Seattle University and the Potential LID Changes to Stormwater Infrastructure on Campus

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Submitted by:
SU Stormwater Team
Abi Wells, Theda Hovind, Tyler Hartje, Lisa Yuodelis, Rose Brallier

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Introduction

We live in Seattle and our greatest commodity could and should be rain. As one of the cloudiest states, rain is nothing new to the native citizens of Seattle. Yet, with all the rain we do receive, why is water treatment and water overflow not taken care of?

In Seattle, the city runs on mostly a combined sewer system. This means that the sewer system and the rainwater system run in the same pipes and go through the same treatment plant. That also means that when there is a large rain and the sewers overflow the capacity of the treatment plant, both rainwater and sewage flow into the natural water systems, such as a Duwamish, along with every other pollutant being put into the sewage system or being picked up by the rainwater from the streets and roofs of our city. While the treatment plant can normally filter and clean the combined amount of water entering the system, a large increase of water that comes from a heavy rain is too much and therefore needs to be let out unfiltered and unclean.

To combat this sort of run-off in a city, people have innovated several natural filters that collect and clean water before it re-enters nature. Examples include swales, rain gardens, green roofs, and permeable pavement. Even increasing the amount of green space a particular area helps clean the polluted rainwater. However, in a city, it is often hard to find the space to plants more trees and native plants, or to create a rain garden or swale. So how do we combat polluted rainwater and water overflow?

At Seattle University, the campus has done its best to address our part of the problem. We have rain gardens, exceptional amounts of green space, and water conserving methods that help with the amount of water that touches and leave our campus (see below for more details). However, several sites on campus have been identified as having the most untreated water run-off. We attempted to find new ways of filtering and/or storing this water so that we can control the sewer overflow in our neighborhood to the best of our ability. While the City of Seattle does not allow for buildings and organizations to recycle the water they collect in cisterns beneath their campuses, we have also remained open to that idea and wish to see it come to fruition in the near future.

Allowing pollutants and run-off to enter the Duwamish River because of a lack of space and forward thinking damages vital natural habitats that struggle enough without this problem.

We also damage the water supply for Puget Sound and Seattle when we allow untreated water to enter back into our natural water areas. At Seattle University, we are committed to environmental sustainability and justice, and making sure the run-off from our campus and the surrounding buildings is treated before returning to the Duwamish River is just a small step we need to take forward.

Combined Sewer Systems and Overflow events

The combined sewer system was introduced in 1855 as a way to prevent waste from accumulating in the streets, taking waste away from waste ditches that could overflow in the rain, the combined sewer took all waste waters (industrial, domestic, and stormwater) in one pipe away from the street and the population. This helped not only a community health problem, but with the eventual addition of wastewater treatment plants, an environmental problem of waste dumping into waterways. The combined sewer is still useful today in this regard, not only does this system mean that industrial and domestic wastewater is cleaned, but that stormwater which does have some pollution, and often has high amount of sediment, is filtered removing sediment and treated microbially and chemically to remove nutrients rather than being deposited into local bodies of water as a pollutant.

In dry weather or cities with small populations this sewer system functions well, but in areas with high rain volume, or more importantly areas with large storm events which produce a significantly larger volume of rainwater than normal, the combined sewer experiences overflows (CSOs). A CSO occurs when the pipes get too full; to prevent sewage from backing up into domestic homes, streets, and other sources of water into the sewer, the pipe overflows into local bodies of water. At this point the water is 90% stormwater and 10% sewage, while better than 100% raw sewage, these overflows still pollute the water with a number of potentially harmful pathogens, extra nutrients, chemical run-off from roads, and sediment. The extra nutrients play a part in spawning algae blooms which can lead to oxygen depletion in the waterbody, starving an ecosystem of its less-tolerant species, leading in a loss of biodiversity over time. Further, these blooms can sometimes contain cyanobacteria which can produce cyanotoxins, this makes recreation in such water extremely dangerous for small animals, such as dogs, who may drink the water, and with continued dermal exposure can be detrimental to humans.

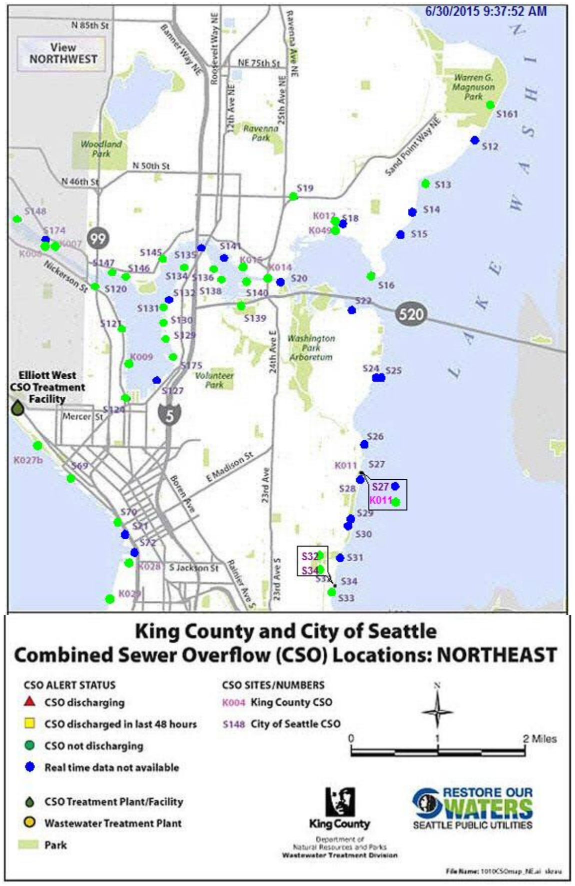

Figure 1: Map of NE Seattle CSO locations from King County and Seattle Public Utilities, the map is available with realtime data on CSO sites at: http://www.kingcounty.gov/environment/wastewater/CSOstatus/Overview/NESeattle.aspx

In Seattle, there are 90 CSO sites run by the City of Seattle, and 38 CSO sites operated by King County, this leads to overflows into waterways including Lake Union, Lake Washington, the Duwamish River, and the Puget Sound. Across the 128 sites operated in the city of Seattle, only a portion of them overflow at a given time. This is often due to relative capacities of the overflow sites, as well as a limited number of storm events which cause significant rainfall. In 2013, there were only four storm events that caused over 30% of the CSO sites to overflow, and only one of these events caused continuous overflows over a period of days (Figure 1). Further, there were only five overflow events in the summer period which would have the most effect on recreation. This suggests that current operations allow for minimal impact to local water bodies during high human impact times, however, during rainier months the impact to the combined sewer is worsened.

