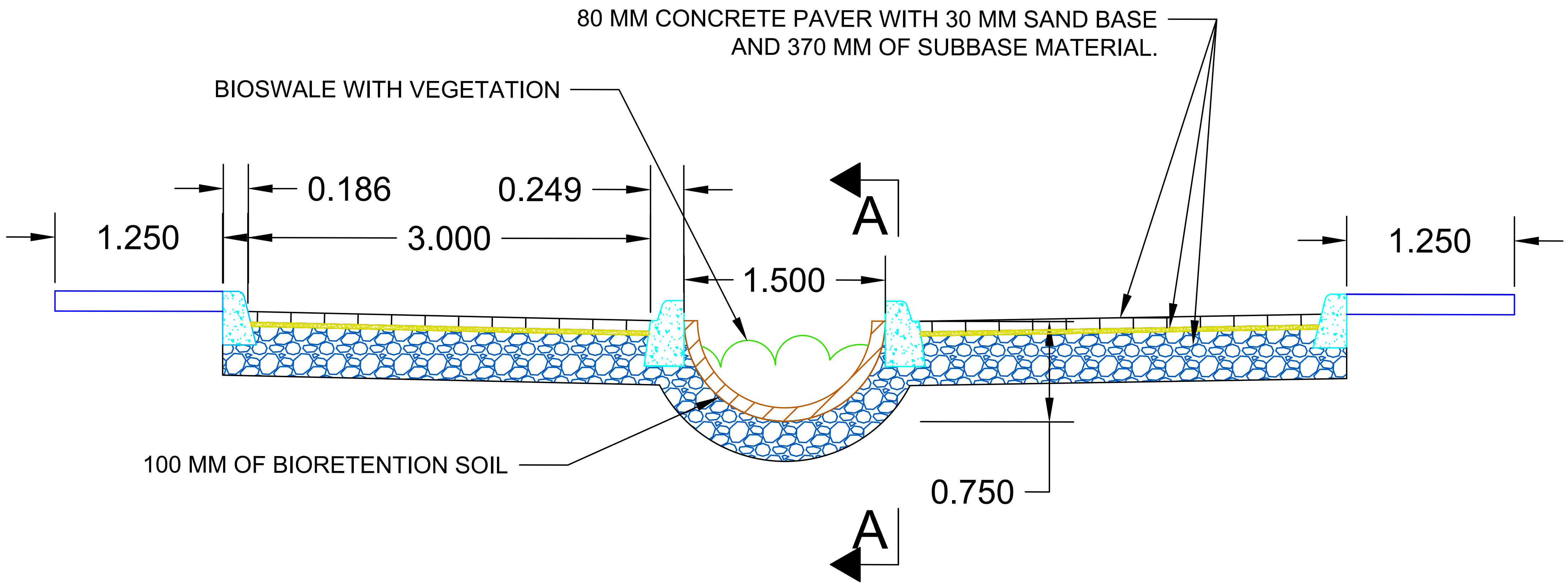
DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

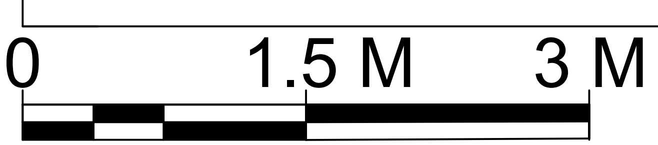
SCALE: 1:250

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS

TYPICAL CROSS-SECTION OF THE NEW PROPOSED LANEWAY





PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- EXISTING TREE OR PLANT
- EXISTING LIGHT POST
- NEW LIGHT POST
- NEW CURB
- NEW TREES
- EXISTING SHRUB
- NEW CONCRETE SIDEWALK
- DROPPED SIDEWALK AND CURB
- BIOSWALE CROSSING
- TABLES

DRAWING: 15
TYPICAL ROAD CROSS-SECTION

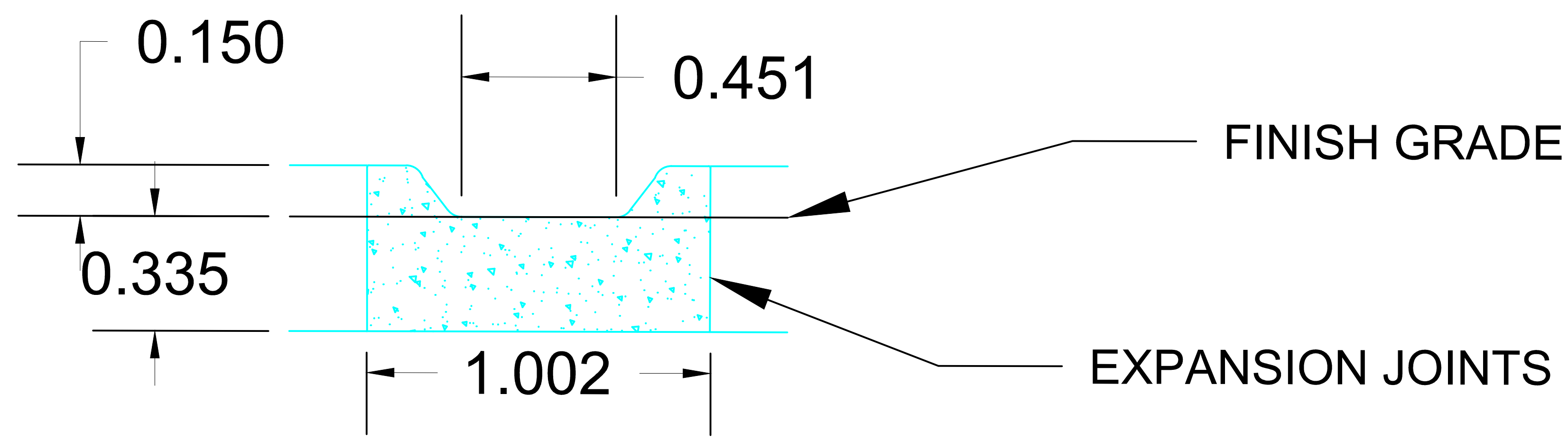
DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: 1:250

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

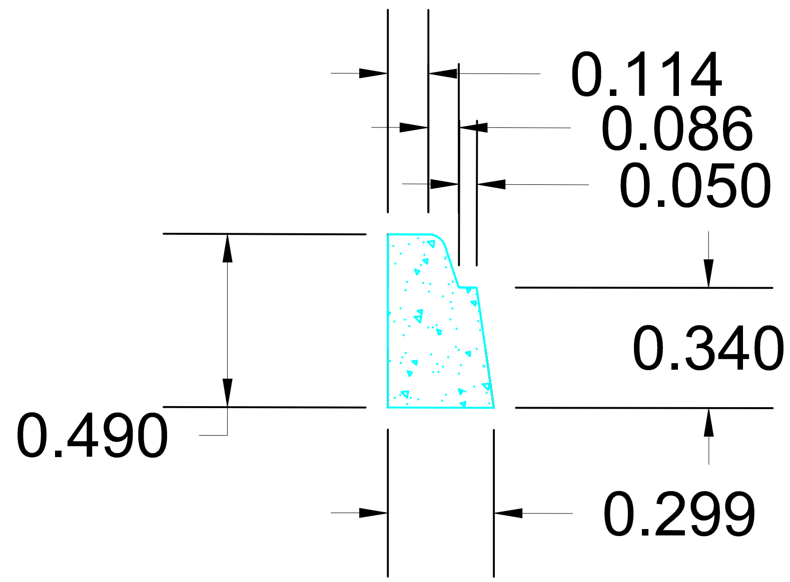
JEMS

SECTION A - A
TAPERED CURB FOR BIOSWALE

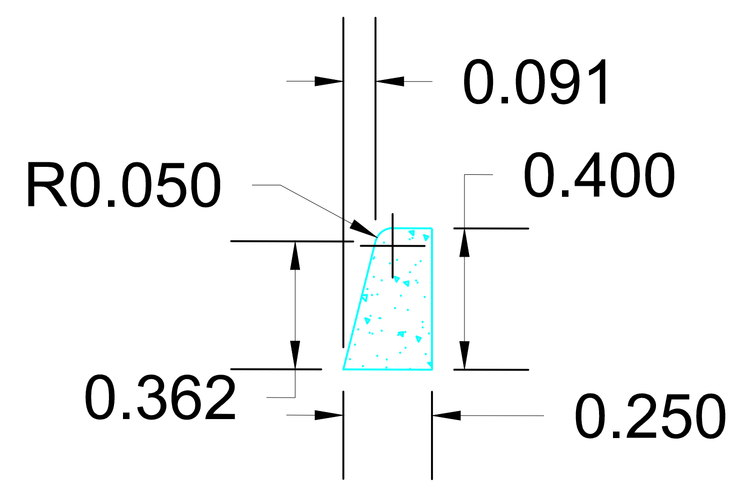


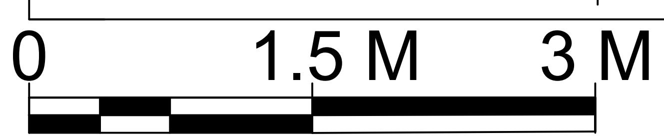
CURB DETAILS

INSIDE CURBS



OUTSIDE CURBS





PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

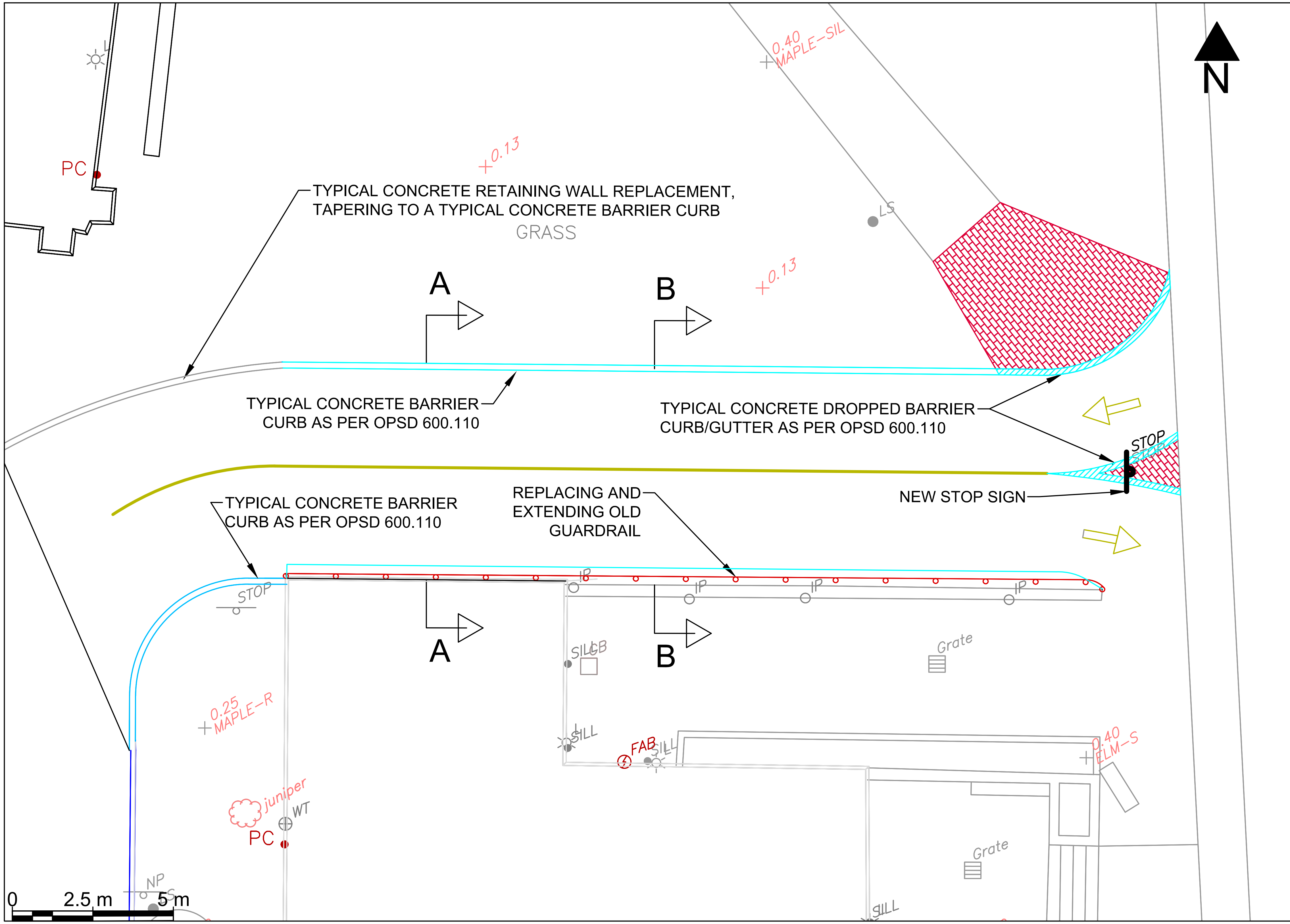
DRAWING: 16
TYPICAL ROAD CROSS-SECTION

DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: NOT TO SCALE

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- EXISTING TREE OR PLANT
- EXISTING LIGHT POST
- NEW BRICK PATHWAY
- EXISTING SHRUB

