Grand Valley State University
ScholarWorks@GVSU

Honors Projects | Undergraduate Research and Creative Practice

4-2018

Spatial Analysis of the Current and Potential Stormwater Management Practices on Grand Valley State University's Allendale Campus

Kyle Hart
Grand Valley State University

Spatial Analysis of the Current and Potential Stormwater Management Practices on Grand Valley State University's Allendale Campus

Kyle Hart

Grand Valley State University

HNR 499

Winter 2018

Abstract

Low impact development is an alternative to traditional urban design with the goal of reducing the amount of stormwater runoff generated from impermeable surfaces. Increased stormwater runoff can mobilize surface pollutants such as oil, road salt, and heavy metals, as well as accelerate the erosion and slope destabilization near natural waterways. Green infrastructure such as rain gardens and green roofs have been shown to remediate these pollutants and reduce the peak discharge of stormwater during storm events. This study evaluates the current stormwater management practices on the Allendale Campus of Grand Valley State University as well as provides management suggestions for the implementation of additional green infrastructure. Geographic information system (GIS) software was used to determine the land use types of two areas of interest in the campus and provide estimates of the peak discharge rate during a 25-year 24-hour rain event. The peak discharge of four stormwater management scenarios was estimated for the northern area of interest based on current conditions, and the implementation of rain gardens, green roofs, and permeable parking lots. The peak discharge for current conditions is estimated to be 4.76 m^3/sec or 168.14 cfs (Table 1). The highest reduction in peak discharge occurred in the permeable parking lot scenario with a total reduction of 22.37% (Table 1).

Introduction

A high volume of stormwater runoff is a consequence of urban development due to the increased area of impermeable surfaces such as parking lots, roads, sidewalks, and buildings. The increase in these surfaces facilitates rapid discharge of stormwater runoff during rain as well as degrades water quality. Nonpoint source pollution from stormwater runoff is one of the leading causes of the degradation of the quality in the receiving waters (Lee and Bang 2000). Incoming precipitation cannot infiltrate into the soil profile at a natural rate and can mobilize pollutants such as road salt, automotive chemicals, and suspended solids from these surfaces (Dietz 2007, Paul and Meyer 2001). An abundance of grey infrastructure can also make an urban landscape aesthetically displeasing, especially during rain events due to flooding in pedestrian areas. A high peak discharge of stormwater during rain events can also enhance the rate of erosion and distribute pollutants into waterways such as the ravines surrounding Grand Valley State University's Allendale campus.

Municipal stormwater systems are constructed to manage the high volume of stormwater during rain events. After collection, the stormwater is discharged, often into natural waterways in the landscape at rates that are higher than the natural conditions. Urbanized areas with combined sewer overflows during intense storm events can exceed the capacity of the system and discharge untreated wastewater. There are just under 800 communities in the United States that have potential for a combined sewer overflow (EPA 2008).

Low impact development as an alternative to impermeable surfaces can mitigate some of the consequences of high stormwater discharges by intercepting pollutants and slowing the rate of infiltration into the landscape. Rainwater will infiltrate slowly through dense vegetation and then into the soil profile rather than discharging at once through a constructed collection system. Excess sediment, heavy metals, nitrates, and phosphorous that is mobilized from the impermeable surfaces will also be retained at higher rates through several stormwater best management practices (BMPs) (Hatt, Fletcher and Deletic 2009, Dietz 2007). Biofiltration methods such as rooftop or rain gardens and permeable pavement will decrease the peak discharge rate during rain events and also have the capacity to sequester pollutants.

Different biofiltration media and designs have shown to greatly reduce concentrations of copper, lead, and zinc (>92%), as well as moderately reduce phosphorous (~80%), mobile nitrogen (~65 to 75%), and ammonium (60 to 80%) (Davis et al. 2006). Rooftop gardens absorb incoming solar radiation and can reduce the amount of energy required to cool buildings by up to 48%, which has the potential to save on HVAC costs in both summer and winter (Vijayaraghavan 2016). Public green spaces within a developed urban landscape can also provide aesthetic and ecological benefits by providing plant species diversity, insect habitat, as well as reducing the urban heat island effect by absorbing incoming solar radiation (Oberndorfer et al. 2007). Biofiltration gardens often support a diversity of grasses and seasonal flowers which facilitates pollination. Implementation of one or multiple low impact development BMPs can reduce the rate of peak discharge and concentrations of collected pollutants of stormwater during rain events in urbanized areas.