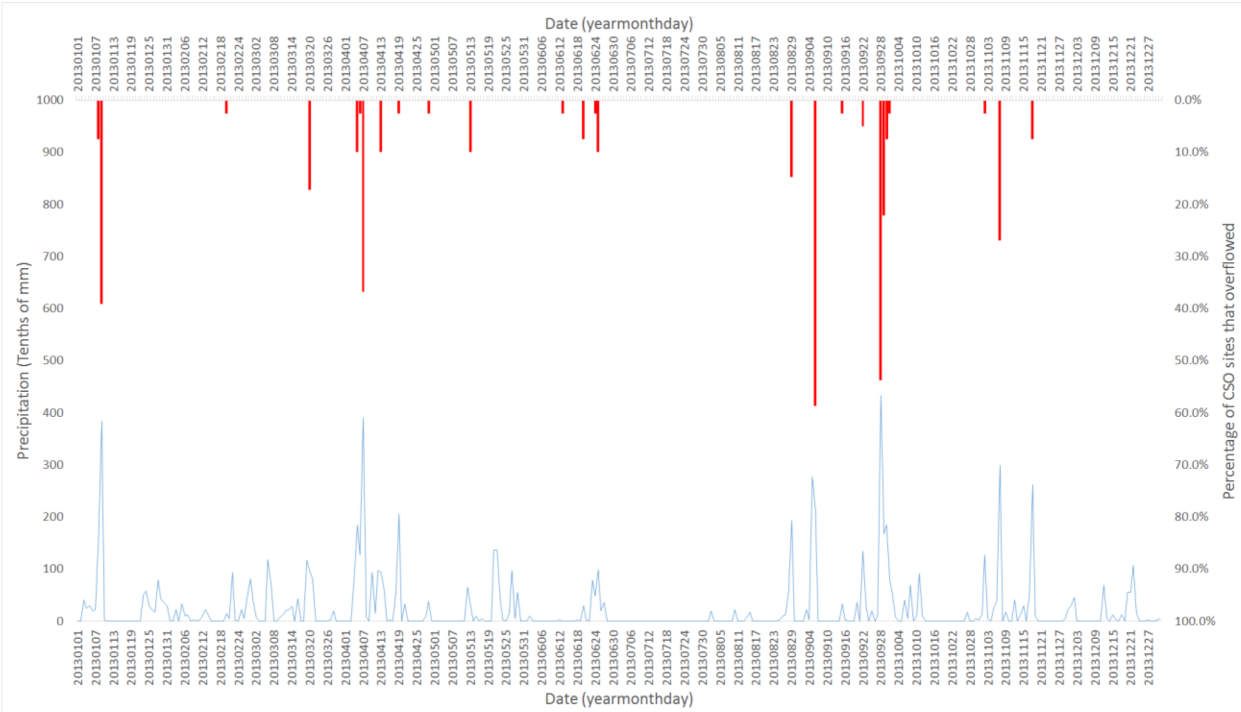

Figure 2: Hydrograph of Seattle precipitation in tenths of a millimeter from Seattle Tacoma International Airport (blue) with the percentage of combined sewer outflow points that overflowed (red) for dates in the year 2013.

Because the combined sewer system does take a toll on local water bodies, it is important that not only does the city aim to improve capacities of treatment centers and CSO sites, but that local inhabitants and industries reduce water flowing into the combined sewer system. As seen in the above hydrograph (Figure 2), CSO events occur primarily after a storm event. By reducing the volume of water expended throughout the year and especially during storm events, the chance of an overflow of the combined sewer system decreases. Consecutively, if the water from storms is caught in slowly-draining tanks and in soil-beds and thus is prevented from entering the sewer in large volumes at once, but rather small volumes over time, the number of CSO events that occur will decrease. It is these measures which we ask Seattle University to expand upon in the aims of preventing contamination of our local water bodies.

Seattle University's Dedication to Sustainability

Seattle University is one of the nationally acclaimed universities that has put in a concentrated effort to be a green and sustainable campus. Some of the most prevalent practices visitors can see are the electric vehicles we use for campus maintenance and the NightHawk, solar panels fueling two of our buildings, and a lack of disposable plastic water bottles to cut down on waste. There are also many other efforts SU has done to be an environmentally-minded campus. As our fellowship group focuses on creating a better system for the excess of water waste on our campus, we have discovered the many current practices SU has employed on the grounds of the campus to create not only a healthy and thriving campus, but also sustainably-minded neighborhood.

To create an environmentally-friendly campus, SU has committed to several practices that teach students in addition to accomplishing the goal of being sustainable. As a part of our campus' Climate Action Plan, they say "We believe higher education must educate students and conduct research to develop the social, economic, and technological solutions to reverse global warming and lead by example to reduce our campus's operational emissions." To accomplish these goals, the campus has purchased and installed a gas boiler to provide heating for five of our buildings, and they also have bought carbon offsets; these changes together have reduce carbon emissions by 83% from 2009. Additionally, Seattle University has dedicated itself to the goal that all new buildings on campus must be LEED Gold certified, and any major renovations to existing buildings must also bring those building up to LEED Gold.

More than just visible practices, the university aims to show their determination to sustainability through teaching practices. Seattle University strongly encourages classes to teach about environment sustainability, and has created an example for their students and other universities alike, like they aimed to, by hosting an annual hard-to-recycle event for students and by creating Learning Communities that focus on environmentally-friendly practices and companies.

In terms of sustainable water systems at SU, their main concern is the run-off, or stormwater, from the roofs and sidewalks around campus. When the library was redesigned, SU created two rain gardens that redirect the roof run-off. These rain gardens can collect up to 100,000 gallons of rain during a bad storm, and they hold the water as it gradually seeps back into the ground, being naturally filtered by the plants found in the garden. The campus' two green roofs also help reduce the amount of run-off from the buildings. The largest green roof on campus is over part of the Bannan Science building. The large garden absorbs most of the water coming from the upper levels of Bannan, as well as helping to insulate the building and providing a natural habitat for the wildlife. The rain garden placed in front of the Lynn building not only cleans waste water of pollutants, but also prevents flooding in the four surrounding buildings. These practices are meant to create a healthier environment for the people on the campus, but also for the wildlife that is found in Seattle.