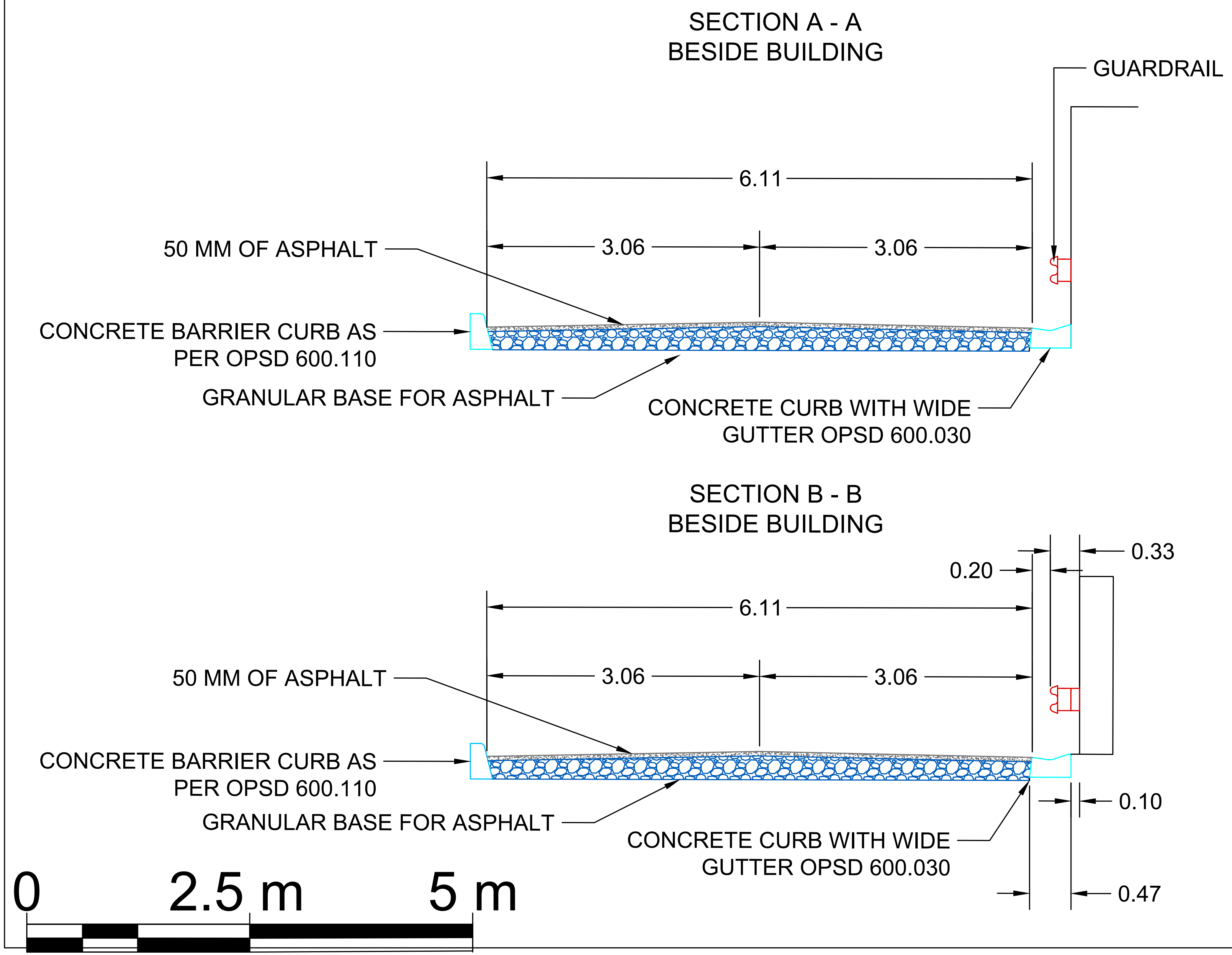
DRAWING: 17
ARCH ST. PARKING ENTRANCE LAYOUT

DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: 1:125

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

NEW ASPHALT

GRANULAR BEDDING

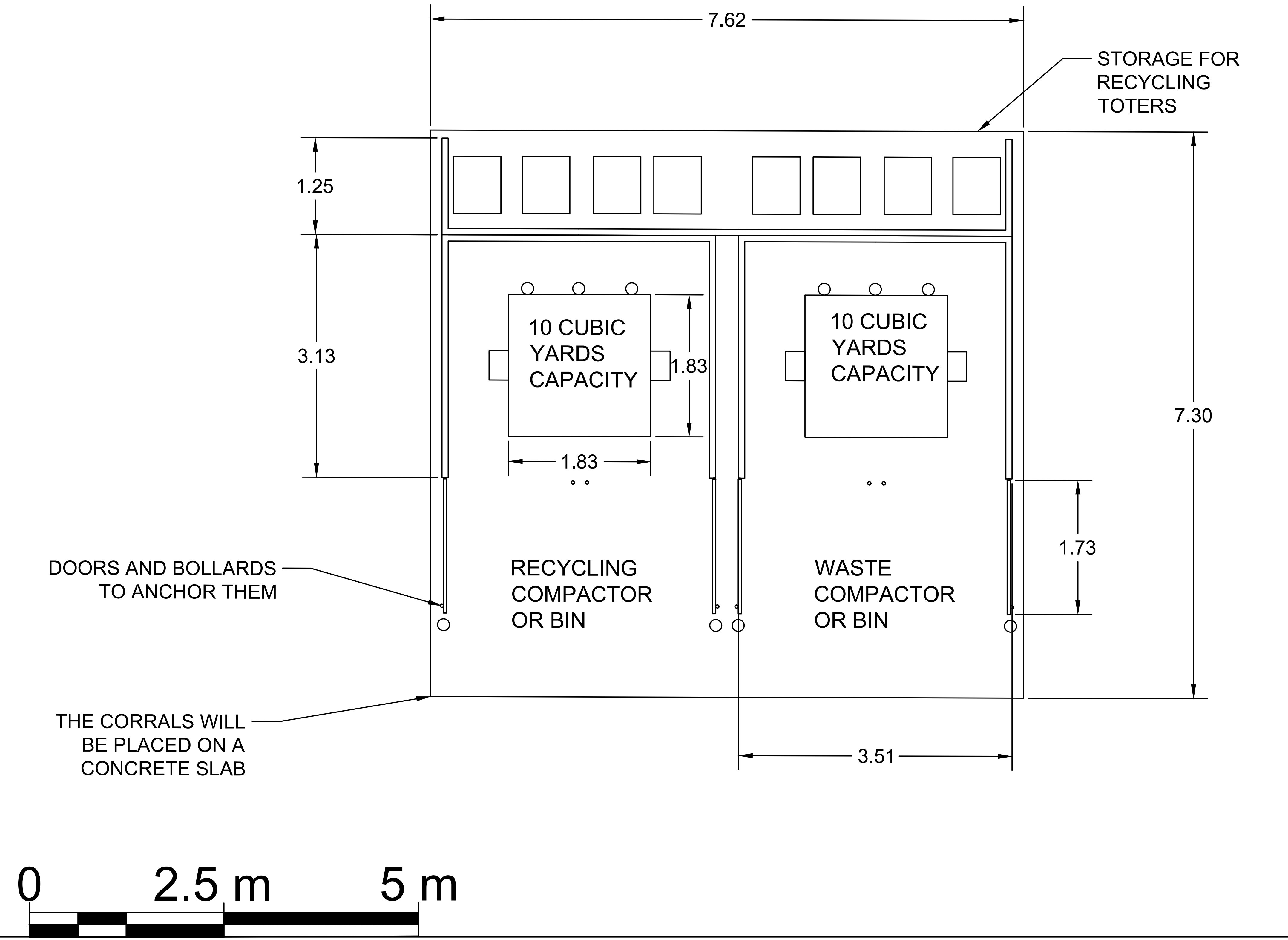
DRAWING: 18
ARCH ST. PARKING ENTRANCE DETAILS

DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: 1:50

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED OTHERWISE

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

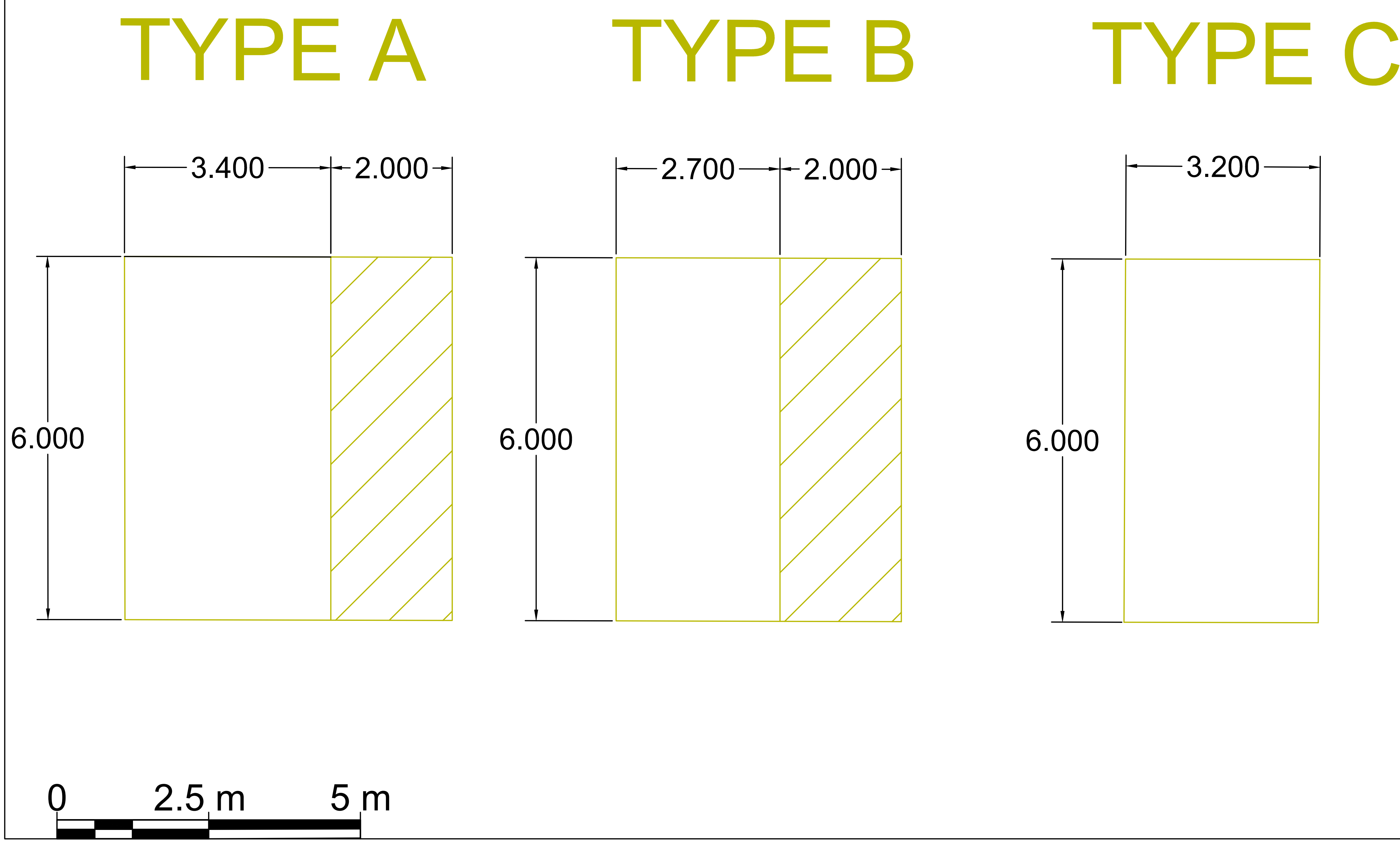
DRAWING: 19
WASTE BIN CORRAL DETAILS

DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: NOT TO SCALE

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED OTHERWISE

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

DRAWING: 20
PARKING DIMENSIONS FOR ACCESSIBILITY SPACES

DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: NOT TO SCALE

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED OTHERWISE

JEMS

PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

INFILTRATION REGIONS:

IMPERVIOUS REGIONS:

BIOSWALE OR POND:

PAVERS:

SWMM ANALYSIS BOUNDARY:

DRAWING: 21

SWMM ANALYSIS LAYER DELINEATION: WHOLE SITE

DRAFTER(S):

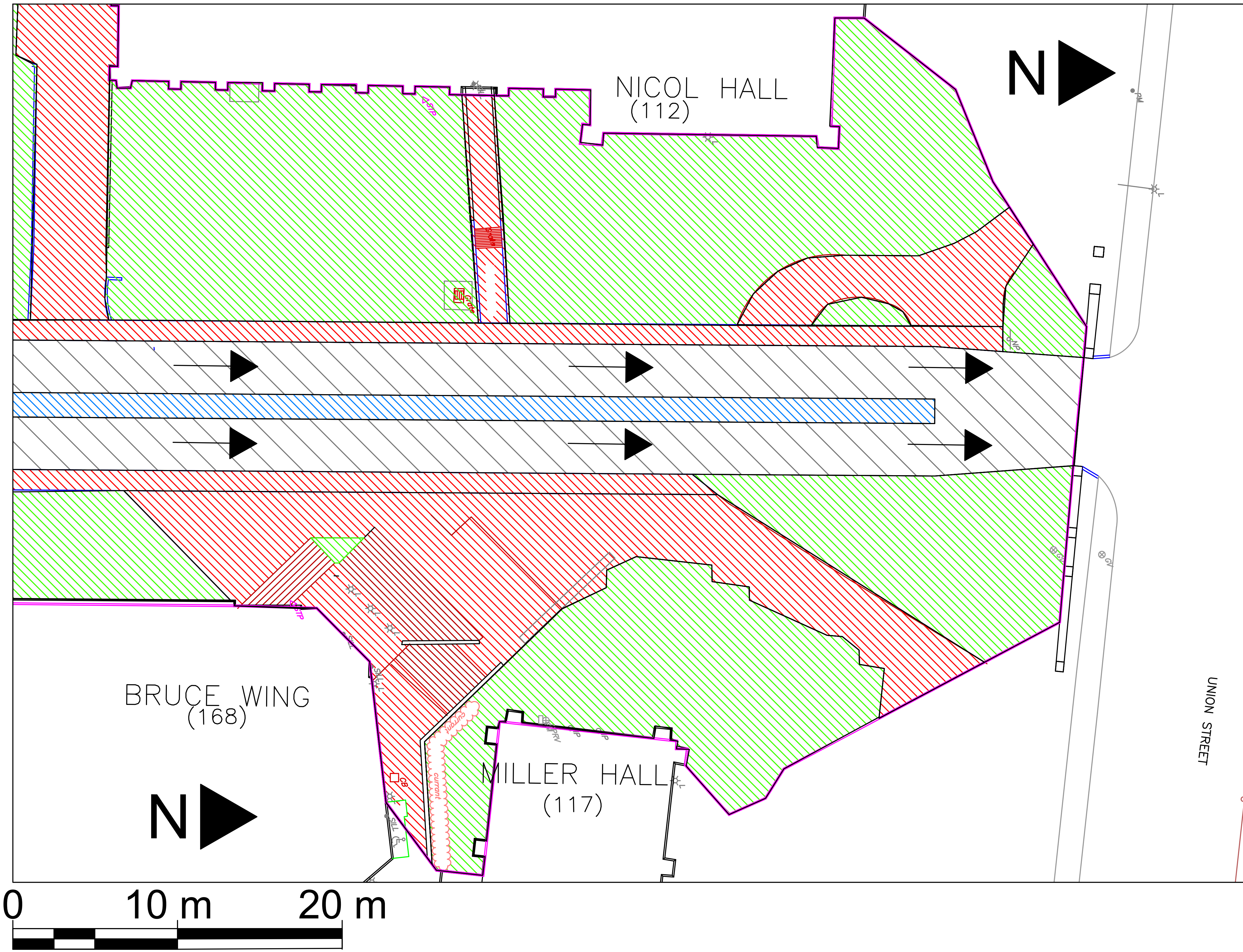
- JEAN-SEBASTIEN YOUNG

SCALE: NOT TO SCALE

NOTES:

THESE DRAWINGS ARE ONLY FOR DELINEATING DIFFERENT REGIONS ANALYZED BY THE SWMM MODELING SOFTWARE

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

INFILTRATION REGIONS:

IMPERVIOUS REGIONS:

BIOSWALE OR POND:

PAVERS:

SWMM ANALYSIS BOUNDARY:

DRAWING: 22

SWMM ANALYSIS LAYER DELINIATION: NICOL HALL, BRUCE WING, AND MILLER HALL

DRAFTER(S):

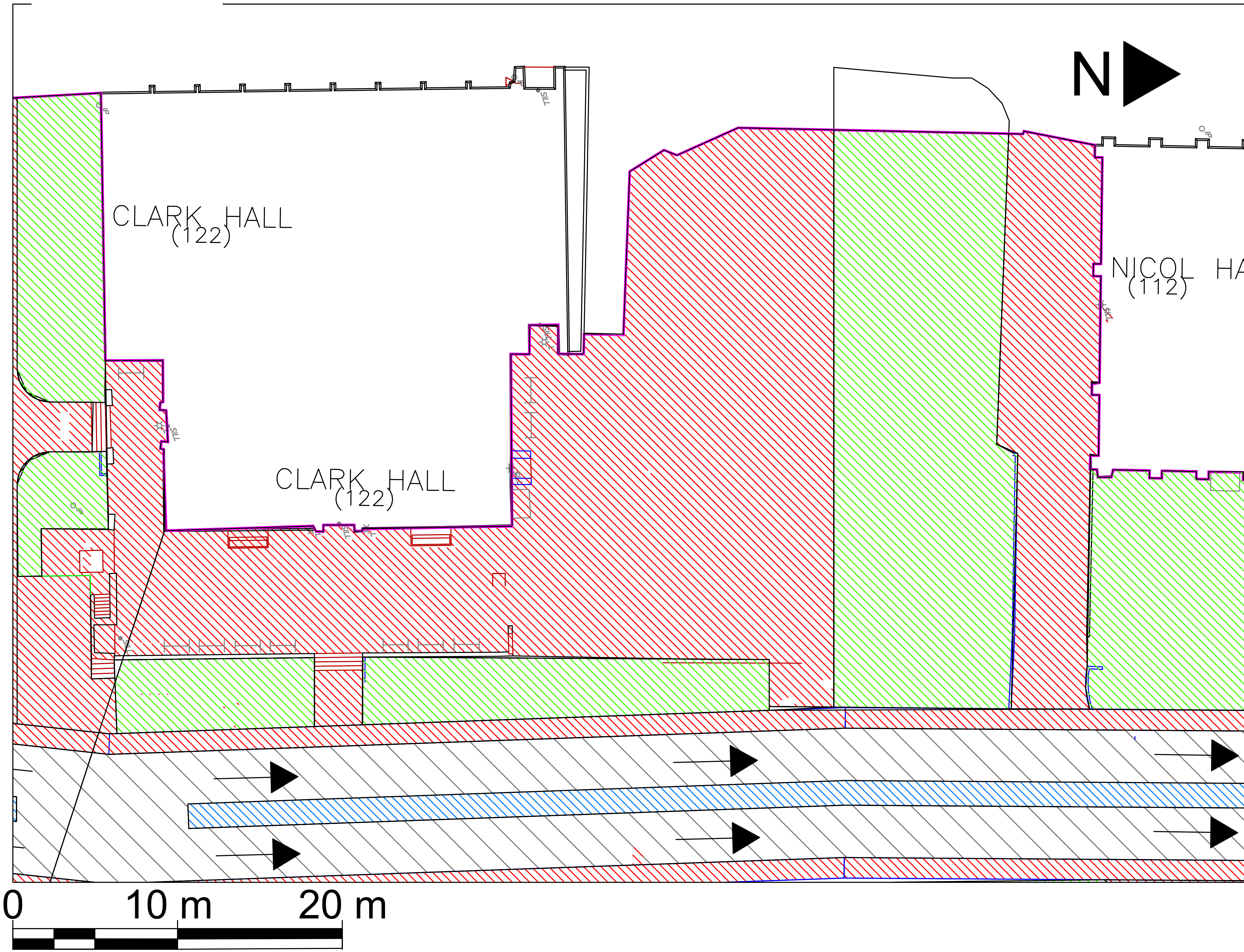
- JEAN-SEBASTIEN YOUNG

SCALE: 1 : 240

NOTES:

THESE DRAWINGS ARE ONLY FOR DELINEATING DIFFERENT REGIONS ANALYZED BY THE SWMM MODELING SOFTWARE

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

INFILTRATION REGIONS:

IMPERVIOUS REGIONS:

BIOSWALE OR POND:

PAVERS:

SWMM ANALYSIS BOUNDARY:

DRAWING: 23

SWMM ANALYSIS LAYER DELINIATION: BETWEEN CLARK AND NICOL

DRAFTER(S):

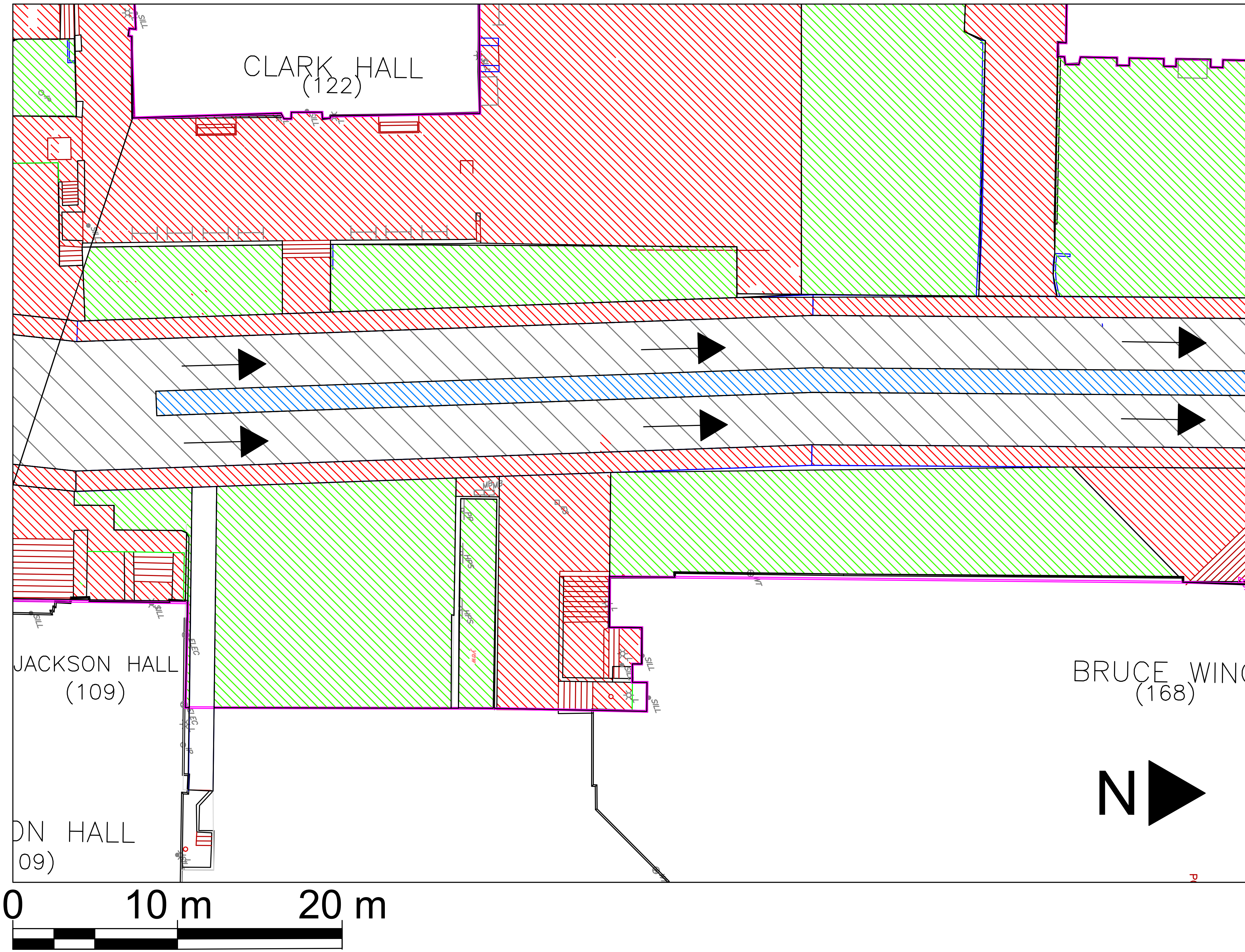
- JEAN-SEBASTIEN YOUNG

SCALE: 1 : 240

NOTES:

THESE DRAWINGS ARE ONLY FOR DELINEATING DIFFERENT REGIONS ANALYZED BY THE SWMM MODELING SOFTWARE

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- INFILTRATION REGIONS:
- IMPERVIOUS REGIONS:
- BIOSWALE OR POND:
- PAVERS:
- SWMM ANALYSIS BOUNDARY:

DRAWING: 24

SWMM ANALYSIS LAYER DELINIATION: BETWEEN CLARK, JACKSON HALL AND BRUCE WING

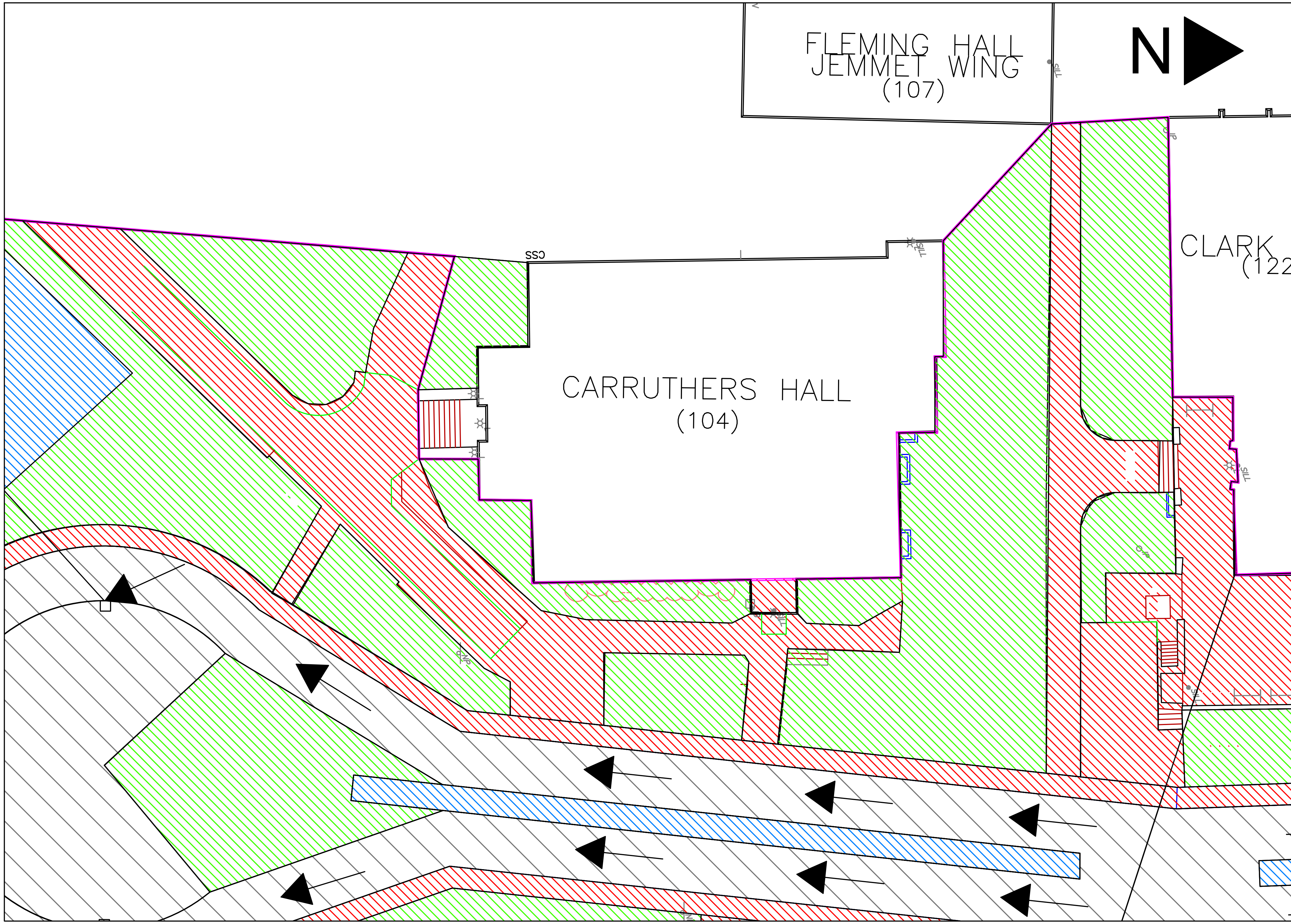
DRAFTER(S):

- JEAN-SEBASTIEN YOUNG

SCALE: 1 : 240

NOTES:

THESE DRAWINGS ARE ONLY FOR DELINEATING DIFFERENT REGIONS ANALYZED BY THE SWMM MODELING SOFTWARE



0 10 m 20 m

PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

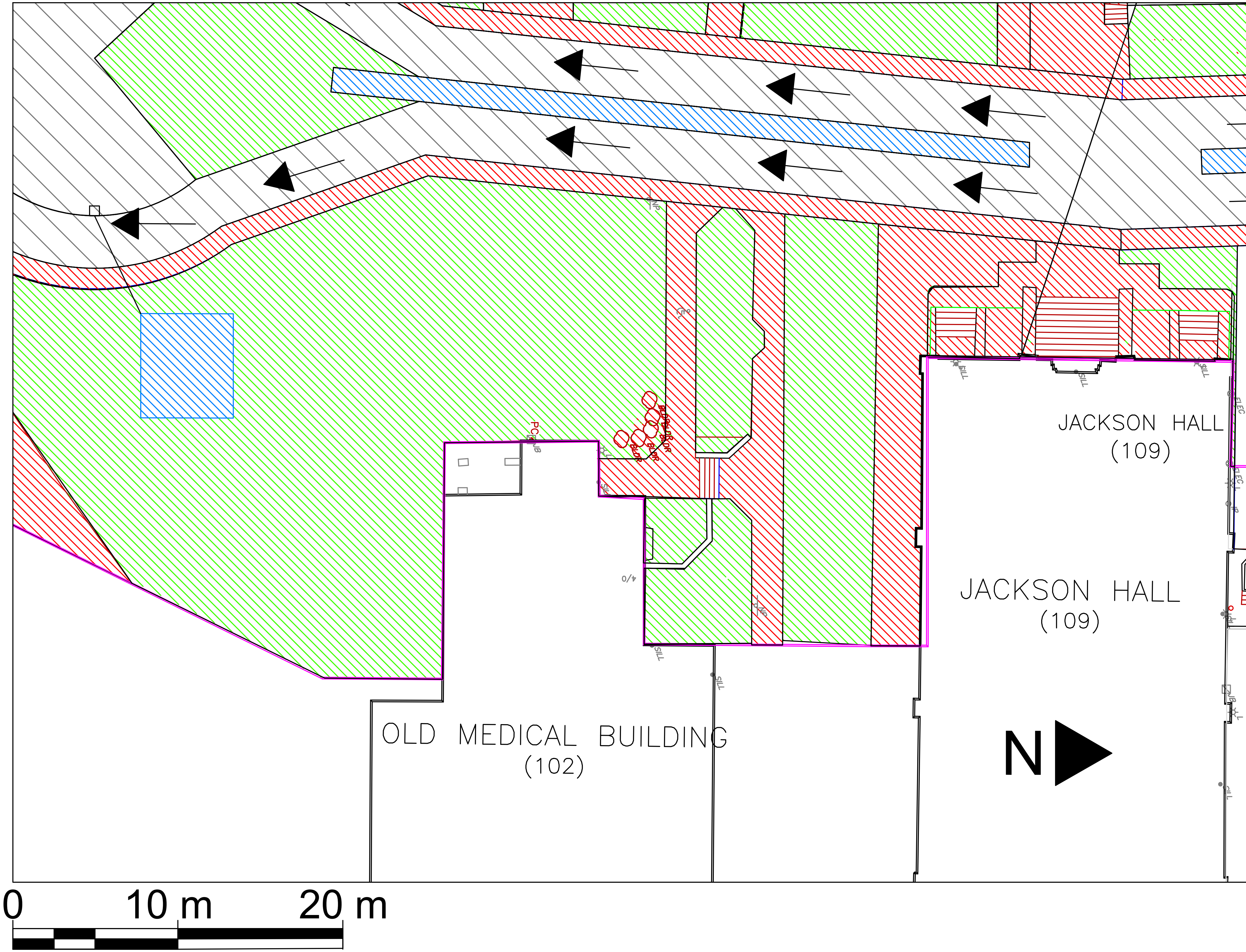
- INFILTRATION REGIONS:
- IMPERVIOUS REGIONS:
- BIOSWALE OR POND:
- PAVERS:
- SWMM ANALYSIS BOUNDARY:

DRAWING: 25
SWMM ANALYSIS LAYER DELINIATION: SURROUNDING CARRUTHERS HALL

DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: 1 : 240

NOTES:
THESE DRAWINGS ARE ONLY FOR DELINEATING DIFFERENT REGIONS ANALYZED BY THE SWMM MODELING SOFTWARE



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- INFILTRATION REGIONS:
- IMPERVIOUS REGIONS:
- BIOSWALE OR POND:
- PAVERS:
- SWMM ANALYSIS BOUNDARY:

DRAWING: 26

SWMM ANALYSIS LAYER DELINIATION: SURROUNDING OLD MEDICAL BUILDING AND JACKSON HALL

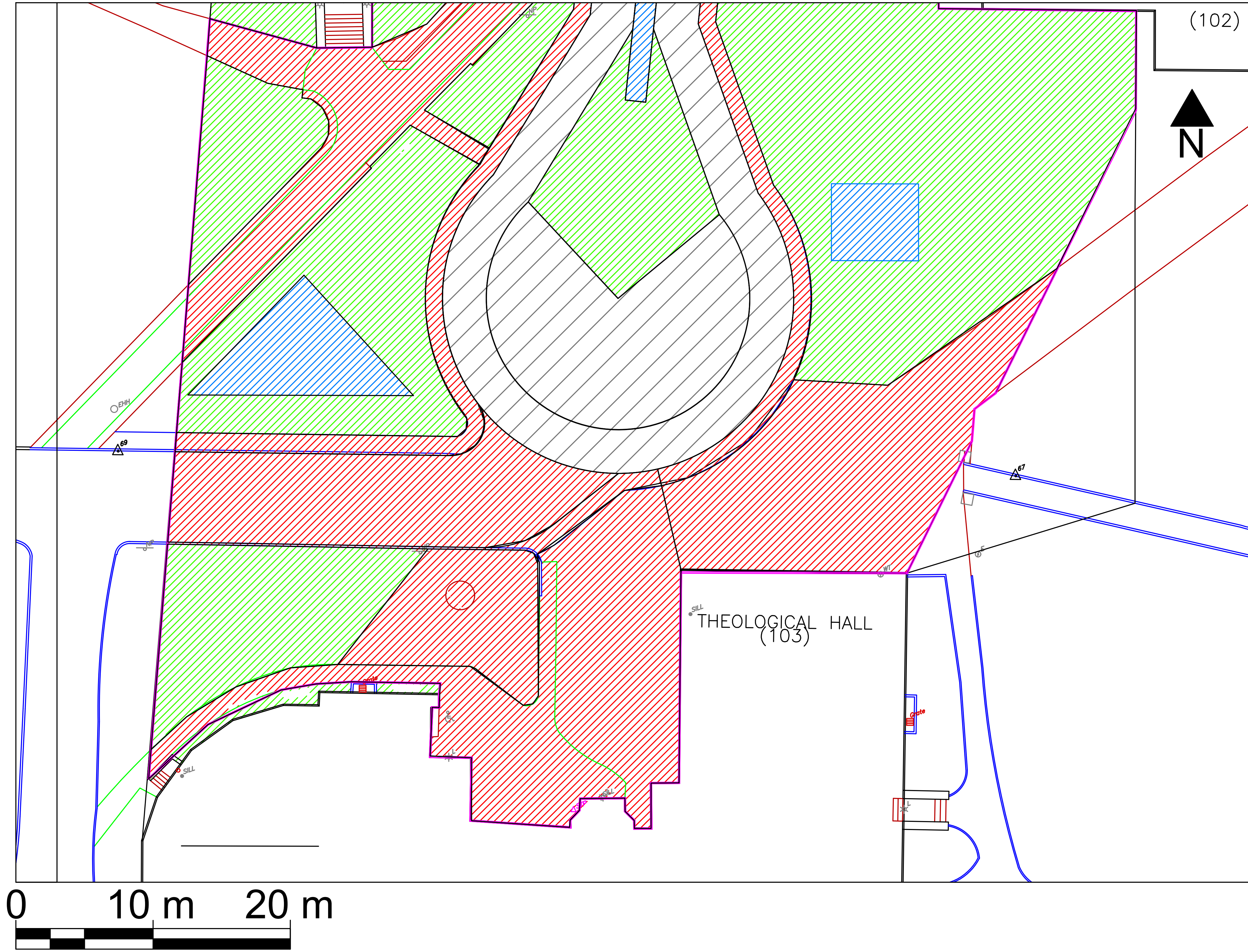
DRAFTER(S):