Project Goals and Design

This paper presents an inventory of the current management practices located on Allendale campus as well as three scenarios of stormwater management recommendations in order to decrease the peak discharge of stormwater generated on campus during rain events. The goals of this project are to identify where on the Allendale Campus of GVSU are the current stormwater management efforts and also determine where additional BMPs can be implemented around the freshman living centers on north Allendale campus and which ones are most suitable to be included in the existing development. Management efforts to reduce the volume of stormwater runoff on the Allendale Campus of GVSU will benefit from this study by providing estimates of the peak discharge of the based-on calculation of area for each land use type. I hypothesize that the implementation of green infrastructure such as rain gardens, permeable pavement, and rooftop gardens will reduce the peak discharge of stormwater produced by urban land uses that surround the freshman living centers of GVSU’s Allendale campus.

Three scenarios of management recommendations were developed and the peak discharge for each scenario was estimated using the Rational Runoff Equation and assumptions about changes to runoff coefficients. The first scenario proposed the addition of rain gardens within the sidewalk medians between the freshman living centers of north Allendale campus. The second scenario proposed the construction of several rooftop gardens on existing buildings within the area of interest. The final scenario proposed the conversion of the D parking lots to permeable pavement with underground stormwater storage. The new land use types were evaluated and the reduction of the peak discharge for each scenario was compared to the current conditions.

Understanding the mechanisms that influence stormwater runoff such as land cover type, slope, and drainage basin boundaries will assist resource managers in mitigating the negative consequences associated with urban stormwater pollution. Previous studies have been conducted concerning land use changes at GVSU and the subsequent increase of stormwater runoff. An estimated 189% increase in impermeable surfaces for the campus has occurred between 1973 and 2004 with a total of 679, 872 m^2 of impermeable cover constructed (Womble and Wampler, 2006). The construction of several new buildings has occurred since 2004, so this value is likely to be even higher at present. This study aims to supplement the stormwater management efforts of Grand Valley State University by providing spatial data of current land uses, estimates of discharge, and management recommendations of several low impact development strategies.

Methods

Geographic Information Systems (GIS) software was used to map the land use types and stormwater management practices within two areas of interest (AOIs) within the Allendale Campus of Grand Valley State University. The southern AOI currently contains several stormwater management practices such as sections of permeable sidewalk, rain gardens, and rooftop gardens (Figure 1). The northern AOI has no stormwater management practices and the land use types consist of only impermeable surfaces, lawn, and forest (Figure 2).

Land use types as well as the three scenarios of stormwater management recommendations were mapped within the northern AOI. The boundaries of the northern AOI extend east from North Campus Drive to the western edge of Lot D-8, the northern edge of Lot D-7 and the southern edge of the Kenneth W. Robinson Living Center. Every land use type and BMP was mapped within the southern AOI and the cumulative peak discharge was calculated. The boundaries of the southern AOI extend south of West Campus Drive to the property line of GVSU along the intersection of Pierce Street and 42nd Avenue, and between the western edge of Lot J and the eastern edge of the Alexander Calder Fine Arts Center.

New polygon shapefiles were created for each parking lot, major road, sidewalk, and stormwater management practice on campus (Figure 1). The Editor Toolbar in ArcMap was used to define the boundaries of the feature and create spatial information within the polygon shapefile. Two new attribute fields were added to each shapefile that were titled *Area* and *Surf_Type* (Table 1). The *Area* field was populated with the Calculate Geometry function and was calculated in square meters. The *Surf_Type* field was determined for each feature based on its land use type such as Parking Lot, Sidewalk, Rain Garden etc.

Rational Runoff Equation: $Q = i\ (A_1 * c_1 + A_2 * c_2 + A_3 * c_3 \ldots)$

Q = peak discharge (m3/sec) i = rainfall intensity (in/hour)

A_x = drainage area for each surface type c_x = runoff coefficient for each surface type

Equation 1. The Rational Runoff Equation and metrics (Adapted from Kuichling 1889)

The Rational Runoff Equation was used to determine peak discharge of stormwater for each AOI based on the estimated land use areas and the rainfall intensity (in/hour) of a 25-year 24-hour rain event for Allendale, Michigan (Equation 1). The rainfall intensity was determined from a rainfall frequency atlas of the Midwest compiled by The Midwestern Climate Center and runoff coefficients were provided by the Michigan Department of Transportation (MDOT, 2006; Huff & Angel, 1992).