Seattle University also has several holding reservoirs called cisterns under the campus to collect extra run-off that can then be gradually let into the combined sewer system after the rain has stopped. In a previous senior design project that also focused on run-off on campus, they were able to install a valve on one of the reservoirs so that the water collected can be gradually released into sewer system rather than all at once. While the valve helped lessening the amount of water entering the sewer system at any given point, it has not been employed to its full potential. As SU considers options for expanding the campus, our group hopes to encourage water-sustainable designs that help reduce run-off even more, if not also using run-off for purposes on campus. As well as a commitment to LID practices that school documentation outlines as a priority to use in the future.

At the moment, the practices mentioned above, while helpful in encouraging the cleaning of waste water coming from the campus, are somewhat isolated. We hope to use our findings from our project to find a practice that can help the campus more as a whole. What we also want to do in our study is to find the places on campus that need continued attention to reduce flooding, standing water, and pollutants running into the combined sewer system around our neighborhood. Our campus has made commendable efforts at lessening the impact of run-off from our campus, but more can be done to keep the local streams and rivers, specifically the Duwamish, from further damage.

Potential Low Impact Development Systems

Our team investigated the different kinds of low impact development systems that could be implemented to reduce the amount of peak stormwater flow off campus. A paragraph for each investigated system follows.

Bioretention is the practice of treating stormwater by using plants and a graded soil bed to filter the stormwater (Figure 3). It involves an optional pretreatment area if large volumes of debris are expected, a ponding area to hold the runoff, a groundcover layer, a soil layer and plants to help manage the runoff. It is ideally used where there is plenty of space and soils are permeable. The most significant flaw of this technology is the amount of space required and its loss of effectiveness in situations where the soil is already saturated (such as in recurring rainstorms). Seattle's long wet season (fall-spring) reduces the effectiveness of this technology due to the ground being saturated for the majority of the year. The cost is around $13.19 per square foot on average (ranging from $2.22 to $30.00).

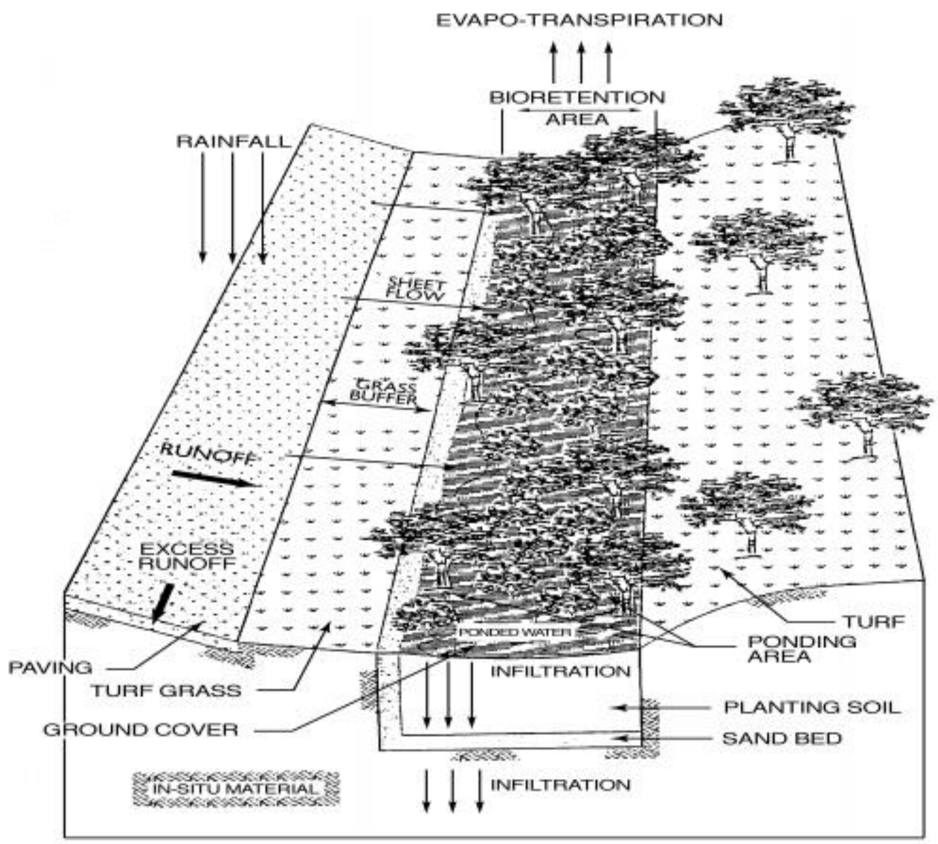

Figure 3: An example diagram of bioretention as outlined by the EPA in the Stormwater Technology Sheet for Bioretention.

Green roofs (also known as vegetated roofs) consist of a layer of soil and plant matter, which retains water during storm events (Figure 4). Green roofs come in two varieties: the first is an intensive roof, which is designed with six inches of soil or deeper, and often planted with ground covers, shrubs and trees. Intensive roofs are often designed simultaneously as public spaces. The second is an extensive roof, with a shallow soil profile, and hardy, ground cover plants. Extensive roofs are designed with a light-weight soil mixture and vegetation on top of a drainage and filtration layer, all over a waterproof membrane. Research has demonstrated that soil profiles from 3 to 4 inches in depth provide the most runoff mitigation relative to cost; however, depending on the depth of the soil, green roofs can result in loads of 15 to 50 pounds per square foot when saturated. For higher loads, the roof must be retrofitted in order to support the system. Flaws of green roofs include that they take time to establish themselves before reaching peak performance, and they retain lower percentages of rainfall when rainfall distributions are more even. Therefore, green roofs are best suited to climates with intermittent rainfall. Depending on rainfall patterns, types of vegetation and other factors, the effectiveness of green roofs at mitigating stormwater runoff can vary wildly. Costs of installation vary significantly, but generally fall between $10 and $15 per square foot for new construction, and $15 to $25 per square foot for retrofitting.

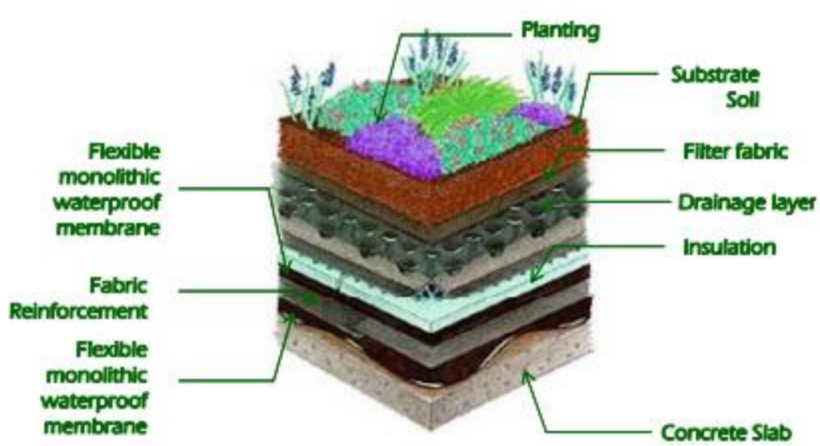

Figure 4: Green roof cross section for Seattle City Center green roof.