- JEAN-SEBASTIEN YOUNG

SCALE: 1 : 240

NOTES:
THESE DRAWINGS ARE ONLY FOR DELINEATING DIFFERENT REGIONS ANALYZED BY THE SWMM MODELING SOFTWARE

JEMS



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- INFILTRATION REGIONS:
- IMPERVIOUS REGIONS:
- BIOSWALE OR POND:
- PAVERS:
- SWMM ANALYSIS BOUNDARY:

DRAWING: 27

SWMM ANALYSIS LAYER DELINIATION: NORTH OF THEOLOGICAL HALL AND SOUTH OF CARRUTHER

DRAFTER(S):

- JEAN-SEBASTIEN YOUNG

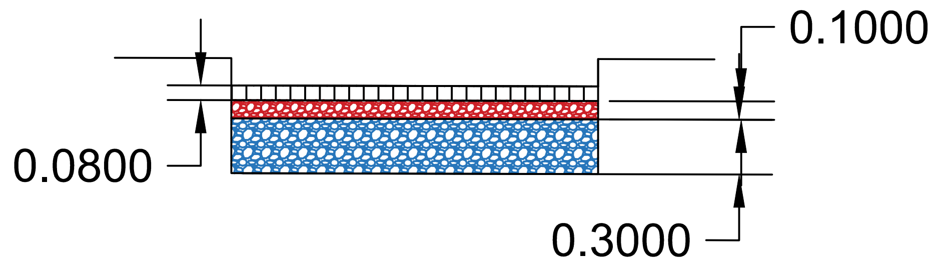
SCALE: 1 : 300

NOTES:

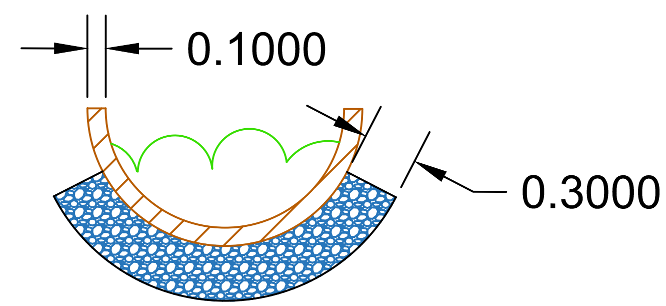
THESE DRAWINGS ARE ONLY FOR DELINEATING DIFFERENT REGIONS ANALYZED BY THE SWMM MODELING SOFTWARE

JEMS

PERMEABLE STONE PAVERS

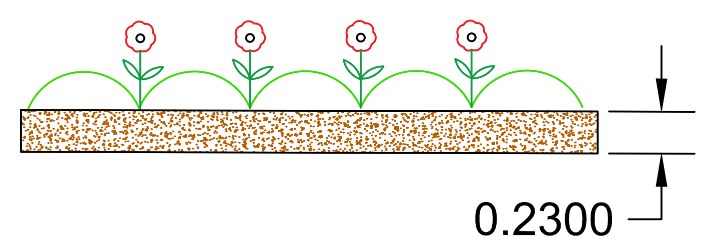


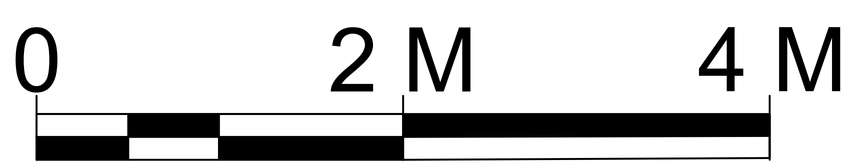
BIOSWALE



THESE ELEMENTS WERE USED IN THE ASSUMPTIONS FOR THE SWMM ANALYSIS

RAIN GARDENS





PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

- GRAVEL
- CLEARSTONE STORAGE LAYER
- TOPSOIL
- CONCRETE PAVERS

DRAWING: 28
SWMM ANALYSIS ELEMENTS DETAIL DRAWINGS

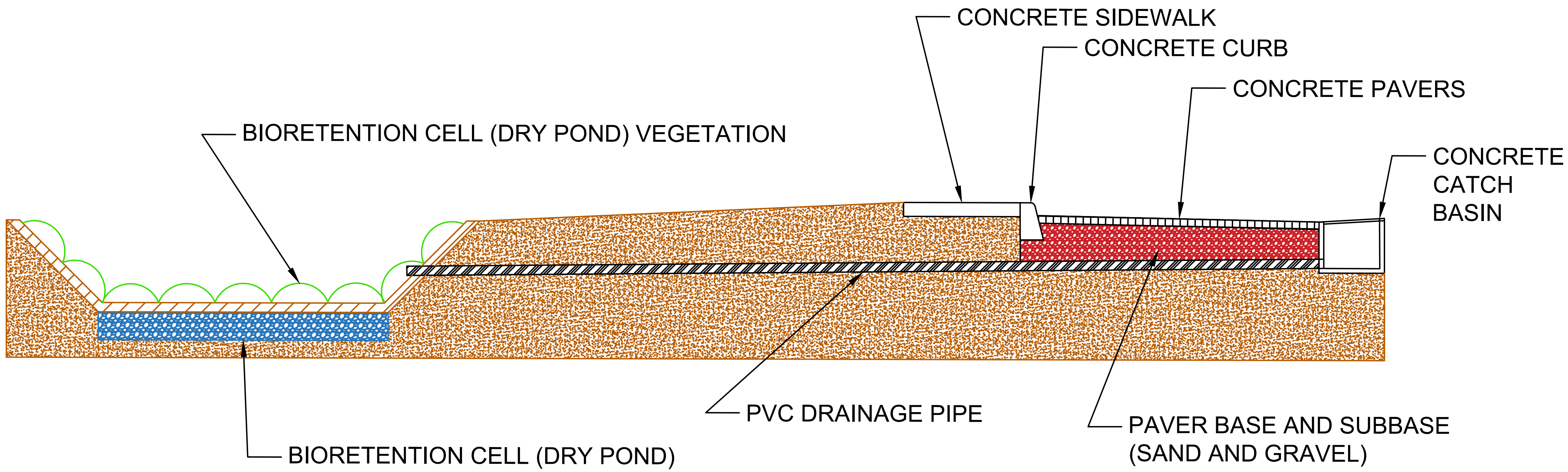
DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: NOT TO SCALE

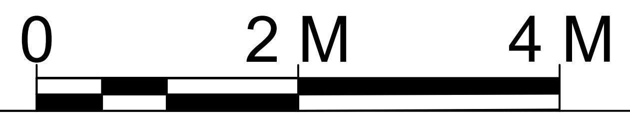
NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS

GENERAL DRAINAGE LAYOUT FOR THE CATCH BASINS IN
THE TURNAROUND POINT



PIPE LENGTH WILL VARY DEPENDING ON THE CATCH BASIN



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND:

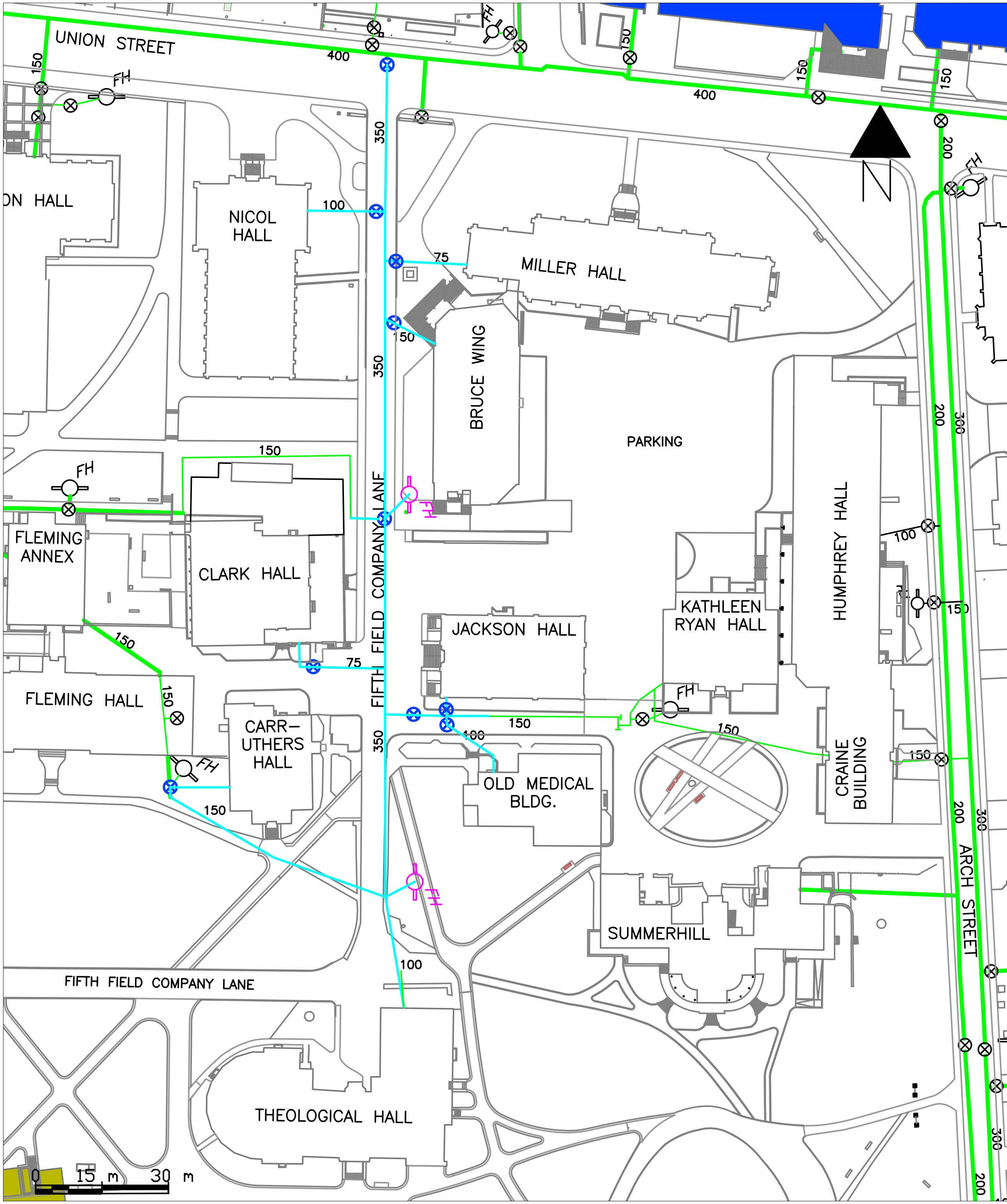
- GRAVEL
- CLEARSTONE STORAGE LAYER
- TOPSOIL / EXISTING SOIL
- CONCRETE PAVERS
- BIORETENTION SOIL
- PVC PIPE

DRAWING: 29
THE DRAINAGE LAYOUT FOR THE CATCH BASINS IN THE TURNAROUND POINT

DRAFTER(S):
- JEAN-SEBASTIEN YOUNG

SCALE: NOT TO SCALE

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED



PROJECT: 5TH FIELD COMPANY LANE REDESIGN

LEGEND

⊗	WATER VALVE
FH	FIRE HYDRANT
⊗	NEW WATER VALVE
FH	NEW FIRE HYDRANT
⊕ WM	WATER METER
△ STP	SIAMESE CONNECTION (STAND PIPE)
▲ SPR	SIAMESE CONNECTION (SPRINKLER)
(green line)	WATER MAIN
(magenta line)	WATER MAIN ABANDONED
(cyan line)	NEW WATER MAIN
(red line)	PIPE FOR REMOVAL
⊗	WATER VALVE FOR REMOVAL
FH	FIRE HYDRANT FOR REMOVAL

DRAWING: 30

NEW WATER MAIN LAYOUT

DRAFTER(S):
- PPS STAFF

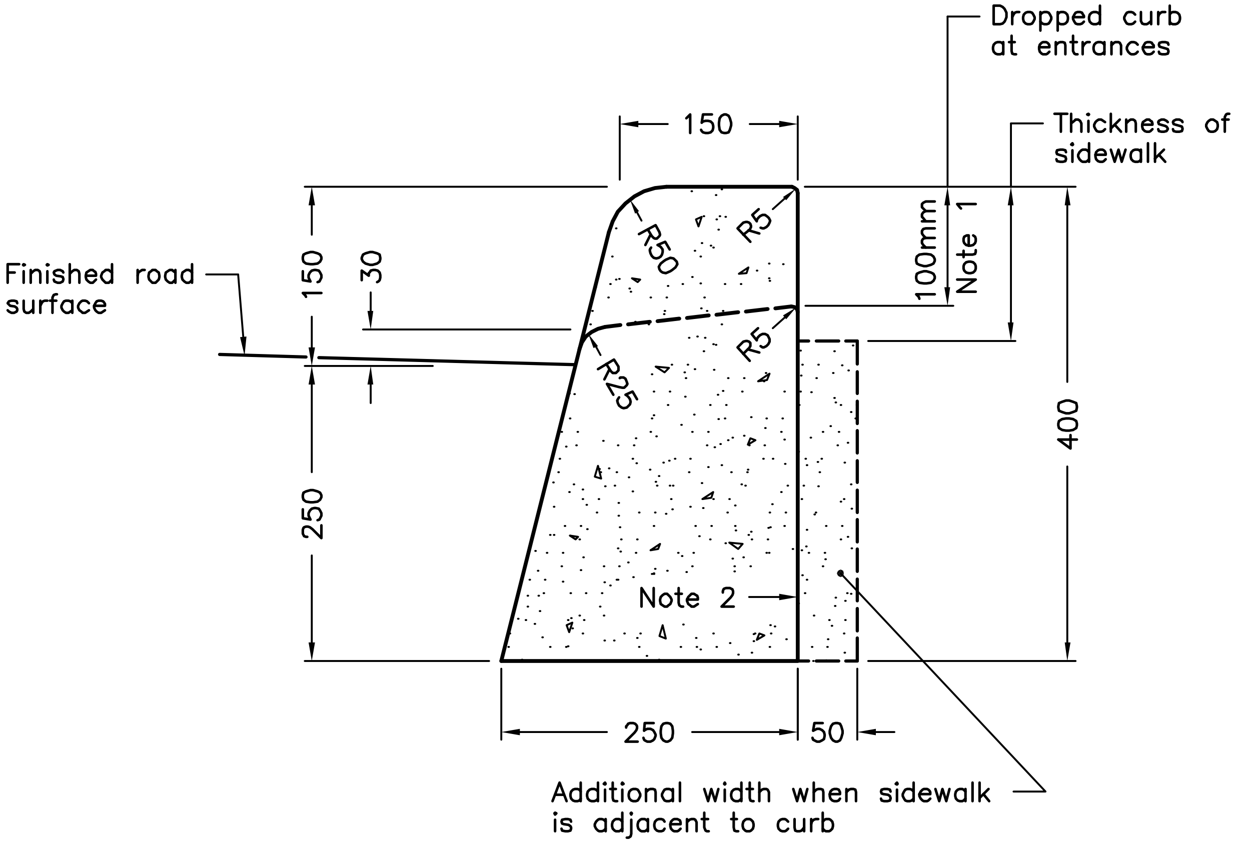
MODIFIED BY
- JEAN-SEBASTIEN YOUNG

SCALE: NOT TO SCALE

NOTES:
ALL MEASUREMENTS ARE IN METERS UNLESS MENTIONED

JEMS

The following drawings are not the work of *JEMS Consulting*, but the accommodating OPSDs that are necessary for the completion of the project.