This project's materials consisted of a 2014 aerial photo of Grand Valley State University's Allendale campus to use as reference for determining the boundaries of the surfaces, which was provided by Dr. Kim Ma of Grand Valley State University. A map of the stormwater BMPs created in 2010 by Dr. Peter Wampler of Grand Valley State University was also used as reference. The software used for this project was Esri's ArcMap and ArcCatalog. ArcMap was used to analyze the spatial distribution of existing stormwater management practices and land uses for the Allendale campus. Polygons were created and classified in ArcMap and the files were managed using ArcCatalog.

Results and Discussion

Site selection varied for each type of stormwater management practice. Existing flat roofed buildings would be most cost effective to retrofit with green roofs, whereas locations for rain gardens are restricted by available greenspace present between developed surfaces. The site selection for permeable asphalt or concrete is not restricted by environmental conditions such as topography or slope. Any existing parking lot could potentially be suitable for underdrain storage of stormwater, for this study however, parking lots D1 through D5 were chosen for scenario three.

Further site analysis should be conducted to determine factors such as soil type, hydrology, and feasibility of the construction of each stormwater management BMP recommendation.

South Campus

Just under 40% of the southern AOI of Allendale Campus is estimated to be of developed land use types with the majority of that area dedicated to parking lots (Table 2). This large area of impermeable surfaces present in south campus will create a higher level of peak discharge of stormwater during rain events. Higher velocity and volume of stormwater can facilitate increased rates of erosion and degrade natural waterways of surface pollutants such as road salt, automotive chemicals, and heavy metals (Hunt, Davis and Traver 2012, Paul and Meyer 2001). The cumulative peak discharge for the southern AOI is estimated to be 12.85 m^3/sec or 453.96 cfs (Table 3). Existing stormwater management practices cover just under three percent of the total developed land (Table 3). Increasing the amount of stormwater mitigation practices such as permeable pavement or rooftop gardens would sequester pollutants and delay the peak discharge during a rain event by allowing stormwater to slowly infiltrate into the water table (Dietz 2007).

North Campus

The total area of impermeable land uses for the north AOI of Allendale Campus was estimated to be 125,737 square meters and was just over 40 percent of the total area of interest (Table 4). Like south campus, the major impermeable land use type for the north AOI was parking lots, which represented just over half of the total area of developed land (Table 4). The total estimated peak discharge for the area under current land uses is 4.76 m^3/sec or 168.14 cfs (Table 4).

The first stormwater BMP scenario proposes the installation of 13 rain gardens around the freshman living centers of north campus. These rain gardens were estimated to mitigate 30,946 square meters of impermeable surfaces (Table 6). The area of the surrounding buildings and sidewalks whose stormwater would be mitigated by the nearby rain gardens was reevaluated with a range of runoff coefficients from 0.20 to 0.40. The lower c value represents a base case scenario in which the rain gardens are able to mitigate all of the stormwater produced by the surrounding impermeable land uses. The higher c value represents a scenario in which the rain gardens are at drainage capacity and reduce less runoff volume. The implementation of these rain gardens is estimated to reduce stormwater peak discharge by 12.5% to 18.3% from current conditions (Table 6). Rain gardens will retain stormwater from their surrounding area as well as remediate several heavy metals and excess nutrients. Increasing the amount of rain gardens surrounding the living centers can absorb runoff fertilizer and sidewalk salt used in the maintenance of the surrounding lawns. Rain gardens can also increase other ecosystem services such as habitat diversity and pollination (Hunt et al. 2012). The proposed rain gardens are located in grass medians between sidewalks and would also provide a natural aesthetic value to the residents of the living halls.

The second stormwater BMP scenario proposes the construction of five green roofs on existing flat-roofed buildings within the AOI. Approximately 25% of the buildings' area would be converted to rooftop gardens (Table 7). The area of the buildings whose stormwater would be mitigated by the gardens was reevaluated with a range of runoff coefficients of 0.20 to 0.40. The lower c value represents a base case scenario in which the rooftop gardens are able to retain all of the precipitation during a rain event and produces little stormwater runoff. The higher c value represents a scenario in which the rooftop gardens are at capacity and stormwater will be discharged. The construction of these green roofs is estimated to reduce stormwater peak discharge by 2.43% to 3.83% from current conditions (Table 7). Green roofs provide several ecosystem services such as providing habitat for pollinating insects and stormwater capture (Dietz 2007, Oberndorfer et al. 2007). Rooftop vegetation also reduces the urban heat island effect surrounding a structure due to the higher albedo provided by the vegetation, as compared to a standard shingled roof, as well as the absorption of incoming solar radiation through photosynthesis.