Swales are either dry (providing volume and quality control by facilitating infiltration) or wet (using time and plant growth to limit peak discharge and to treat runoff). The type to be used is determined by the type of soil, with dry swales requiring soil infiltration rates between 0.27 and 0.5 inches per hour. Fatal flaws are situations where the soil infiltration rates are poor. Similar to bioretention, Seattle’s long wet season (fall-spring) reduces the effectiveness of this technology due to the ground being saturated for the majority of the year. Cost is around $89.52 per linear foot (ranging from $24.70 to $385.00).

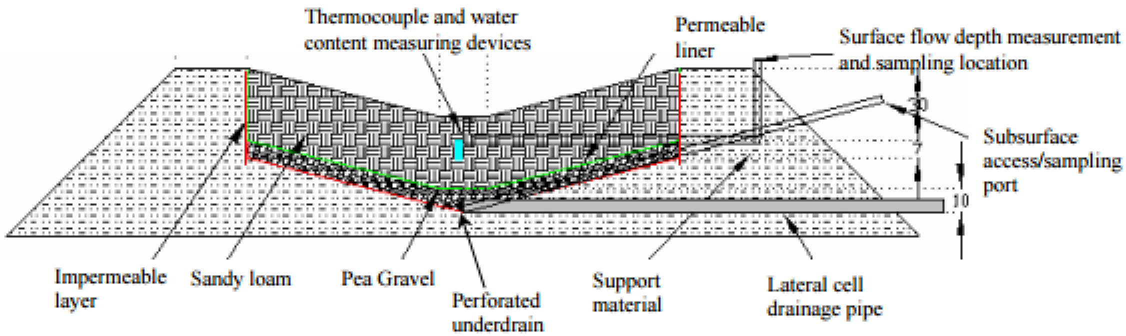

Figure 5: Diagram of a swale used for the purpose of stormwater runoff treatment.

Permeable pavement is used in place of the common, traditional, impermeable pavement on parking lots, sidewalks, driveways, and residential roads. Unlike some other LID technology, it is appropriate for climates with heavy rainfall such as the Pacific Northwest. Permeable pavement consists of porous material that allows for water to infiltrate and be collected at the aggregate base, which provides structural support and acts as a stormwater reservoir (Figure 6). The infiltration rate of the soil below the pavement is what determines the amount of surface runoff being reduced. To maintain the infiltration rate, surfaces of the permeable pavements should be cleaned and inspected annually, while the surrounding soil erosion and sediment areas should be kept from exposure by mixing it with compost or mulch. Permeable pavement must also not be built on steep slopes that are prone to deliver erosion, and where water cannot be controlled by detention structures. If guidelines are not met, the pavement will have long-term excessive sediment deposition. The cost per square foot of the pavement can range anywhere from $2.00-$6.50.

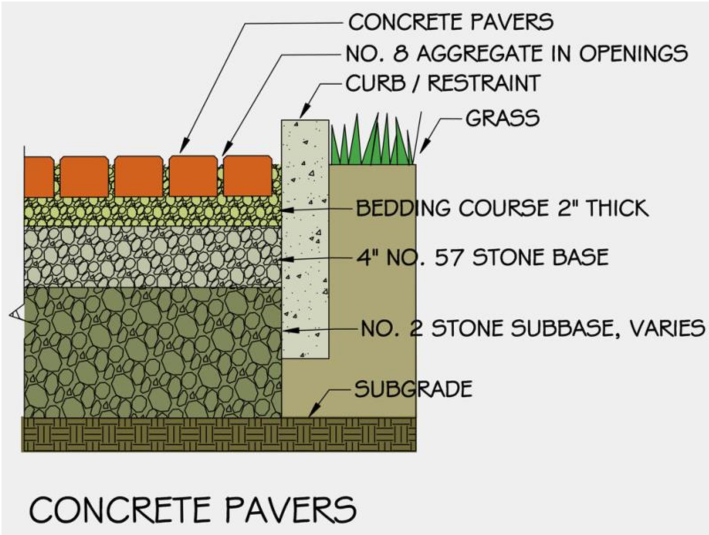

Figure 6: Crosscut of pervious pavement.

Areas of Concern for Water Treatment

Our team used previous data collected by Seattle University students for a senior design project to determine which areas of campus are in the most need for treatment. Figure 7 is a map of campus which highlights the amount of untreated surface area per each section of campus, with Figure 8 showing the current treatment of either pervious surface or area above a water detention tank. Notably, blocks A, E, I, J, N, S, and U have the highest percent of untreated area. However, not all buildings in these areas are under Seattle University domain, this occurs most prominently in blocks A, I, J, and S. Section A contains the Xavier residence hall, but is mostly made up of spaces with non-university uses, primarily the storage-unit. Section I is primarily non-university owned apartments and offices, and while SU has space in some of these buildings, the school is not in a position to make decisions about future changes to the lot. Section J was at the time of this investigation non-university owned, since then SU has purchased one of the larger buildings on the lot, but has not made publicly available the intended use of it. Section S contains the recently built Douglas Apartments which the university leases for use as a student living space, and two additional student-living houses, however, the rest of the lot is non-affiliate housing.

Thus, sections E (Ignatius chapel, Lee center, and parking lot), N (Rianna Building, School of Law Annex, and the O'Brien center), and U (Connolly center and adjacent parking lot) will be our prime candidates for changes to be made. Other areas (B-Fine Arts Building and

Hunthausen, K- Arrupe Jesuit Residence and a parking lot, M-Bellarmine Residence Hall and Pigott Pavilion) with above average untreated area will be investigated secondarily.