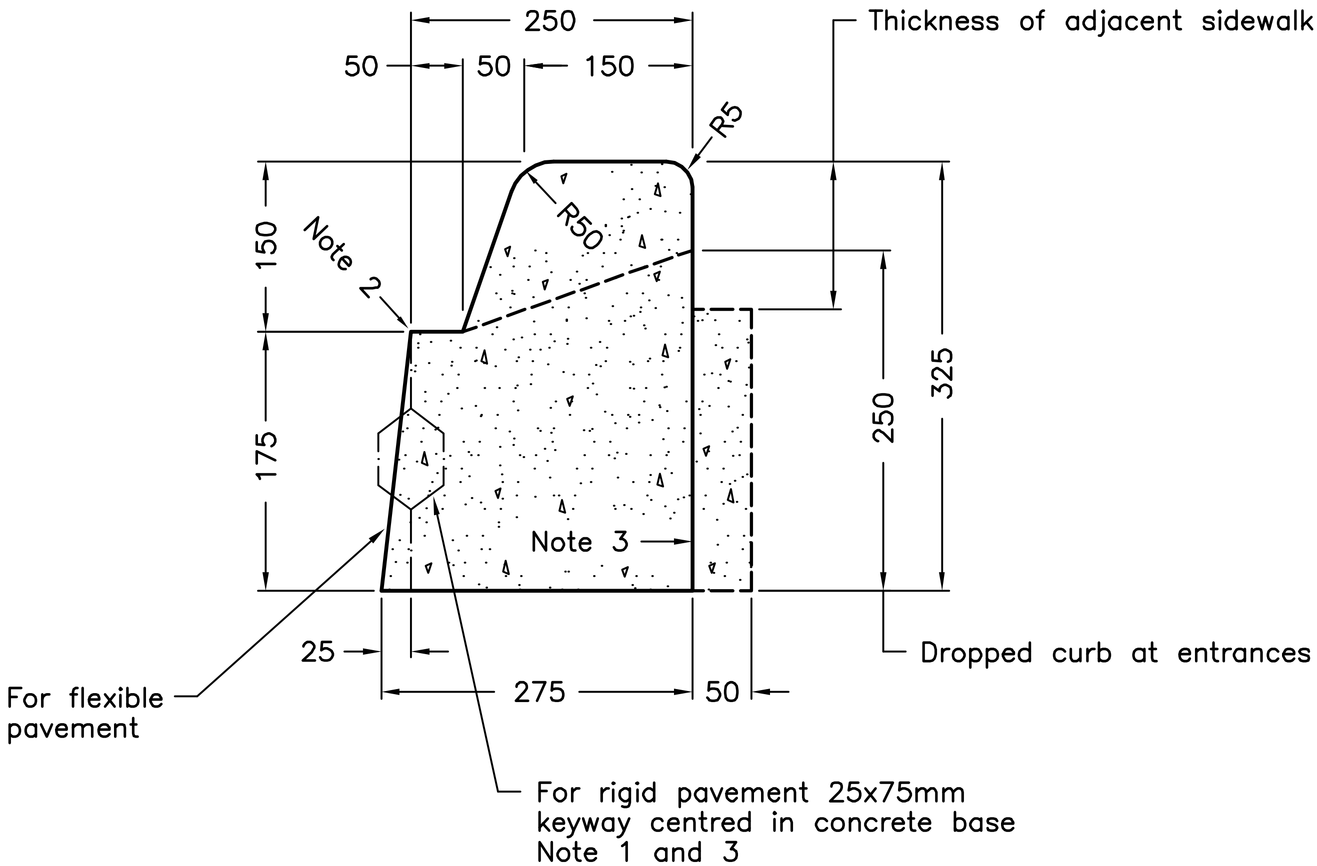


NOTES:

1 When sidewalk is continuously adjacent, the dropped curb at entrances shall be reduced to 75mm.
2 For slipforming procedure a 5% batter is acceptable.

A Treatment at entrances shall be according to OPSD 351.010.
B Outlet treatment shall be according to the OPSD 610 Series.
C The transition from one curb type to another shall be a minimum length of 3.0m, except in conjunction with guide rail where it shall be according to the OPSD 900 Series.
D All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2012	Rev 2
CONCRETE BARRIER CURB		
	OPSD 600.110	



NOTES:

1 When curb and gutter is adjacent to concrete pavement or base, this drawing shall be used in conjunction with OPSD 552.010 and 552.020.

2 Flexible and composite pavement shall be placed 5mm above the adjacent edge of gutter.

3 For slipforming procedure a 5% batter is acceptable.

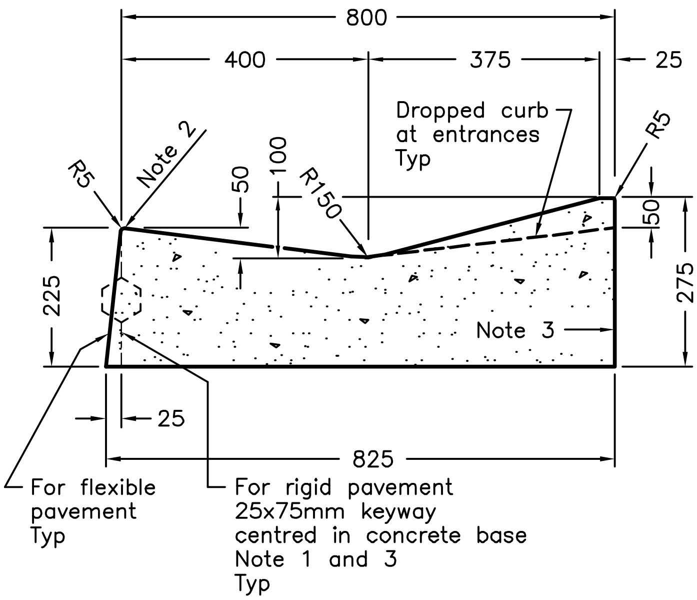
A Treatment at entrances shall be according to OPSD 351.010.

B Outlet treatment shall be according to the OPSD 610 Series.

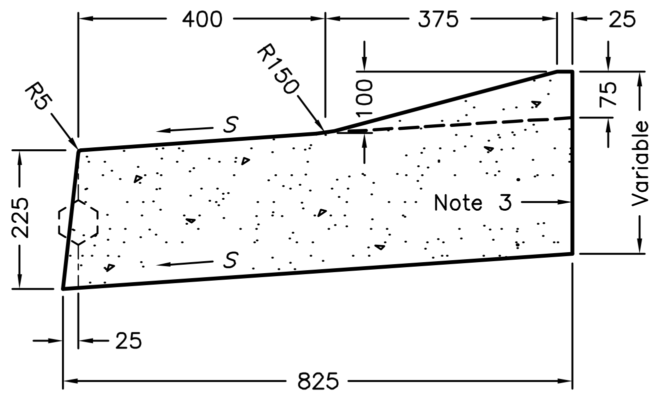
C The transition from one curb type to another shall be a minimum length of 3.0m, except in conjunction with guide rail where it shall be according to the OPSD 900 Series.

D All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2012	Rev 2
CONCRETE BARRIER CURB WITH NARROW GUTTER		
	OPSD 600.080	



TANGENT



SUPERELEVATED

LEGEND:

S – Rate of pavement superelevation in percent, %.

NOTES:

1 When curb and gutter is adjacent to concrete pavement or base, this drawing shall be used in conjunction with OPSD 552.010 and 552.020.

2 Flexible and composite pavement shall be placed 5mm above the adjacent edge of gutter.

3 For slipforming procedure a 5% batter is acceptable.

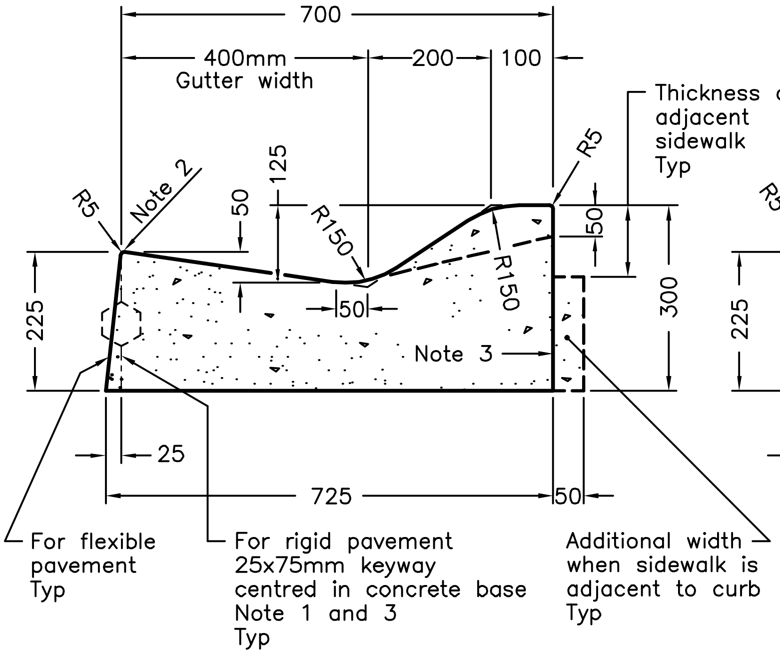
A Treatment at entrances shall be according to OPSD 351.010.

B Outlet treatment shall be according to the OPSD 610 Series.

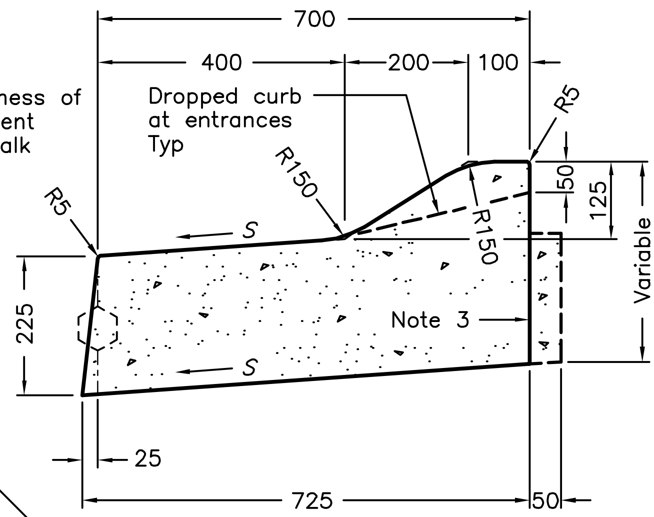
C The transition from one curb type to another shall be a minimum length of 3.0m, except in conjunction with guide rail where it shall be according to the OPSD 900 Series.

D All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2012	Rev 2
CONCRETE MOUNTABLE CURB WITH WIDE GUTTER	OPSD 600.030	



TANGENT



SUPERELEVATED

LEGEND:

S – Rate of pavement superelevation in percent, %.

NOTES:

1 When curb and gutter is adjacent to concrete pavement or base, this drawing shall be used in conjunction with OPSD 552.010 and 552.020.

2 Flexible and composite pavement shall be placed 5mm above the adjacent edge of gutter.

3 For slipforming procedure a 5% batter is acceptable.

A Treatment at entrances shall be according to OPSD 351.010.

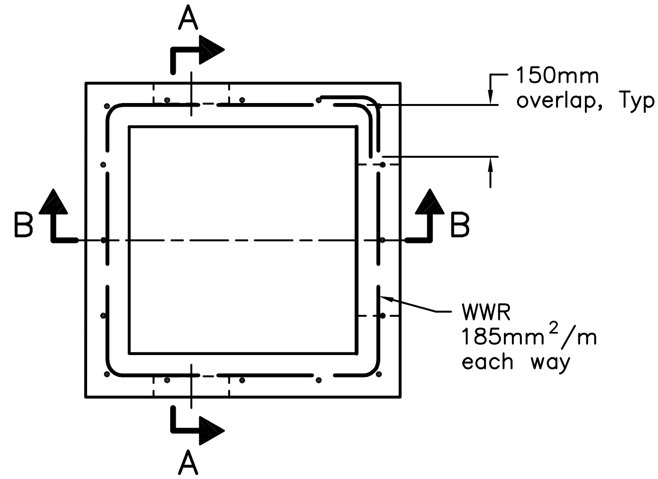
B Outlet treatment shall be according to the OPSD 610 Series.

C The transition from one curb type to another shall be a minimum length of 3.0m, except in conjunction with guide rail where it shall be according to the OPSD 900 Series.

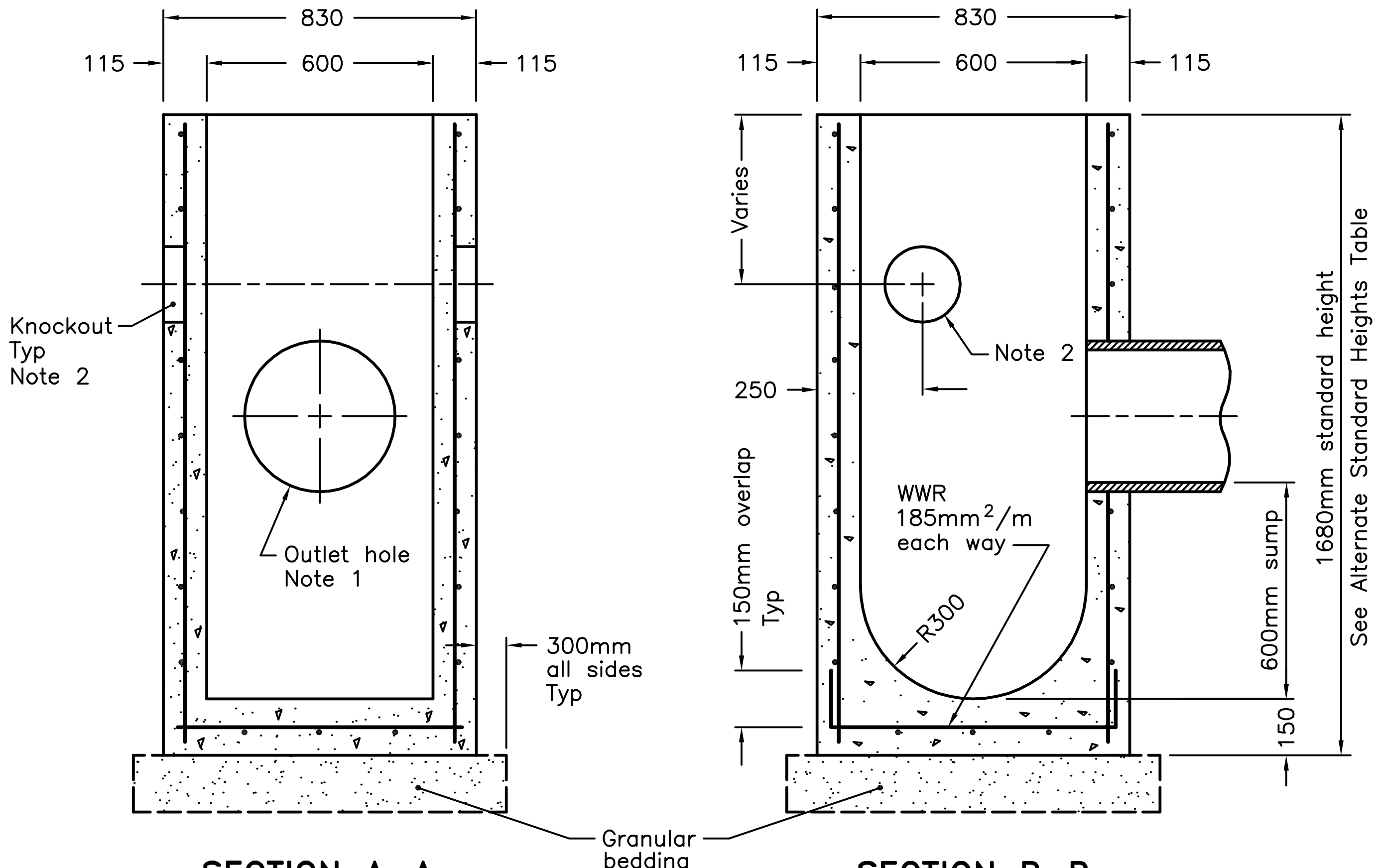
D All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2012	Rev 2
CONCRETE SEMI–MOUNTABLE CURB WITH WIDE GUTTER		
	OPSD 600.020	

ALTERNATE STANDARD HEIGHTS	
ALTERNATIVE	DIMENSION
A	1980
B	1830
C	1520
D	1380



PLAN



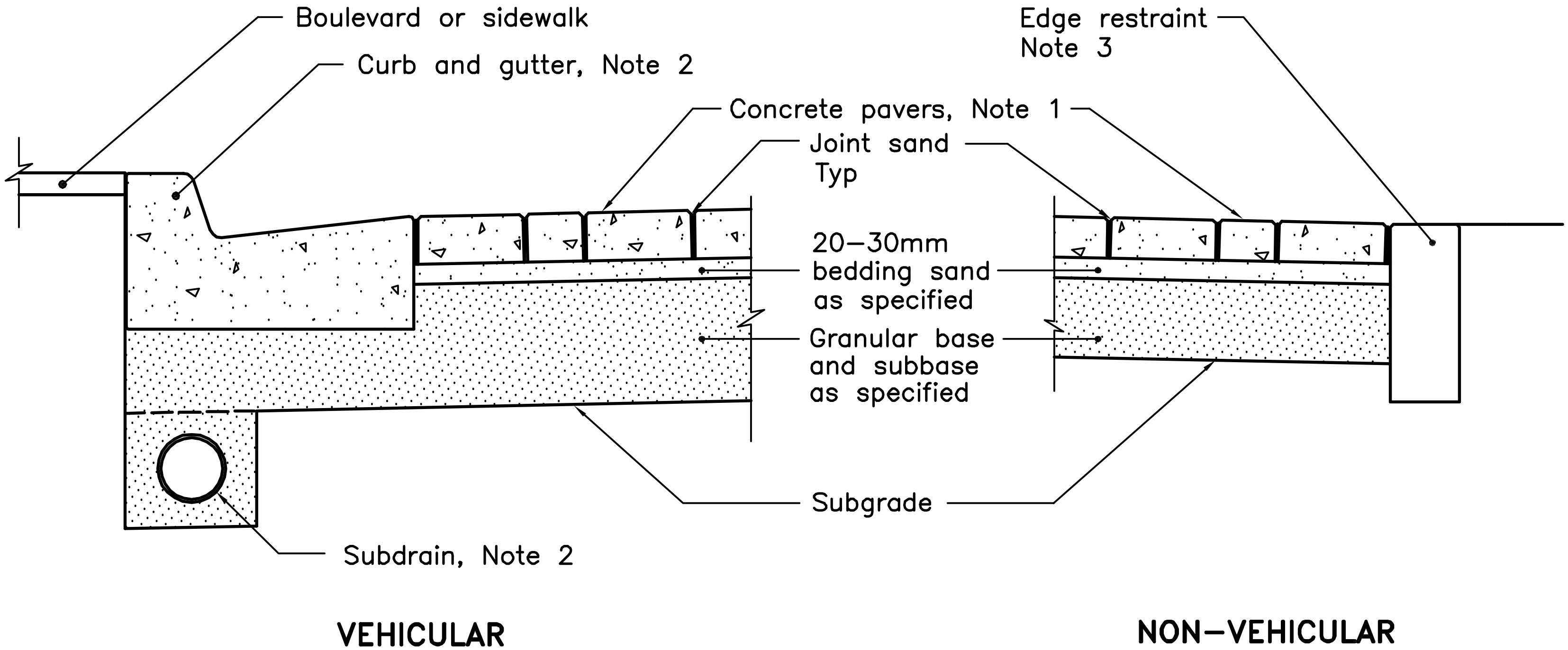
SECTION A–A

SECTION B–B

NOTES:

1 Outlet hole size 525mm diameter maximum, location as required.
2 200mm diameter knockout to accommodate subdrain. Knockout shall be 60mm deep.
A Centre reinforcing in base slab and walls ±20mm.
B Granular backfill shall be placed to a minimum thickness of 300mm all around the catch basin.
C Frame, grate, and adjustment units shall be installed according to OPSD 704.010.
D Pipe support shall be according to OPSD 708.020.
E All dimensions are nominal.
F All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2019	Rev 4
PRECAST CONCRETE CATCH BASIN 600x600mm		**OPSD 705.010**



NOTES:

1 Concrete paver thickness:
   – for vehicular traffic – 80mm minimum.
   – for non–vehicular traffic – 60mm minimum.

2 This OPSD shall be read in conjunction with OPSD 200 and 600 series drawings.

3 Edge restraint according to manufacturer's requirements.

A All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2016	Rev 2
INTERLOCKING CONCRETE PAVERS ON GRANULAR BASE		
	OPSD 561.010	

Appendix E – Final Cost Estimation

Table 28: Material Cost Breakdown

Material Costs					
Material	Unit Price	Unit	Quantity	Price	Reference
Laneway					
Asphalt	$34.00	m^2	430	$14,620.00	(Municipality of Smiths Falls 2019)
Concrete (Curbs and Sidewalks)	$181.00	m^3	210	$38,010.00	(Dufferin Concrete 2019)
80 mm Concrete paver stones	$215.00	m^2 (average)	1524	$327,660.00	(Homeguide 2020)
Gravel (Road and Sidewalk Base)	$53.63	m^3	175	$9,385.25	(Manotick Gardens & Landscaping Supplies 2020)
Landscaping					
Trees	$325.00	unit (average)	20	$6,500.00	(Connon Nurseries 2020)
Sod	$21.53	m^2 (average)	500	$10,765.00	(Ontario Contractors 2020)
Topsoil	$300.00	Truck Load (assuming approx. 7 to 10 m^3 depending on the truck)	3	$900.00	(Earthco (G&L) 2019)
Plants	$85.00	unit (average)	50	$4,250.00	(Connon Nurseries 2020)
Social Infrastructure					
Benches	$950.00	unit (average)	7	$6,650.00	(Barco Products Canada 2019a)
Picnic Tables	$1,100	unit (average)	24	$26,400.00	(Barco Products Canada 2019b)
SWM System					
1" Clear Stone (LID storage)	$44.47	m^3	556.2	$24,734.21	(Bayridge Lanscaping 2021)
Bioretention Soil	$59.00	m^3	75	$4,425.00	(Earthco (G&L) 2019)
100mm diameter DR35 PVC Pipe (Retention Cell Inlet)	$305.00	m	31	$9,455.00	(Filion 2021)
600mm x 600mm x 1m Concrete Catch Basin	$519.00	unit (average)	2	$1037.00	(Concast Pipe 2020)
Watermains					
400mm diameter DR18 PVC Pressure Pipe (Mainline)	$550.00	m	244.16	$134,288.00	(Filion 2021)
150mm diameter DR18 PVC Pressure Pipe (Services)	$350.00	m	125.95	$44,082.50	(Filion 2021)
Miscellaneous					
Signage	$150.00	unit	15	$2,250.00	(Moeur 2021)
Road Paint	$1.00	m	30	$30.00	(City of Kingston 2021)
Garbage Compactors	$13,500.00	unit (average)	2	$27,000.00	(Global Trash Solutions 2021)
			Total Material Price:	**$692,441.96**	

Table 29 below summarizes the total labor and processing costs for the implementation of this design.

Table 29: Labor/Process Cost Breakdown

Labor and Process Costs						
Labor/Process	Unit Price	Unit	Predicted Quantity	Price	Description	Reference
Masons	$25.00	hour/mason	600	$15,000.00	3-person crew over 4 weeks to pave laneway	(Payscale 2020a)
Paving Crew	$18.00	hour/crew member	120	$2,160.00	4-person crew over 3 days	(Payscale 2020b)
Pipe Layers	$27.00	hour/crew member	400	$10,800.00	4-person crew over 2 weeks	(Indeed 2021)
Trench and Swale Excavation	$30.00	m^3	1696.9	$50,907.00	Cumulative volume of watermain trenches and required storage space for LID Technology	(Stantec 2017)
Fire Hydrant Reinstallation	$27.00	hour/crew member	6	$162.00	4-person crew at 3 hours/hydrant	N/A
Sanitary Sewer Pipe Removal and Replacement	N/A	m	258	$311,515.00	Removal and reinstallation of sanitary pipe based off of comparable project	(Queen's University 2017)
Total Labor/Process Cost:				**$390,544.00**		

Table 30 below summarizes the invoicing for the work completed by *JEMS Consulting* for the completion of the design and preparation of the Final Report.

Table 30: JEMS Consulting Final Invoice

JEMS Consulting Invoicing				
Work Completed	Example Tasks	Hours	Unit Price	Cost
Background Research	• Researching rates and prices for goods and services • Regulations pertinent to the project	49	$130.00	$6,370.00
Meetings	• Preparation of a final report summarizing the design process and requirements	208	$130.00	$27,040.00

Design Work	• Drafting by hand or in AutoCAD • Design calculations • SWMM 5.1 Modelling • EPANet 2.2 Modelling	84	$145.00	$12,180.00
Report Writing	• Preparation of a final report summarizing the design process and requirements	207	$145.00	$30,015.00
Report Editing and Formatting	• Correcting grammar • Organizing the report • Creating and labelling tables and figures	191	$145.00	$27,695.00
Correspondence	• Writing and editing emails	7	$130.00	$910.00
Administrative Work	• Reorganizing the Gantt Chart • File creation and archiving	17	$130.00	$2,210.00
Other	• N/A	16	$130.00	$2080.00
			Total Invoice:	$108,500.00

The rates used to calculate the invoice are taken from the OSPE Fee Guidelines (OPSE 2012).

Appendix F – Modelling Results

SWMM 5.1 Direct Runoff Summaries

The tables below show the SWMM 5 outputs for all six runoff models completed as part of the SWM system analysis.

Table 31: Runoff Produced for Moderate Intensity Storm Under Initial Conditions

Moderate Intensity Storm		
Time (hours)	Runoff (L/s)	Runoff (m^3/s)
0	0	0
0.25	0	0
0.5	0	0
0.75	0	0
1	0	0
1.25	67.3	0.06728
1.5	95.6	0.09555
1.75	108.3	0.10827
2	117.1	0.11705
2.25	81.6	0.08155
2.5	76.6	0.07655
2.75	75.7	0.07568
3	75.9	0.07586
3.25	76.3	0.07634
3.5	76.9	0.0769
3.75	77.5	0.07746
4	78	0.07798
4.25	78.5	0.07846
4.5	78.9	0.0789
4.75	79.29	0.07929
5	79.64	0.07964
5.25	60.13	0.06013
5.5	55.33	0.05533
5.75	53.5	0.0535
6	52.68	0.05268

Table 32: Runoff Produced for Heavy Intensity Storm Under Initial Conditions

Heavy Intensity Storm		
Time (hours)	Runoff (L/s)	Runoff (m^3/s)
0	0	0
0.25	0	0
0.5	0	0
0.75	0	0
1	0	0
1.25	97	0.09697
1.5	133.4	0.13335
1.75	150.3	0.150311
2	161.3	0.16127
2.25	196.3	0.19626
2.5	200.1	0.20012
2.75	204.7	0.20469
3	207.4	0.20742
3.25	185.9	0.18591
3.5	183.2	0.18316
3.75	182.8	0.1828
4	183	0.18304
4.25	206.8	0.20683
4.5	211.5	0.21145
4.75	213.3	0.21329
5	214.3	0.21428
5.25	439.5	0.43952
5.5	472.8	0.47277
5.75	482.4	0.48239
6	485.7	0.48565

Table 33: Runoff Produced for Very Heavy Intensity Storm Under Initial Conditions

Very Heavy Intensity Storm		
Time (hours)	Runoff (L/s)	Runoff (m^3/s)
0	0	0
0.25	0	0
0.5	0	0
0.75	0	0
1	0	0
1.25	401.8	0.40183
1.5	499.2	0.49915
1.75	537.8	0.53778
2	554.4	0.55438
2.25	789.1	0.78911
2.5	815.8	0.81578
2.75	823.7	0.82369
3	827.1	0.82713
3.25	802.1	0.80206
3.5	801	0.80104
3.75	801.7	0.80174
4	802.6	0.80262
4.25	370.9	0.37086
4.5	325.6	0.32561
4.75	313.6	0.3136
5	309.7	0.30971
5.25	435.2	0.43523
5.5	452.1	0.45205
5.75	456.8	0.45684
6	458.5	0.4585

Table 34: Runoff Produced for Climate Change Storm Under Initial Conditions

Climate Change Storm		
Time (hr)	Runoff (L/s)	Runoff (m^3/s)
0	0	0
0.25	0	0
0.5	0	0
0.75	0	0
1	0	0
1.25	86.9	0.08685
1.5	120.6	0.12054
1.75	136.1	0.13614
2	146.5	0.14645
2.25	101.4	0.10137
2.5	95.1	0.09514
2.75	93.9	0.0939
3	93.9	0.09394
3.25	94.4	0.09437
3.5	94.9	0.09492
3.75	95.5	0.09548
4	96	0.09601
4.25	96.5	0.0965
4.5	96.9	0.09694
4.75	97.3	0.09733
5	97.7	0.09769
5.25	73.4	0.07336
5.5	67.7	0.06773
5.75	65.6	0.06563
6	64.7	0.0647

Table 35: Runoff Produced for Moderate Intensity Storm Under Final Conditions

Moderate Intensity Storm		
Time (hours)	Runoff (L/s)	Runoff (m^3/s)
0	0	0
0.25	0	0
0.5	0	0
0.75	0	0
1	0	0
1.25	23	0.02302
1.5	25.1	0.0251
1.75	25.6	0.02558
2	25.8	0.02575
2.25	15.3	0.01527
2.5	15.2	0.0152
2.75	19.6	0.01956
3	19.6	0.01957
3.25	19.6	0.01957
3.5	19.6	0.01957
3.75	22.	0.02264
4	22.6	0.02264
4.25	22.6	0.02264
4.5	22.6	0.02264
4.75	22.6	0.02264
5	22.6	0.02264
5.25	16.9	0.01693
5.5	18.9	0.01885
5.75	18.8	0.01883
6	18.84	0.01884

Table 36: Runoff Produced for Heavy Intensity Storm Under Final Conditions

Heavy Intensity Storm		
Time (hours)	Runoff (L/s)	Runoff (m^3/s)
0	0	0
0.25	0	0
0.5	0	0
0.75	0	0
1	0	0
1.25	31.2	0.03116
1.5	33.1	0.03312
1.75	33.6	0.03357
2	33.7	0.03374
2.25	50.3	0.0503
2.5	56.4	0.05637
2.75	58.3	0.05834
3	58.3	0.05834
3.25	65	0.06503
3.5	64.9	0.06486
3.75	64.9	0.06488
4	64.9	0.0649
4.25	75	0.07495
4.5	75.2	0.07517
4.75	75.2	0.07518
5	75.2	0.07519
5.25	166.5	0.16654
5.5	167.4	0.16743
5.75	167.4	0.16744
6	167.6	0.16759

Table 37: Runoff Produced for Very Heavy Intensity Storm Under Final Conditions

Very Heavy Intensity Storm		
Time (hours)	Runoff (L/s)	Runoff (m^3/s)
0	0	0
0.25	0	0
0.5	0	0
0.75	0	0
1	0	0
1.25	118.4	0.11837
1.5	121	0.121
1.75	153.2	0.1532
2	197.7	0.19767
2.25	284.7	0.28465
2.5	285.1	0.2851
2.75	285.2	0.28515
3	303.6	0.30362
3.25	296.8	0.29678
3.5	296.8	0.29676
3.75	296.8	0.29678
4	296.8	0.29679
4.25	115.7	0.11571
4.5	114.3	0.11429
4.75	114.3	0.11428
5	114.3	0.11429
5.25	169.1	0.16913
5.5	169.8	0.16975
5.75	169.8	0.16975
6	169.8	0.16975

Table 38: Runoff Produced for Climate Change Storm Under Final Conditions

Climate Change Storm		
Time (hr)	Runoff (L/s)	Runoff (m^3/s)
0	0	0
0.25	0	0
0.5	0	0
0.75	0	0
1	0	0
1.25	28.5	0.02845
1.5	30.5	0.03045
1.75	30.9	0.03091
2	31.1	0.03108
2.25	18.6	0.01856
2.5	23.7	0.02368
2.75	23.7	0.02368
3	23.9	0.02389
3.25	27.4	0.0274
3.5	27.4	0.0274
3.75	27.4	0.0274
4	27.4	0.0274
4.25	27.4	0.0274
4.5	35.2	0.03518
4.75	35.2	0.0352
5	35.2	0.03521
5.25	23.5	0.02351
5.5	23	0.02296
5.75	22.9	0.02294
6	22.9	0.02294

Water Demand for Buildings

Table 39: Building Water Demand by Month

Building	Bruce & Miller	Carruthers Hall	Clark Hall	Jackson Hall	Nicol Hall	Old Medical Building	Theological Hall		
Monthly Consumption (m³/s)	3	4	198	63	578	246	5		
	7	5	215	58	365	270	21		
	7	43	359	69	425	307	12		
	10	7	410	62	491	301	11		
	7	8	434	75	426	350	15		
	3	24	341	74	436	288	28		
	3	2	227	42	64	134	5		
	2	11	184	57	60	92	10		
	9	4	150	32	59	35	2		
	12	24	287	46	79	31	34		
	4	39	383	267	77	38	65		
	2	31	404	313	153	47	115		
	4	19	223	332	74	50	30		
	8	34	335	361	88	69	74		
	7	28	536	450	463	91	59		
	11	23	667	575	302	95	68		
	5	17	430	506	603	212	43		
	1	11	335	302	854	234	30		
	4	22	236	315	120	36	23		
	2	17	489		404	41	19		
	5	119	511		143	33	66		
	15	56	317		120	43	52		
	7	26	302		105	35	36		
	5	27	311		119	36	44		
	7	16	168		93	27	29		
	9	50	543		269	45	63		
Maximum Monthly Consumption (m³/s)	15.00	119.00	667.00	575.00	854.00	350.00	115.00	**Total**	2695.00