The third stormwater BMP scenario proposes the conversion of the D parking lots to permeable asphalt and underground storage. The proposed permeable asphalt area was reevaluated with a runoff coefficient of 0.2 from 0.85. A range of c values was not used in the peak discharge estimates for scenario three because it is assumed that enough underground storage would be constructed to retain the whole volume of stormwater created in the D parking lots. It was estimated that a conversion of 86.78% of the impermeable parking lot area to permeable asphalt would result in a reduction of the peak discharge of approximately 31.5% (Table 8). The third scenario resulted in the second largest reduction of the rate of peak discharge but is also would be the most construction intensive and costly.

Conclusion

Stormwater runoff collects hazardous pollutants as it moves across impermeable surfaces during rain events and facilitates erosion and slope destabilization of waterways as it is discharged from the collection system. The construction of green infrastructure as an alternative to traditional impermeable land development is an effective strategy to mitigate high volumes of stormwater runoff. Permeable pavements and biofiltration methods have been shown to both reduce concentrations of runoff pollutants as well as increase the lag time between peak rainfall and peak discharge during rain events (Davis et al 2006, Dietz 2007, Hunt et al. 2012). This study has shown positive results in reducing the peak stormwater discharge and supports my hypothesis that low impact development alternatives will help mitigate stormwater runoff.

Three scenarios of stormwater BMP recommendations were constructed within this report and were estimated to reduce stormwater discharge from 2.43% up to 31.5% (Table 1). The implementation of these recommendations would help reduce the peak discharge as well as increase the natural aesthetic and ecological value of the freshman living centers. Further site analysis should be conducted to determine the feasibility of these scenarios. Additional information such as soil type and slope would be beneficial in determining the placement of rain gardens. Runoff coefficients were estimated from the Michigan Department of Transportation, so *in situ* measurements of infiltration or runoff rates for each land use would also refine the results of this study. The transport of sediment from an upland area through a watershed is driven by gravity and moving water, both of which are often outside the realm of management. Reducing the accumulation of stormwater at the source is a strong management option and will be more effective at reducing its consequences than remediation efforts. Low impact development and environmentally conscious design should be considered as a primary design option for the future development of Grand Valley State University.

References

Davis, A. P., M. Shokouhian, H. Sharma & C. Minami (2006) Water quality improvement through bioretention media: Nitrogen and phosphorus removal. *Water Environment Research,* 78**,** 284-293.

Dietz, M. E. (2007) Low impact development practices: A review of current research and recommendations for future directions. *Water Air and Soil Pollution,* 186**,** 351-363.

Hatt, B. E., T. D. Fletcher & A. Deletic (2009) Hydrologic and pollutant removal performance of stormwater biofiltration systems at the field scale. *Journal of Hydrology,* 365**,** 310-321.

Huff, A. F., Angel J. R., (1992) Rainfall Frequency Atlas of the Midwest. Illinois State Water Survey, Champaign, Bulletin 71

Hunt, W. F., A. P. Davis & R. G. Traver (2012) Meeting Hydrologic and Water Quality Goals through Targeted Bioretention Design. *Journal of Environmental Engineering-Asce,* 138**,** 698-707.

Kuichling, E., (1889) The relation between the rainfall and the discharge of sewers in populous districts. *Transactions, American Society of Civil Engineers,* 20, 1-56.

Lee, J. H. & K. W. Bang (2000) Characterization of urban stormwater runoff. *Water Research,* 34**,** 1773-1780.

Michigan Department of Transportation, (2006) Drainage Manual.

Oberndorfer, E., J. Lundholm, B. Bass, R. R. Coffman, H. Doshi, N. Dunnett, S. Gaffin, M. Kohler, K. K. Y. Liu & B. Rowe (2007) Green roofs as urban ecosystems: Ecological structures, functions, and services. *Bioscience,* 57**,** 823-833.

Paul, M. J. & J. L. Meyer (2001) Streams in the urban landscape. *Annual Review of Ecology and Systematics,* 32**,** 333-365.

U.S. Environmental Protection Agency, 2008. Combined Sewer Overflows: Demographics.