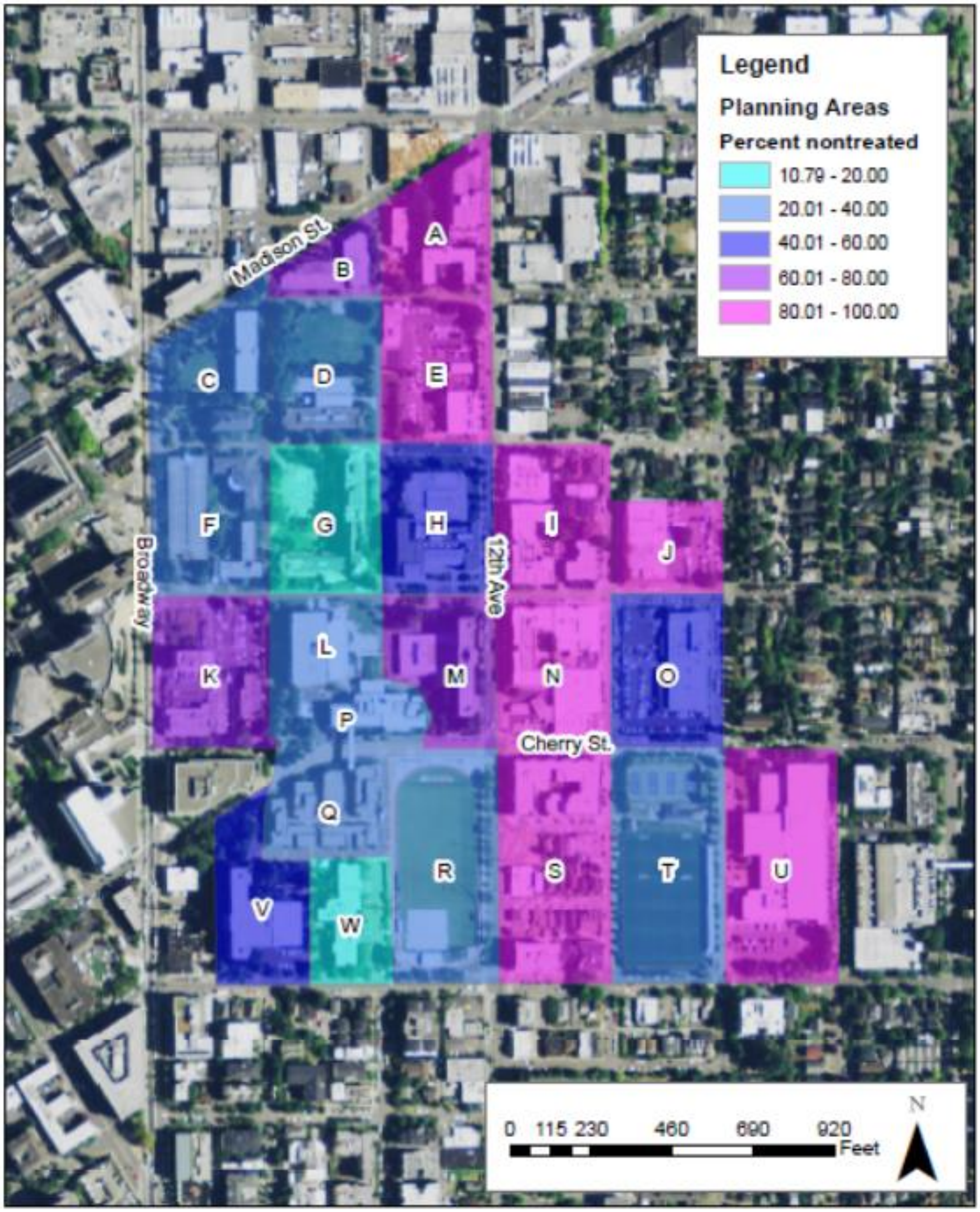

Figure 7: Map of Seattle University campus split into treatment sections each overlaid with a color corresponding to the percent of area untreated by either a detention tank or pervious area.

Figure 8: Map of the Seattle University campus with available treatment type data (2012) for run-off with the options of pervious area (including current rain gardens) and areas that feed cisterns.

Top Three Lots: Two Possible Design Options

Lot E

Lot E contains two buildings, the Lee Center for the Arts and the St. Ignatius Chapel in addition to the main parking lot, which occupies the majority of the area of the lot. According to the university Master Plan, the main parking lot constitutes a potential long-term open space above structured parking; in the future, the parking area may be converted into a standing parking structure or underground parking. In addition, a new building may be constructed on the lot within the next decade. These plans, while not imminent, will have a significant impact on the composition of the area of the lot, converting it from primarily pavement to a combination of green space and rooftops.

Given the high percentage of asphalt on Lot E, a clear option for stormwater runoff mitigation would be the installation of permeable pavement. The cost per square foot of the pavement can range from $2.00-$6.50, and according to a publication by the EPA the pavement can have a lifetime between 20 and 40 years. The parking lot has an approximate area of 55,000 sq. ft. so the total cost of installing permeable pavement over the parking area could range from $110,000-$357,500.

A cistern could also divert and store runoff from the parking lot and from the rooftops of new and existing buildings. While the installation of plumbing to divert water from drains into a cistern can prove expensive, a cistern may prove more adaptable than permeable pavement to the potential changes to Lot E outlined in the university Master Plan. Cisterns can cost between $0.61 and $2.88 per gallon of capacity; assuming a cistern with a capacity of 100,000 gallons, construction of a cistern could cost between $61,000 and $288,000.

Lot N

Lot N on the Seattle University Campus map contains four buildings, two of which are owned by the university: the Ronald A. Peterson Law Clinic (School of Law Annex) and the O’Brien Center. The O’Brien Center is an office for Athletic Administration, Marketing Communications, as well as the Department of Military Science. Other buildings that lie on Lot N are the Rianna Building and a Shell Gas Station, which Seattle University does not have control over. Review of the master plan for Seattle University, paired with conversations with facilities, reveals that there are no construction projects planned for this lot that would install methods for removing any polluted stormwater, nor are there plans for renovations that would require upgrading the building to LEED Gold.

This site is completely covered in asphalt, not including the planting strips near the sidewalk. Space is also limited on lot N other than a small parking lot with seven car spaces located at the corner of 12th and Cherry St. It is approximately 40x70 feet or 2800 sq. ft. A potential green infrastructure implementation would be permeable pavement, preferably a porous hot or warm-mix asphalt pavement. The cost per square foot of the pavement can range anywhere from $2.00-$6.50. The total cost would range from $5,600-$18,200.

A second consideration would be an extensive green roof built on top of the Law Clinic building. A green roof would not be of limited possibility for the O'Brien Center due to the skylight windows on top of the roof. The cost per square foot for retrofitting the green roof would be $15 to $25. The total cost for a 20x40 ft. green roof to be built would cost $12,000-$20,000.