Industrial, Commercial, and Institutional (ICI) Diurnal Peaking Pattern

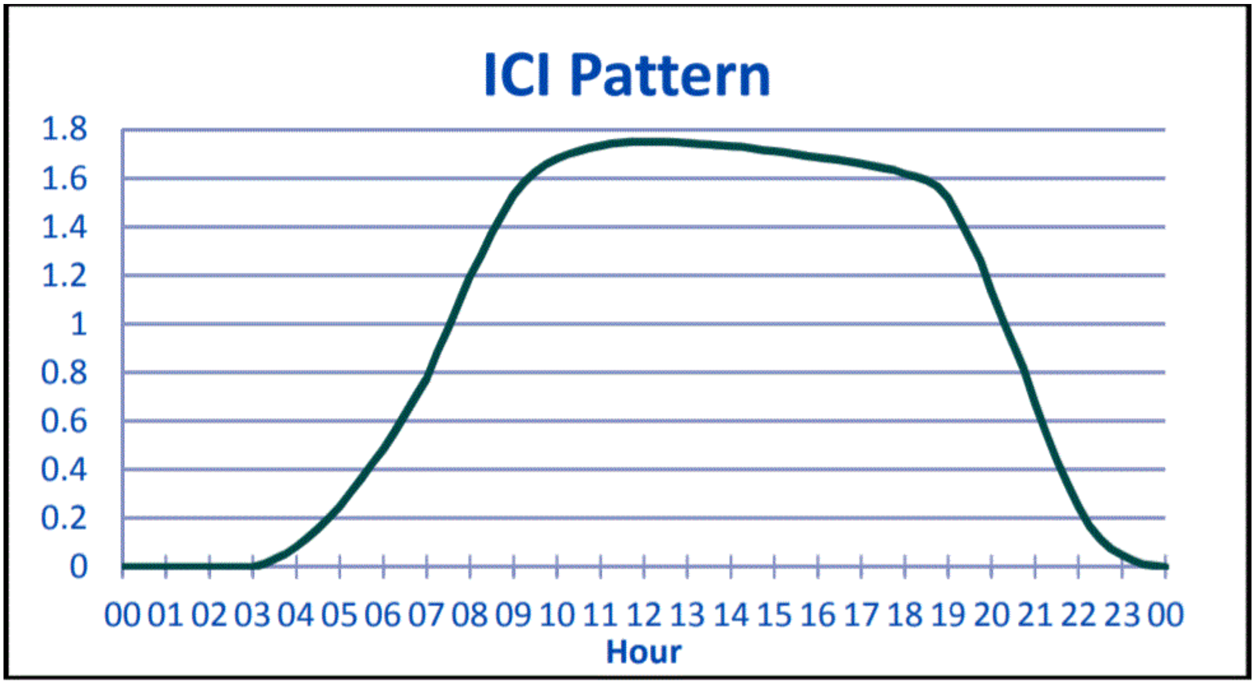


Figure 45: ICI Pattern for Utilities Kingston (Utilities Kingston 2017)

EPANet Results

Table 40: 0-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	578.4
3	0.33	578.4
4	1.03	578.4
5	1.03	578.4
6	1.03	578.4
7	1.03	578.4
8	0.04	578.4
9	0.05	578.4
10	0.22	578.4
11	0.13	578.4
12	1.03	578.4
13	1.03	578.4
14	0.25	578.4
15	1.03	578.4

Table 41: 1-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	578.4
3	0.33	578.4
4	1.03	578.4
5	1.03	578.4
6	1.03	578.4
7	1.03	578.4
8	0.04	578.4
9	0.05	578.4
10	0.22	578.4
11	0.13	578.4
12	1.03	578.4
13	1.03	578.4
14	0.25	578.4
15	1.03	578.4

Table 42: 2-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	578.4
3	0.33	578.4
4	1.03	578.4
5	1.03	578.4
6	1.03	578.4
7	1.03	578.4
8	0.04	578.4
9	0.05	578.4
10	0.22	578.4
11	0.13	578.4
12	1.03	578.4
13	1.03	578.4
14	0.25	578.4
15	1.03	578.4

Table 43: 3-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	578.4
3	0.33	578.2
4	1.03	578.2
5	1.03	578.2
6	1.03	578.2
7	1.03	578.2
8	0.04	578.2
9	0.05	578.2
10	0.22	578.4
11	0.13	578.2
12	1.03	578.2
13	1.03	578.4
14	0.25	578.2
15	1.03	578.2

Table 44: 4-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	578.2
3	0.33	577.4
4	1.03	577.1
5	1.03	578.1
6	1.03	577.3
7	1.03	577.3
8	0.04	577.3
9	0.05	577.3
10	0.22	578.3
11	0.13	578.4
12	1.03	577.3
13	1.03	577.3
14	0.25	578.4
15	1.03	589

Table 45: 5-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	578.4
3	0.33	573.9
4	1.03	572.8
5	1.03	572.8
6	1.03	573.6
7	1.03	573.6
8	0.04	573.7
9	0.05	578.2
10	0.22	573.7
11	0.13	578.4
12	1.03	573.6
13	1.03	578.4
14	0.25	573.6
15	1.03	583

Table 46: 6-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	574.7
3	0.33	562.7
4	1.03	558.5
5	1.03	558.6
6	1.03	561.7
7	1.03	561.7
8	0.04	561.8
9	0.05	577.7
10	0.22	561.9
11	0.13	578.3
12	1.03	561.2
13	1.03	570.1
14	0.25	578.4
15	1.03	570.1

Table 47: 7-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	569.7
3	0.33	541.3
4	1.03	531.8
5	1.03	531.8
6	1.03	539.1
7	1.03	539.1
8	0.04	539.3
9	0.05	576.7
10	0.22	539.5
11	0.13	578.3
12	1.03	578.3
13	1.03	537.1
14	0.25	571.6
15	1.03	545.7

Table 48: 8-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	563.6
3	0.33	515.2
4	1.03	499
5	1.03	499.1
6	1.03	511.5
7	1.03	511.6
8	0.04	511.9
9	0.05	575.4
10	0.22	512.3
11	0.13	578.2
12	1.03	578.2
13	1.03	578.1
14	0.25	508
15	1.03	515.9

Table 49: 9-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	559.3
3	0.33	497.2
4	1.03	476.4
5	1.03	476.5
6	1.03	492.5
7	1.03	492.6
8	0.04	492.9
9	0.05	574.5
10	0.22	493.4
11	0.13	493.9
12	1.03	578.2
13	1.03	578.4
14	0.25	488
15	1.03	495.3

Table 50: 10-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	558.2
3	0.33	492.3
4	1.03	470.3
5	1.03	470.4
6	1.03	487.4
7	1.03	487.5
8	0.04	487.8
9	0.05	574.2
10	0.22	488.4
11	0.13	578.2
12	1.03	578.4
13	1.03	482.6
14	0.25	576.7
15	1.03	489.7

Table 51: 11-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	558.2
3	0.33	492.3
4	1.03	470.3
5	1.03	470.4
6	1.03	487.4
7	1.03	487.5
8	0.04	487.8
9	0.05	574.2
10	0.22	488.4
11	0.13	578.2
12	1.03	578.4
13	1.03	482.6
14	0.25	576.7
15	1.03	489.7

Table 52: 12-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	558.8
3	0.33	494.7
4	1.03	473.3
5	1.03	473.5
6	1.03	489.9
7	1.03	490
8	0.04	490.3
9	0.05	574.3
10	0.22	575
11	0.13	491
12	1.03	578.2
13	1.03	578.3
14	0.25	485.3
15	1.03	492.6

Table 53: 13-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	558.8
3	0.33	494.7
4	1.03	473.3
5	1.03	473.5
6	1.03	489.9
7	1.03	490
8	0.04	490.3
9	0.05	574.3
10	0.22	575
11	0.13	491
12	1.03	578.2
13	1.03	578.3
14	0.25	485.3
15	1.03	492.6

Table 54: 14-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	559.3
3	0.33	497.2
4	1.03	476.4
5	1.03	476.5
6	1.03	492.5
7	1.03	492.6
8	0.04	492.8
9	0.05	574.5
10	0.22	493.4
11	0.13	578.2
12	1.03	578.4
13	1.03	578.1
14	0.25	488
15	1.03	495.3

Table 55: 15-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	560.5
3	0.33	501.9
4	1.03	482.4
5	1.03	482.5
6	1.03	497.5
7	1.03	497.6
8	0.04	497.9
9	0.05	574.7
10	0.22	498.4
11	0.13	578.2
12	1.03	578.4
13	1.03	578.2
14	0.25	493.2
15	1.03	500.7

Table 56: 16-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	561
3	0.33	504.1
4	1.03	485.2
5	1.03	485.3
6	1.03	499.9
7	1.03	499.9
8	0.04	500.3
9	0.05	500.8
10	0.22	578.2
11	0.13	578.3
12	1.03	578.4
13	1.03	578
14	0.25	495.8
15	1.03	503.3

Table 57: 17-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	561.6
3	0.33	506.5
4	1.03	488.1
5	1.03	488.1
6	1.03	502.3
7	1.03	502.4
8	0.04	502.7
9	0.05	574.9
10	0.22	503.1
11	0.13	578.2
12	1.03	578.4
13	1.03	578.2
14	0.25	498.2
15	1.03	505.9

Table 58: 18-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	562.6
3	0.33	510.9
4	1.03	493.6
5	1.03	493.7
6	1.03	507
7	1.03	507.1
8	0.04	507.3
9	0.05	575.1
10	0.22	507.9
11	0.13	578.2
12	1.03	578.4
13	1.03	578.4
14	0.25	503.2
15	1.03	520.8

Table 59: 19-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	570.5
3	0.33	544.4
4	1.03	535.7
5	1.03	535.8
6	1.03	542.4
7	1.03	542.4
8	0.04	542.6
9	0.05	576.8
10	0.22	542.9
11	0.13	578.3
12	1.03	578.3
13	1.03	578.4
14	0.25	540.5
15	1.03	549.3

Table 60: 20-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	576.1
3	0.33	568.3
4	1.03	565.7
5	1.03	565.7
6	1.03	567.8
7	1.03	567.8
8	0.04	567.8
9	0.05	578
10	0.22	567.9
11	0.13	578.4
12	1.03	578.4
13	1.03	578.4
14	0.25	567.7
15	1.03	576.7

Table 61: 21-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	578.1
3	0.33	576.7
4	1.03	576.2
5	1.03	576.2
6	1.03	576.6
7	1.03	576.6
8	0.04	576.6
9	0.05	578.3
10	0.22	576.6
11	0.13	578.4
12	1.03	578.1
13	1.03	578.4
14	0.25	576.6
15	1.03	586.2

Table 62: 22-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	578.4
3	0.33	578.4
4	1.03	578.4
5	1.03	578.4
6	1.03	578.4
7	1.03	578.4
8	0.04	578.4
9	0.05	578.4
10	0.22	578.4
11	0.13	578.4
12	1.03	578.4
13	1.03	578.4
14	0.25	578.4
15	1.03	578.4

Table 63: 23-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	578.4
3	0.33	578.4
4	1.03	578.4
5	1.03	578.4
6	1.03	578.4
7	1.03	578.4
8	0.04	578.4
9	0.05	578.4
10	0.22	578.4
11	0.13	578.4
12	1.03	578.4
13	1.03	578.4
14	0.25	578.4
15	1.03	578.4

Table 64: 24-hour Node Pressure Values

Node	Demand (LPS)	Pressure (kPa)
2	1.03	578.4
3	0.33	578.4
4	1.03	578.4
5	1.03	578.4
6	1.03	578.4
7	1.03	578.4
8	0.04	578.4
9	0.05	578.4
10	0.22	578.4
11	0.13	578.4
12	1.03	578.4
13	1.03	578.4
14	0.25	578.4
15	1.03	578.4

Appendix G – Sample Calculations

SWM System Design Calculations

The following section shows the calculation process used to design the underlaying 50mm diameter ASTM C33 No. 57 clear stone storage layer for the permeable paver and bioretention systems system. Additionally, the calculations used to determine the maximum aboveground depth for the bioretention cells can be found below.

Permeable Paver and Bioretention Underground Storage

Equation 1 shown below was used to determine the minimum depth of the underlaying storage layer.

$$d_{min} = \frac{(Q_c x R) + P - (ixT)}{V_r} \qquad (1)(Credit\ Valley\ Conservation\ 2011)$$

Table 65 below defines all of the variable used in Equation 1.

Table 65: Input Parameters for Underlaying Storage Layer Design Calculations

Variable	Description	Value Used	Units	Assumption/Source
d_{min}	Minimum depth of underlaying stone layer	N/A	m	N/A
Q_c	Depth of runoff from contributing drainage Area	0.077	m	Gathered from results of the initial SWMM modelling with the heavy intensity storm
R	Ratio of permeable pavement area to permeable paving area	6.37	Unitless	Determined from CAD areas: (4860.5+4855) m/ (792+732) m
P	Total rainfall depth from storm of interest	0.089	m	Gathered from the results of the initial SWMM modelling with the heavy intensity storm
i	Infiltration rate of native soils	0.24	m/day	Underlaying soil assumed to be sandy/silty loam for Kingston and surrounding regions (Natural Resources Conservation Service n.d.)
T	Time needed to fill underlaying stone layer	2	hours	Typically assumed 2hr fill period from 50mm diameter clear stone (Credit Valley Conservation 2011)
V_r	Void ratio of underlaying stone layer	0.4	Unitless	Typically assumed to be 0.4 for 50mm diameter clear stone (Credit Valley Conservation 2011)

Using Equation 1, the minimum depth of the storage layer was determined:

$$d_{min} = \frac{(0.077x6.37) + 0.089 - (0.24x2)}{0.4}$$

$$d_{min} = 0.25m = 25cm$$

The calculation shows that a minimum required design depth of 25 cm was necessary for storage under the permeable paver system and bioretention system(s). However, a depth of 30cm was used in the design to accommodate the future worsening of storms due to climate change, clogging effects, and construction practicality (easy for contractors to implement a 1-foot layer of gravel).

Bioretention Cell Maximum Aboveground Depth

Equation 2 was used to determine the maximum depth required for the bioretention cells:

$$d_{cellMax} = \frac{i\left(t_s - \frac{d_p}{i}\right)}{V_R} \qquad (2)(Credit\ Valley\ Conservation\ 2011)$$

Table 66 below defines all of the variable used in Equation 2.

Table 66: Input Parameters for Bioretention Cell Depth Design Calculations

Variable	Description	Value Used	Units	Assumption/Source
$d_{cellMax}$	Minimum depth of underlaying stone layer	N/A	m	N/A
i	Infiltration rate of native soils	10	mm/hr	Underlaying soil assumed to be sandy/silty loam for Kingston and surrounding regions (Natural Resources Conservation Service n.d.)
t_s	Time needed to drain retention cell	48	hours	Typically assumed 48hr drainage period (Credit Valley Conservation 2011)
d_p	Maximum surface ponding depth	77	mm	The amount of runoff produced in the initial modelling for a heavy intensity storm
V_r	Void ratio of underlaying stone layer	0.4	Unitless	Typically assumed to be 0.4 for 50mm diameter clear stone (Credit Valley Conservation 2011)

Using Equation 2, the minimum depth of the storage layer was determined:

$$d_{cellMax} = \frac{(10)\left(48 - \frac{77}{10}\right)}{0.4}$$

$$d_{cellMax} = 1007.5mm = 1.0m$$

EPANet Fire Servicing Calculations

$$F = 220C\sqrt{A} = 220 * 1.0 * \sqrt{1330} = 8023.22\frac{L}{min} \quad (3) \quad (CGI\ Risk\ Managment\ Services\ 1999)$$

$$F = \frac{8023.22\frac{L}{min}}{60\frac{s}{min}} = 133.7\frac{L}{s}$$

Appendix H – Project Management

Work Breakdown Structure

Work Breakdown Structure Legend	
Box Colour	Significance
	Items/tasks which have yet to be completed
	items which have already been completed
	items/tasks associated with deliverables which have yet to be completed