Vijayaraghavan, K. (2016) Green roofs: A critical review on the role of components, benefits, limitations and trends. *Renewable & Sustainable Energy Reviews,* 57**,** 740-752.

Womble, P., Wampler, P.J., (2006). Urbanization induced changes to a ravine system and evaluation of land use and infrastructure sustainability at Grand Valley State University, Allendale, MI. *Grand Valley State University Student Summer Scholars Showcase.*

Table 1

Summary of peak discharge reduction per stormwater management recommendations

Land use type	Management Recommendation	Estimated Peak Discharge (m^3/sec)	Estimated Peak Discharge (cfs)	Percent Reduction
Existing Conditions	None	3.39	119.66	*N/A*
Scenario One	Rain Gardens	2.75 to 2.94	97.1 to 104	13.09% to 18.85%
Scenario Two	Rooftop Gardens	4.35 to 4.40	114 to 116	3.13% to 4.52%
Scenario Three	Permeable Pavement	2.30	81.36	32.01%

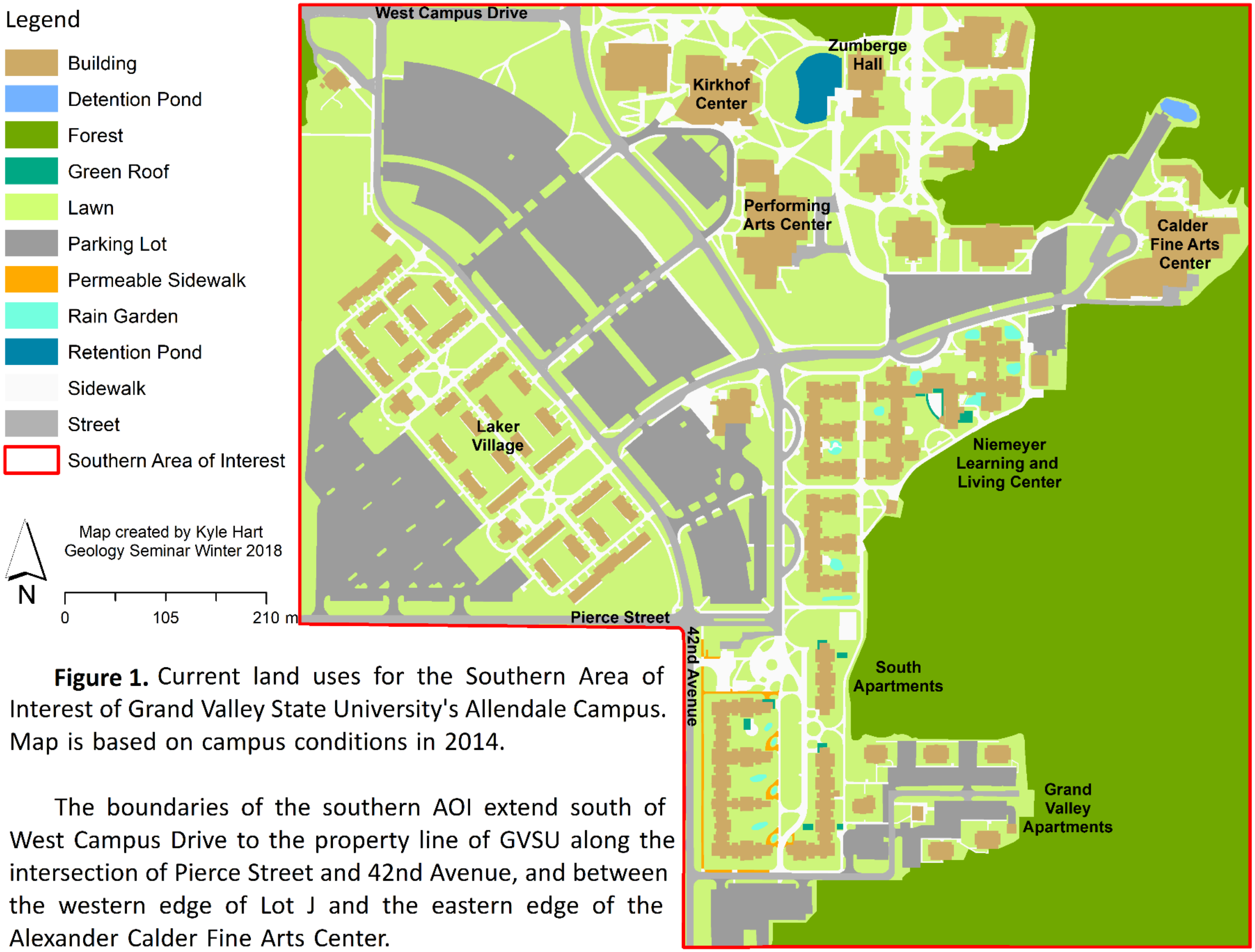


Figure 1. Current land uses for the Southern Area of Interest of Grand Valley State University's Allendale Campus. Map is based on campus conditions in 2014.