Lot U

Lot U at the time of data collection was one of the most untreated areas on Seattle University's campus in terms of stormwater treatment (80%-100% untreated), and it contains both the Connolly Center and William F. Eisiminger Fitness Center, as well as an adjacent parking lot. The fitness center was built in 2011, and per university policy, is rated LEED Gold standard; in regards to water waste, low-flow utilities were used where possible, and a small swale stocked with drought-resistant plants requiring minimal irrigation was installed in front of the building. Additionally, the Connolly center is undergoing some minor renovations, though there are no major plans for the next ten years. There will be some construction to the entrance to the North Court, which is currently a paved courtyard. The university will be replacing that area with an elevated ramp to a second story entrance. In the plan, they hope to use permeable pavement and native Seattle plants that soak up rainwater to help offset the stormwater run-off. Nevertheless, the Connolly Center and the adjacent parking lots remain largely unchanged and so it is likely that much of the stormwater on the lot remains untreated. Further, because there are two pools housed within the Connolly Center which produce large amount of water waste our team considers it a high priority site for implementing a stormwater treatment plan in line with our goal of reducing Seattle University's total stormwater runoff.

Out of the options we have studied (permeable pavement, cisterns, rain barrels, bioretention, swales, infiltration trenches, and green roofs), permeable pavement and cisterns appear to be the most viable for this site. While a green roof might be appealing given the large roof of the Connolly center, green roofs are not well suited to the Seattle area where we have consistent rain for a good portion of the year. Further, there would also be substantial costs required to strengthen the existing roofs to support the weight of a green roof system. Permeable pavement would be a good option for the parking lot of the Connolly center, as they are appropriate for our climate region and generally cost less than other options.

Cisterns would be another good option to divert and store runoff from the roof of the Connolly center, and could help reduce our summer water usage. However, not only are cisterns expensive, the installation of pipes to move the rainwater from the building to the cistern is also costly. Cisterns cost anywhere from $0.61 per gallon to $2.88 per gallon. Thus, if we were to install a 10,000 gallon cistern, it would cost anywhere from $6,100 - $28,800. Despite the initial upfront cost of a cistern, it might be worthwhile to investigate the usage of this stored rainwater to water the Championship Field, which would help offset the cost of installation and maintenance, as well as lower the university's water use and resulting water bill and environmental impact.

Top Three Lots: Top Design Option

Lot E

Because the paved area on Lot E will likely exist for a much shorter period of time that the lifetime of a surface of permeable pavement covering it, replacing the asphalt parking lot would have a much higher annualized cost than it would if no new development were planned for the area. Assuming that the new garage is completed in 2019 as planned, and the permeable pavement installed in 2015, the pavement would have a maximum usable life of four years which, given an annual rate of inflation of 4% results in an annualized equivalent cost of $30,303.9-$103,446.51. By contrast if the pavement were useful for even its minimum lifetime of 20 years it would have an annualized equivalent cost of $8,093.99-$27,629.95. This demonstrates that, given the planned construction on Lot E, the installation of permeable pavement to mitigate stormwater runoff from the site would not be an efficient use of funds for permeable pavement.

By contrast, a cistern could continue to divert runoff before, during and after new construction. In Seattle, the maximum average monthly rainfall occurs in December with 5.43 inches of rain. Since the parking lot on Lot E covers 55,000 sq. ft, on average a maximum of 186,171 gallons would drain from the parking lot in a month. A 100,000 gallon cistern, draining at a rate of at least 2.5 gallons per minute could certainly drain stormwater from the area at a sufficient rate to eliminate changes in runoff rates due to storm events by draining 108,000 gallons over the course of a month and retaining up to 100,000 additional gallons. As discussed previously, the construction of such a cistern would cost between $61,000 and $288,000.

Lot N

This site is completely covered in asphalt, not including the planting strips near the sidewalk. Space is also limited on lot N other than a 2800 sq. ft. small parking lot with seven car lots located at the corner of 12th and Cherry St. Since space is limited, swales as well as cisterns, bioretention, and infiltration trenches, are not the optimal infrastructure for this area. Green roofs are a potential infrastructure, however the roof of the Law Clinic building would have to be retrofitted in order to support the heavy load of the roof when saturated. Green roofs also take time to establish themselves before reaching peak performance and retain lower percentages of rainfall compared to permeable pavement. The price ranging from $15 to $25 per square foot is also more costly than the cost of permeable pavement.

The green infrastructure implementation would be permeable pavement, preferably a porous hot or warm-mix asphalt pavement. The cost per square foot of the pavement can range anywhere from $2.00-$6.50. The total cost would range from $5,600-$18,200. However, the cost including excavation, installation, materials, and labor is $9.50 per square foot. The total cost for this 2,800 sq. ft. parking lot would be $26,600. Porous asphalt has the ability to retain 25 percent to 100 percent of stormwater volume if maintained properly. This means that if a 1 in. rainfall occurred, 393.59-1,574.37 gallons of water would be saved. This amount also takes into account the amount of water lost through evaporation. Based off of the US Climate Data, Seattle receives an average of 34.1 inches of rain annually. If the permeable asphalt was maintained properly to retain 100 percent of stormwater, 53.686 gallons of water could be saved per year. If the permeable asphalt does not get maintained and could only retain 25 percent of stormwater, only 13,421.5 gallons of water could be saved per year.

Available Contractors in the Seattle Area:

- Pervious Concrete, Inc. Seattle, WA
- Watson Asphalt Paving Company Inc. Redmond, Wa

Lot U

Based on the cost estimates and on the amount of rainfall Seattle receives, permeable pavement seems like the best option to treat the Connolly center. Because Seattle receives the bulk of its rainfall (26.11 in. out of 34.1 in yearly) during a 6-month timeframe (October through March), the ground remains saturated for much of the winter, and fields such as the Championship Field don't have to be watered often. Storing this vast amount of water from just the parking area would require large cisterns (enough for 488,291 gallons), which may not prove to be cost effective for the university. For reference, a 5,100 gallon cistern costs around $7000.

Thus the option we are suggesting is permeable pavement. Permeable pavement, while requiring the water to penetrate into the ground to work, may prove effective on its own or when combined with other techniques (infiltration trenches or wells). Total costs (design and construction) for permeable pavement come out to an average of $14.41 per sq. ft. in the Seattle area. The Connolly parking lot is approximately 120 ft. x 250 ft. totaling 30,000 sq. ft., yielding a cost of $432,300 to replace the lot with permeable pavement. With Seattle receiving an average of 34.1 in. of rainfall per year (2.84 ft.), permeable pavement could save 85,250 cubic ft., or 637,714 gallons per year from going into the sewage system as run-off, if all the water went into the pavement instead of into the storm drain. While, a study by the Virginia Water Resources Research Center shows permeable pavement effectiveness to be between 45% and 75%, so actual results could be between 286,971 gallons and 478,285 gallons, this is still a significant amount of water that is prevented from going into the combined sewer system.