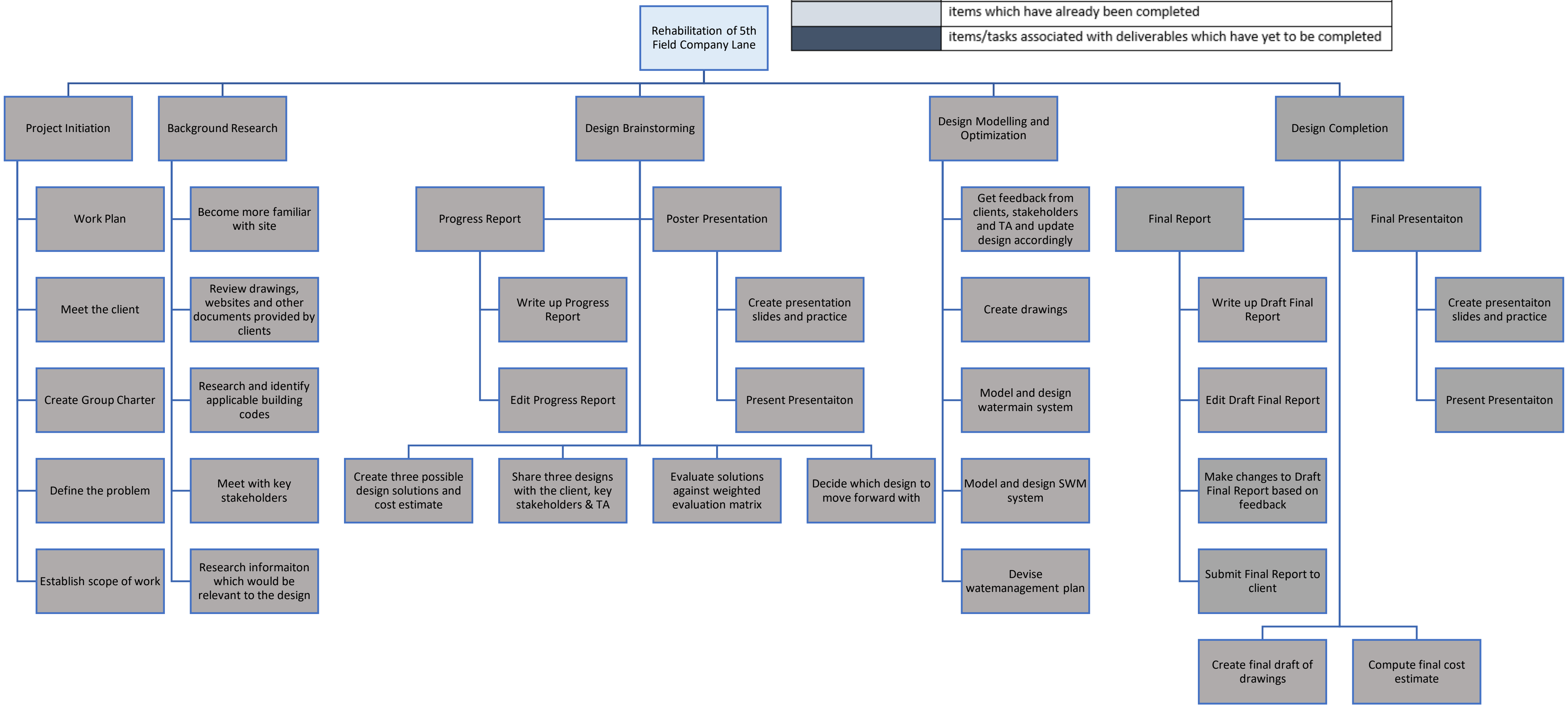


Figure 46: Work Breakdown Structure

Gantt Chart Legend

Table 67: Gantt Chart Legend

Colour	Significance
Purple	Group Meeting
Red	Client/Stakeholder Meeting
Blue	TA Meeting
Light Grey Purple	Phase
Dark Grey Purple	Task associated with a phase
Orange	Deliverable
Light Orange	Tasks associated with a deliverable
Yellow with X	Deadline

JEMS

Gantt Chart

Refurbishment of 5th Field Company Lane

Item	People Assigned	Days
Work Plan Due	JS, Elliott, Matt, Sophia	1
Background Research		21
Meetings (purple = group, blue = TA, red = client)	JS, Elliott, Matt, Sophia	
Research applicable building codes and standards	Elliott, Matt	12
Review drawings, websites and other documents provided by clients	JS, Sophia	12
Become more familiar with the site	JS, Elliott, Matt, Sophia	22
Research similar projects	JS, Sophia	12
Prepare and send emails to stakeholders asking questions about the project	JS, Elliott, Matt, Sophia	5
Prepare for stakeholder meetings and meet with them	JS, Elliott, Sophia	2
Design Brainstorming		43
Meetings (purple = group, blue = TA, red = client)	JS, Elliott, Matt, Sophia	
Create three possible design solutions	JS, Elliott, Matt, Sophia	17
Share three design solutions with the client, key stakeholders and TA	JS, Elliott, Matt, Sophia	1
Evaluate solutions angainst weighted evaluation matrix	JS, Elliott, Matt, Sophia	10
Decide which design to move forward with	JS, Elliott, Matt, Sophia	8
Create conceptual drawing for final design	Sophia	3
Progress Report	JS, Elliott, Matt, Sophia	43
Write up progress report	JS, Elliott, Matt, Sophia	36
Internal Deadline for Progress Report (send to Sandra)		1
Edit Progress Report	JS, Elliott, Matt, Sophia	6
Progress Report due		1

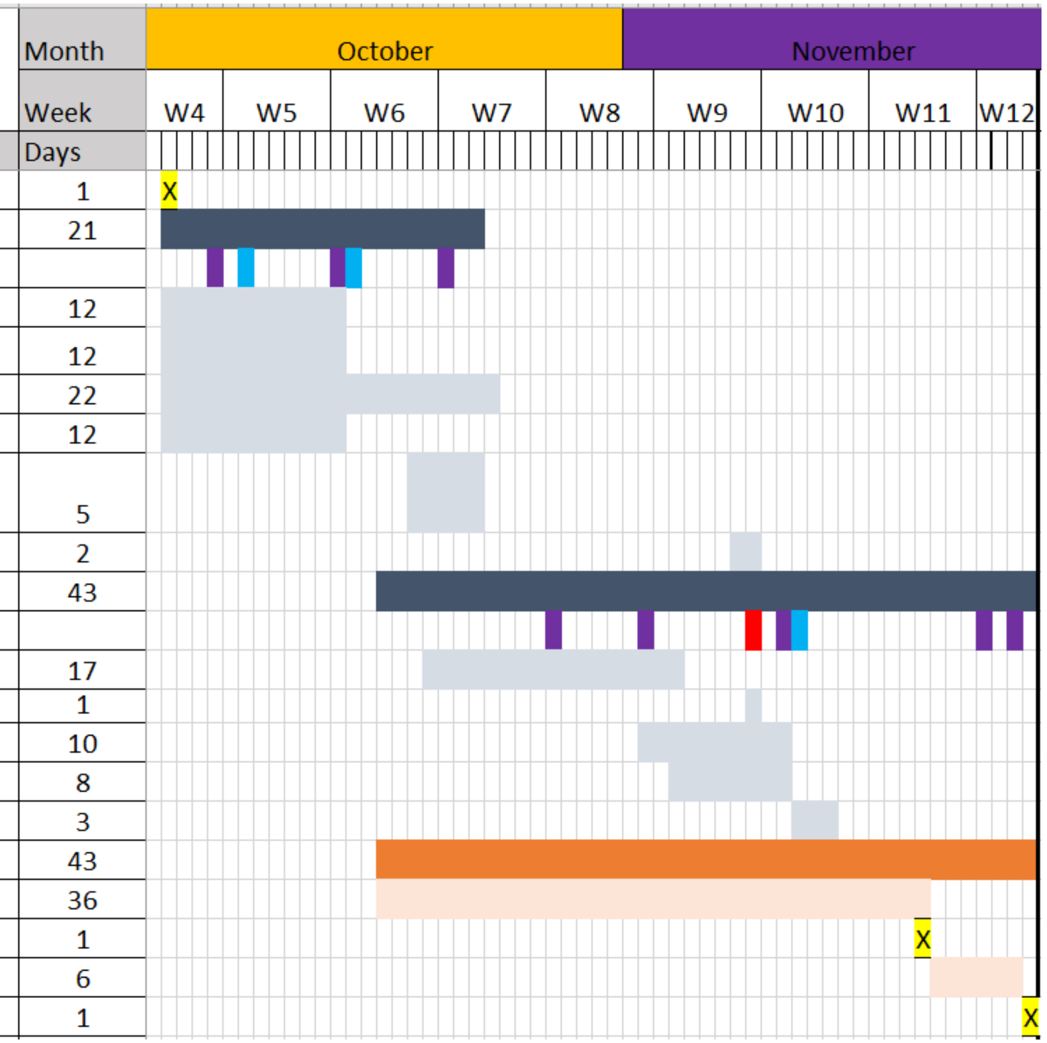


Figure 47: Updated Gantt Chart for Background Research and Design Brainstorming Phases from Progress Report

Refurbishment of 5th Field Company Lane

Item	People Assigned	Days
Design Brainstorming		53
Meetings (purple = group, blue = TA, red = client)	JS, Elliott, Matt, Sophia	
Create three possible design solutions	JS, Elliott, Matt, Sophia	17
Share three design solutions with the client, key stakeholders and TA	JS, Elliott, Matt, Sophia	1
Evaluate solutions angainst weighted evaluation matrix	JS, Elliott, Matt, Sophia	10
Decide which design to move forward with	JS, Elliott, Matt, Sophia	8
Create conceptual drawing for final design	Sophia	3
Progress Report	JS, Elliott, Matt, Sophia	43
Write up progress report	JS, Elliott, Matt, Sophia	36
Internal Deadline for Progress Report (send to Sandra)		1
Edit Progress Report	JS, Elliott, Matt, Sophia	6
Progress Report due		1
Poster Presentation		10
Create Poster	JS, Elliott, Matt, Sophia	8
Internal deadline for Poster		1
Practice Presentation	JS, Elliott, Matt, Sophia	2
Poster Presentations	JS, Elliott, Matt, Sophia	1
Design Modelling and Optimization		17
Meetings (purple = group, blue = TA, red = client)	JS, Elliott, Matt, Sophia	37

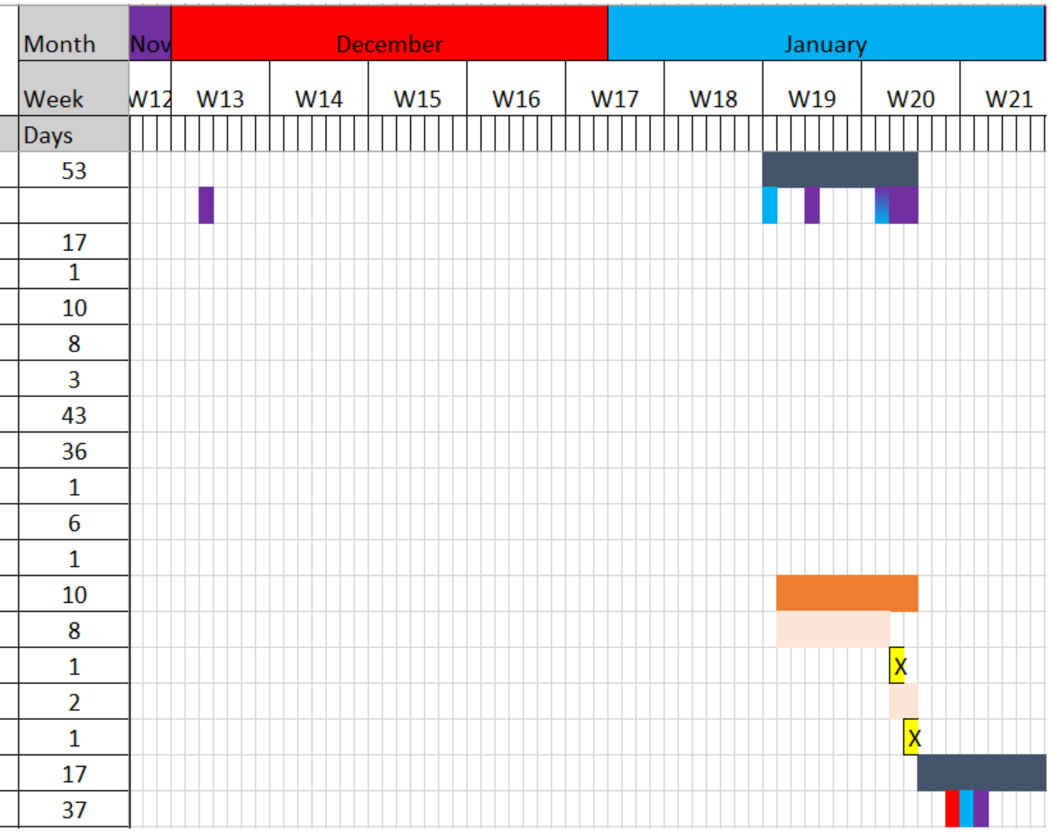


Figure 48: Updated Gantt Chart with remaining tasks for Design Brainstorming Phase and meetings for the Design Modelling and Optimization phase up until the end of January

Refurbishment of 5th Field Company Lane

Item	People Assigned	Days
Design Modelling and Optimization		17
Meetings (purple = group, blue = TA, red = client)	JS, Elliott, Matt, Sophia	37
SWMM Modelling of Initial Conditions	Elliott with help from Sophia	9
SWMM Modelling of Proposed Conditions	Elliott	10
EPANET Modelling of Water Main	Matt	7
Various CAD tasks for design and modelling	JS (for Matt and Elliott)	9
CAD for Main Site	JS	15
CAD for Arch St.	JS	4
Design Completion		36
Meetings (purple = group, blue = TA, red = client)	JS, Elliott, Matt, Sophia	
Final Report	JS, Elliott, Matt, Sophia	36
Write up Draft Final Report	JS, Elliott, Matt, Sophia	36
Internal Deadline for Draft Final Report		1
Edit Draft Final Report	JS, Elliott, Matt, Sophia	6
Draft Final Report Due		1
Edit Final Report	JS, Elliott, Matt, Sophia	11
Final Report due		1
Final Presentation	JS, Elliott, Matt, Sophia	6
Create presentation slides	JS, Elliott, Matt, Sophia	6
Practice presentation	JS, Elliott, Matt, Sophia	6

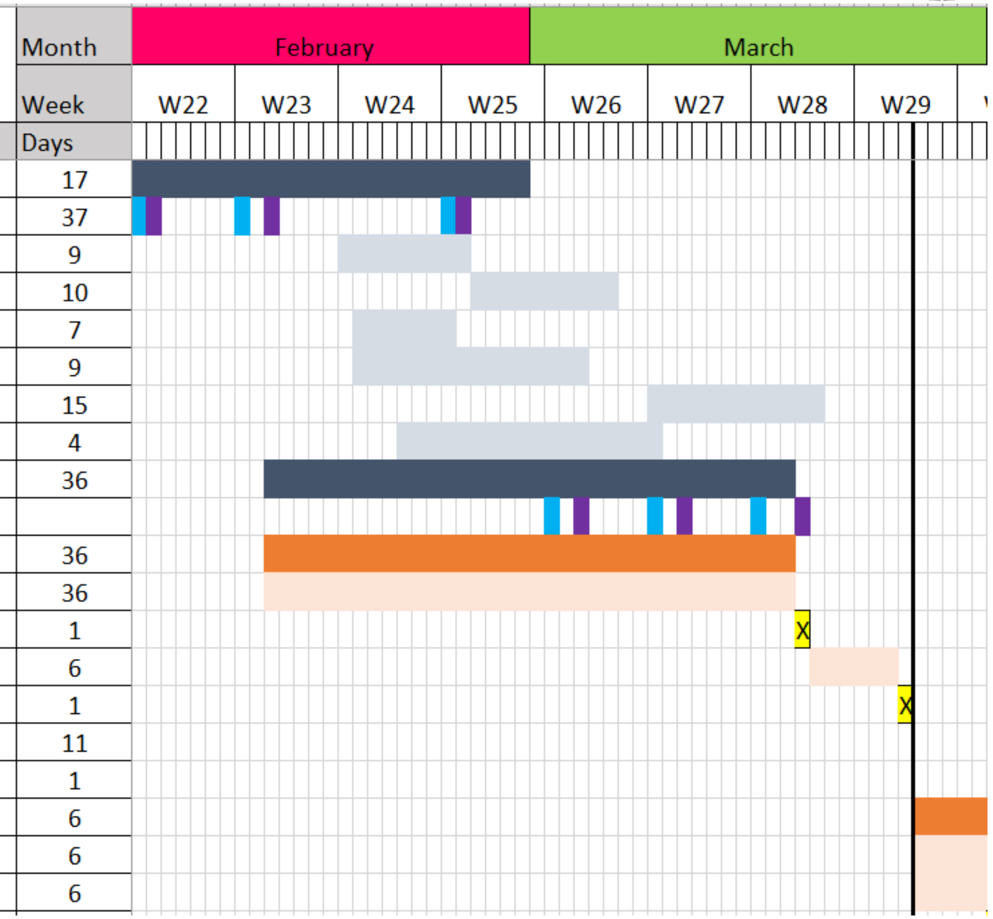


Figure 49: Updated Gantt Chart with tasks for Design Modelling and Optimization and Design Completion phases for February and March

Refurbishment of 5th Field Company Lane

Item	People Assigned	Days
Design Completion		36
Meetings (purple = group, blue = TA, red = client)	JS, Elliott, Matt, Sophia	
Final Report	JS, Elliott, Matt, Sophia	36
Write up Draft Final Report	JS, Elliott, Matt, Sophia	36
Internal Deadline for Draft Final Report		1
Edit Draft Final Report	JS, Elliott, Matt, Sophia	6
Draft Final Report Due		1
Edit Final Report	JS, Elliott, Matt, Sophia	11
Final Report due		1
Final Presentation	JS, Elliott, Matt, Sophia	6
Create presentation slides	JS, Elliott, Matt, Sophia	6
Practice presentation	JS, Elliott, Matt, Sophia	6
Deliver presentation		1

Month: March, April
Week: W29, W30, W31, W32, W33

Figure 50: Gantt Chart with Tasks which have Yet to be Completed

Severity						
Probability		Negligible	Minor	Moderate	Significant	Severe
	Very likely	Low Medium	Medium	Medium High	High	High
	Likely	Low	Low Medium	Medium	Medium High	High
	Possible	Low	Low Medium	Medium	Medium High	Medium High
	Unlikely	Low	Low Medium	Low Medium	Medium	Medium High
	Very Unlikely	Low	Low	Low Medium	Medium	Medium

Figure 51: Risk Assessment Matrix