The boundaries of the southern AOI extend south of West Campus Drive to the property line of GVSU along the intersection of Pierce Street and 42nd Avenue, and between the western edge of Lot J and the eastern edge of the Alexander Calder Fine Arts Center.

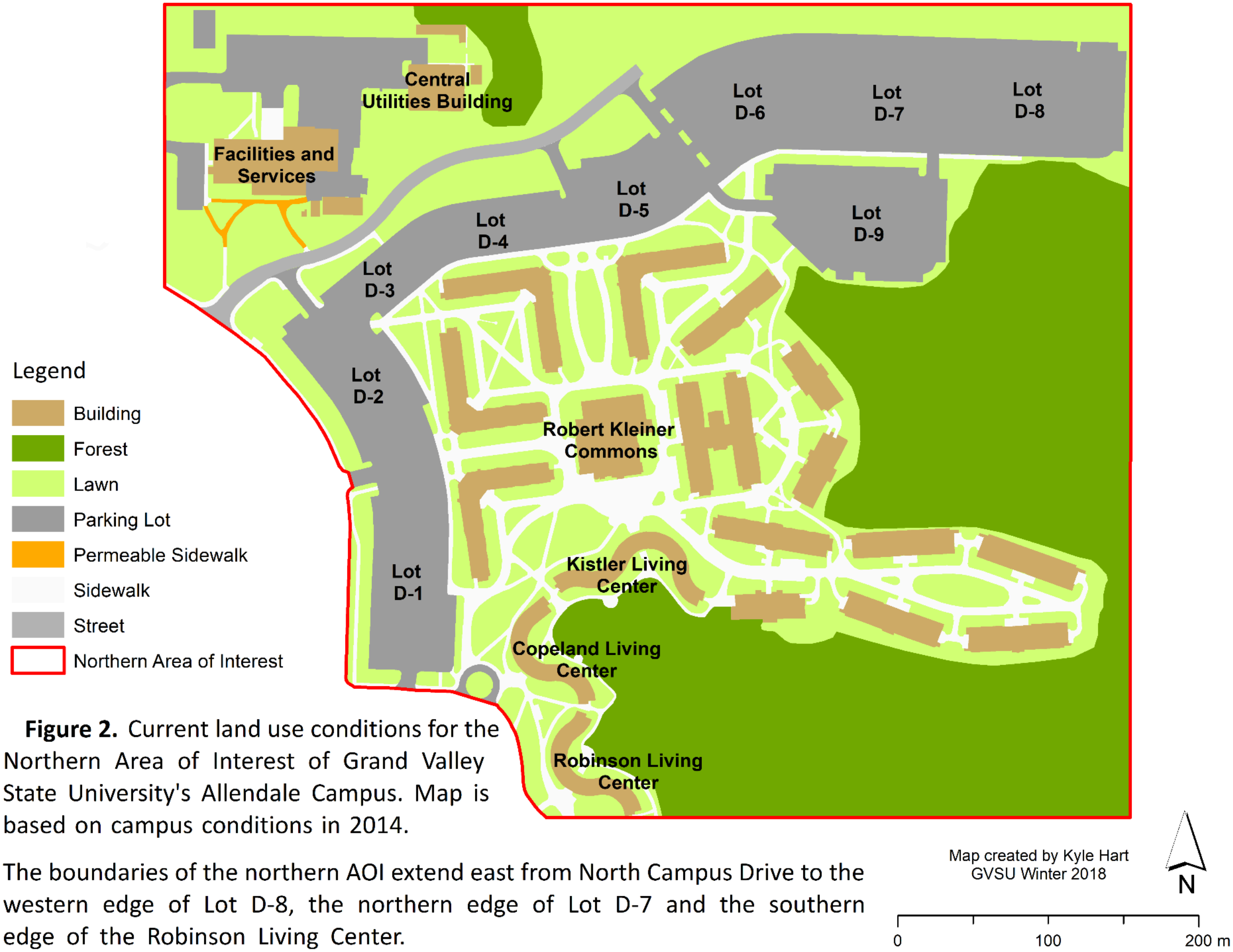


Figure 2. Current land use conditions for the Northern Area of Interest of Grand Valley State University's Allendale Campus. Map is based on campus conditions in 2014.