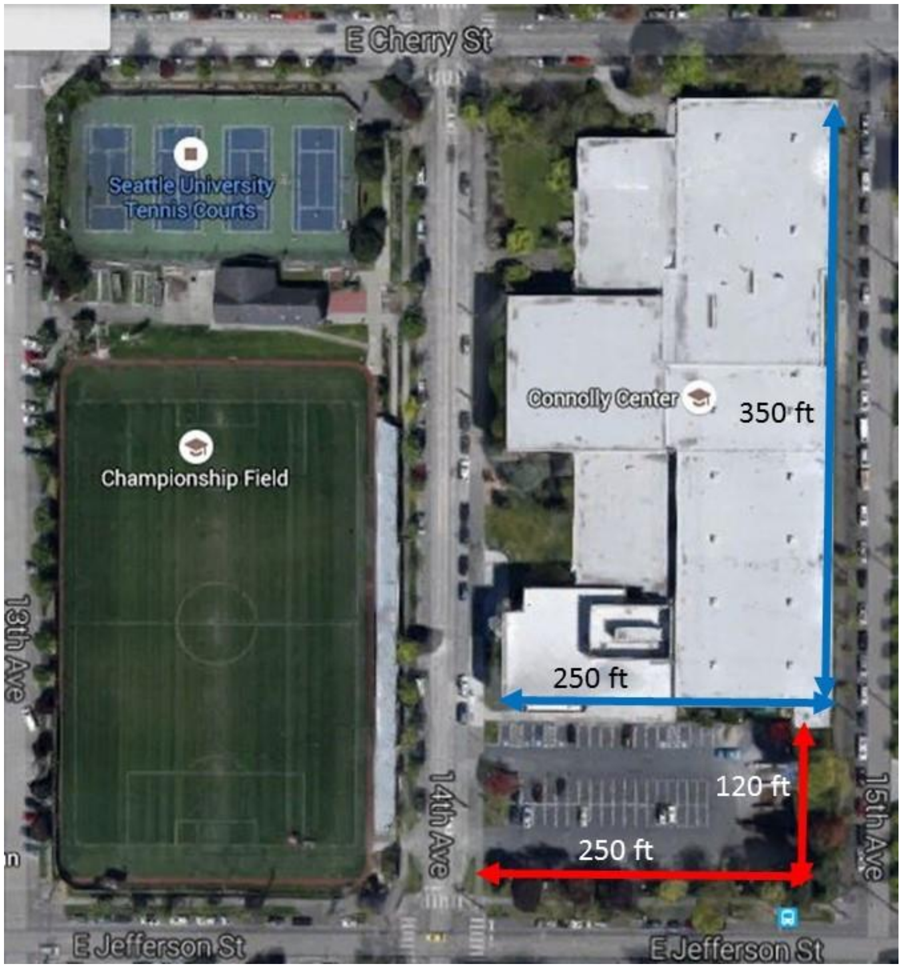

Figure 9: Diagram and measurements for lot U, the Connolly Center and associated parking lot.

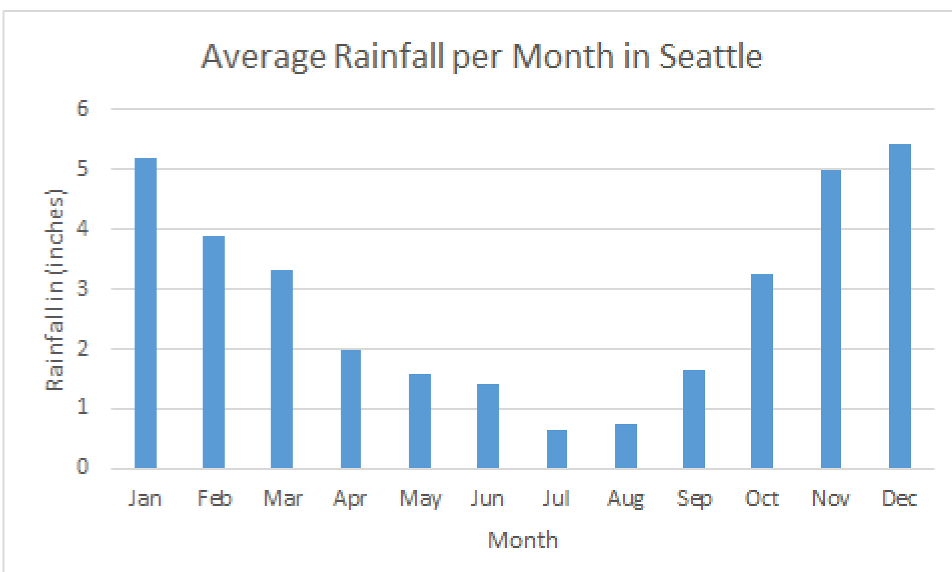

Figure 10: Average amount of rainfall in Seattle by month. Data from US Climate Data.

Above Average Lots: Potential Ideas

We also explored potential options for three other lots that had 60-80% of the surface area untreated for water runoff. These lots were B, K, and M. Lot B contains the Fine Arts Building, and Hunthausen Hall. Lot K has buildings for other institutions, but also contains the Arrupe Jesuit Residence, a parking lot, and a green space. Finally, Lot M covers the area containing Bellarmine Residence hall and the Pigott Pavilion.

Lot B

Lot B follows along E Madison St. and is between lower and upper mall, there are two buildings which occupy the lot, the Fine Arts Building and Hunthausen Hall. The Fine Arts Building was designed not only to support students in faculty with classrooms, office space, and gallery space, it act as a safe place for students to create art in a number of ways. Hunthausen Hall is primarily home to the School of Theology and Ministry which provides a number of graduate degrees, professional certificates, and continuing education opportunities. Hunthausen also houses the Fine Arts Annex, and the McGoldrick Collegium, a dedicated space for graduate students, non-traditional students, and military veterans. Review with facilities resulted in the conclusion that no major renovations or building plans are intended for this lot for the foreseeable future.

Out of the options we investigated, many are not applicable due to size. This includes permeable pavement, and swales or infiltration trenches; there is limited pavement to replace except the portion of campus walkways that intersect the plot, and swales and other such LID techniques require a certain distance from the building to maintain structural stability. The remaining options are to create a cistern or a green roof. Green roofs would help to provide a reduction of run-off for an individual building, but because of the likely high costs of reinforcing the roof, this option would only be chosen if other options prove infeasible. Because there is no cistern in this area save for the one that chapel uses, a new cistern could serve as a detention tank for water from other surrounding areas. If that were to be the case, the cistern would likely be placed in the adjacent D lot under the union green.

Alternatively, in neighboring lot A, there is the Lee Miley Rain Garden, if the roof-run off from Hunthausen and even the Fine Arts building could be moved via gravity to add to the inflow of the rain garden without exceeding the gardens max flow, this could be a low-cost way of reducing the run-off from this section of campus.

Lot K

This lot hosts a school parking lot, as well as a small green space where garden bed plots are available to members of the university community, as well as the Arrupe Jesuit Residence. There are two non-university owned buildings as well, however, the university does lease lab space for researching faculty and students in the College of Science and Engineering in one of these buildings. Research and communications with facilities does not show any plans for development in this lot in the near future.

While parking lots tend to favor the LID technique of permeable pavement, the steepness of this lot rules out permeable pavement as an option. Another difficulty to this lot is that while the green space helps reduce run-off coming in off Broadway Ave, it is higher on the hill than the Arrupe Jesuit house and parking lot, and thus it cannot serve as a rain garden. Further, the Jesuit residence is already served by a detention tank, and thus there is little more that is financially reasonable to undertake. Therefore, the parking area is the most important area to address, and similar to an option presented in the above section on Lot B, the best way to manage the water run-off is to catch the water and move it to other sites with current rainwater systems.

At the base of the parking-lot there is a garden strip, this is currently separated from the parking lot be concrete parking strip blocks. If the strips were removed the water could flow into this garden strip. While the strip cannot be the final location of the water again because of the steepness of the area, the strip could be converted to an infiltration trench or swale where the water infiltrates into the soil and then collects in a piping system to move the water away. Such a system is already in place about twenty feet away on the west side of the library where water is collected in the soil in pipes and transported to the east side of the library where there is a water attraction feeding into a recently renovated rain garden. If the parking lot water could also be diverted into this system instead of the sewer, the volume of water entering the sewer overall would decrease, and the water that did enter the sewage system would be spread out over a period of time rather than immediately following a storm, which is essential to decreasing CSO events.

Lot M

Lot M includes the Bellarmine residence hall and James C. Pigott Pavilion for Leadership. Bellarmine Hall provides housing for around 400 students, and the building also houses the Student Health Center and Bellarmine Advising Center. The Pigott Pavilion houses a number of offices and student support spaces including: Supercopy, Repographics, the office of SU's Continual, Online, and Professional Education program, Career Services, the International Student Center, the Counseling and Psychological Services office, the Education Abroad office, Commuter and Transfer Student Life office, the New Student and Family Programs office, mailing services, and Magis Alumni community office. There appears to be no attempt at, or goal of, renovation or construction in this lot.

The reason this lot has an above average rating for area untreated is that both the pavilion and Bellarmine do not have a cistern that they drain to. The best way to treat this area is with a cistern because there is limited area to develop a rain garden or swale, and a green roof would be extremely sun-limited on the pavilion, and require retrofitting the roof to support the extra weight on Bellarmine, which would be too disruptive to normal functions. While there are limitations to the placement of the cistern, the least disruptive to install would likely be an underground detention tank under the courtyard of the pavilion outside Repographics. Alternatively, if the library's rain garden can take in extra flow, the water from the roof could also be run through there.

Alternatives to LID

Reducing Interior Usage

The main intent of this investigation was to investigate LID methods that could be implemented on campus in order to reduce the amount of water entering the sewage system after a storm to prevent CSO events. However, the overall water added to the system can be reduced by using low-flow devices across campus. Recent investigations by Seattle University Environmental Science and Environmental Engineering students in a Green Engineering course highlighted that many of the older buildings on campus are not water-efficient, the top problems were that many of the facilities were 1) operating poorly resulting in constant running, and 2) installed pre-regulations which require a smaller volume of water toilet tank, and lower flow of water from sinks. Updating the many buildings on campus which suffer from these problems with low-flow toilets, sinks, and urinals would all reduce the amount of water introduced to the sewer on a daily basis. Additionally, ensuring that all facilities are working correctly will help reducing the problem of constantly running fixtures. These changes are also of financial interest to the university due to the savings both in less water in and less water out, and as such have a return of investment which many of the LID techniques otherwise mentioned in the report do not have.

While our report focuses on reducing the amount of water off-campus, even if it cannot be in reducing the amount of run-off, each building may have other, higher priority, changes that need to occur first. For example, in the same Green Engineering class mentioned above, students recognized that there were often both environmental comfort and energy-efficiency problems in each of the buildings investigated. However, we urge that water-efficiency changes should be made a priority, or be undertaken conversely with other changes.

Greywater

Greywater is water that comes from the pipe system in buildings that has not come in contact with feces. Greywater is usually associated with wastewater from laundry machines, sinks, and showers. While greywater should not come into contact with humans after being used, there are many beneficial uses that can recycle this water instead of feeding it into the sewer system. What that means for Seattle University is that this water can be used instead of flushed into the combined sewer system that threatens to overflow. Greywater is often recycled to irrigate plants or flush toilets, but in Seattle laws have restricted the use of greywater.

As of 2011, Washington edited its laws concerning greywater. Historically, it has been illegal to use greywater, instead it has been required to enter a sewer system directly. Now, however, greywater can now be used to water gardens and plants, as long as it is underground and does not come into contact with any edible part of a plant. Greywater systems are also limited to under 3,500 gallons a day, making recycling almost impossible for larger institutions, such as Seattle University. These changes have been made largely in part to the increase in population and the diminishing of water resources. While the state is making steps in the right direction for utilizing greywater, there is still a ways to go before we can use greywater to its greatest potential.

Rainwater

Rainwater, is unlike greywater in that it has never gone through a piping system before it enters the sewers, and it also has restrictions on how it can be recycled, though those restrictions are less strict than for greywater. Rainwater can only be collected from a building's roof. Rainwater can be stored (unlike greywater, which must be treated first), and it can be piped into a building for use in restrooms, laundry, and additionally for irrigation. Once rainwater is used indoors is treated as grey water and so must enter a sewer system. Although there are cisterns on campus, the largest being under the Admissions and Alumni Building, none of the collected water is being sourced into indoor plumbing, but instead is being gradually released back into the combined sewer system or used for irrigation.

Team Conclusions

Our team hopes that we have provided you with a better understanding of CSO events and what are some changes Seattle University can do to help reduce the frequency of these events occurring. There are a number of potential sites and options where SU can improve the campus stormwater infrastructure with LID techniques, and we encourage further analysis of both the practicality and the engineering of these options by Seattle University to continue to engage in the mission for campus sustainability.

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