The boundaries of the northern AOI extend east from North Campus Drive to the western edge of Lot D-8, the northern edge of Lot D-7 and the southern edge of the Robinson Living Center.

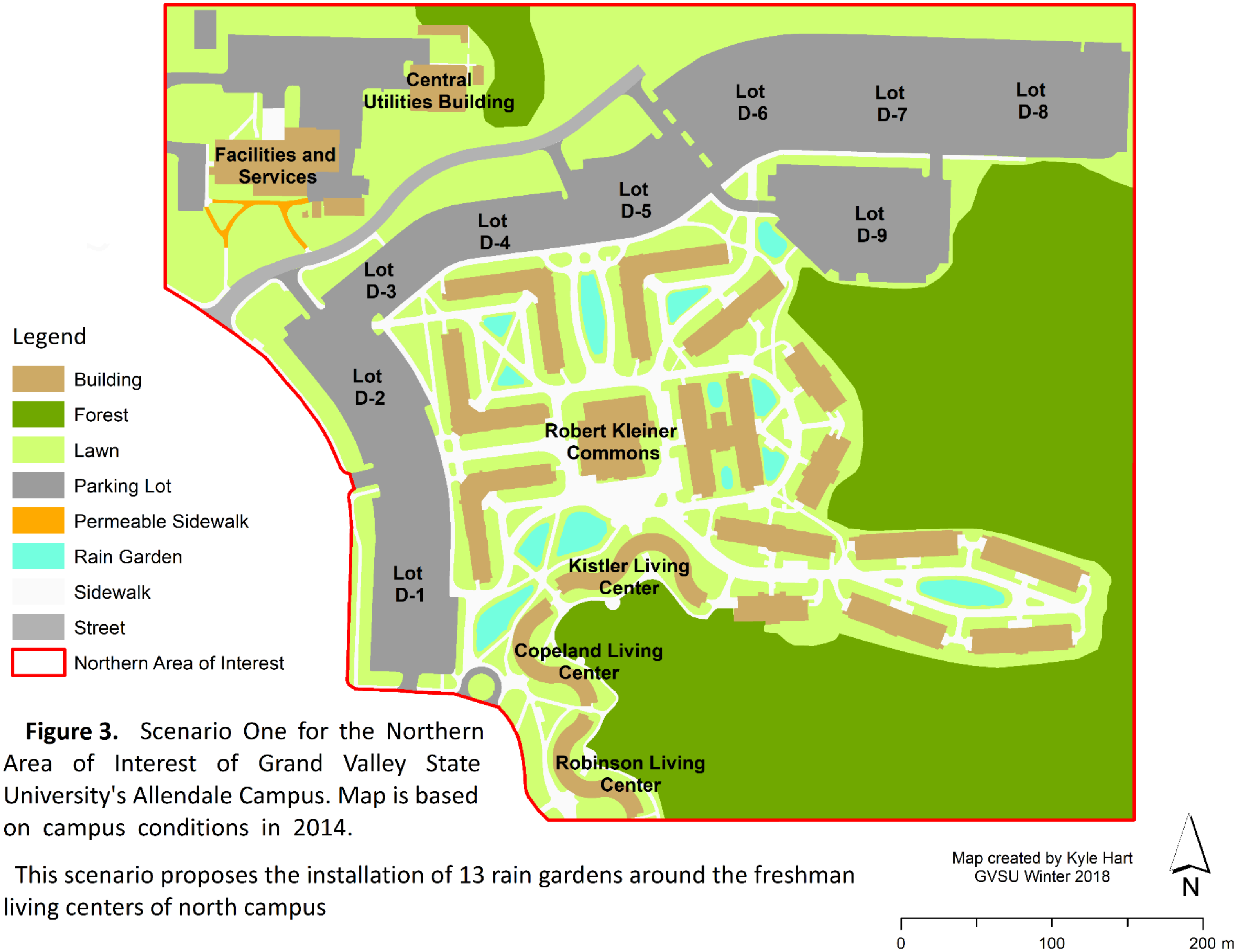
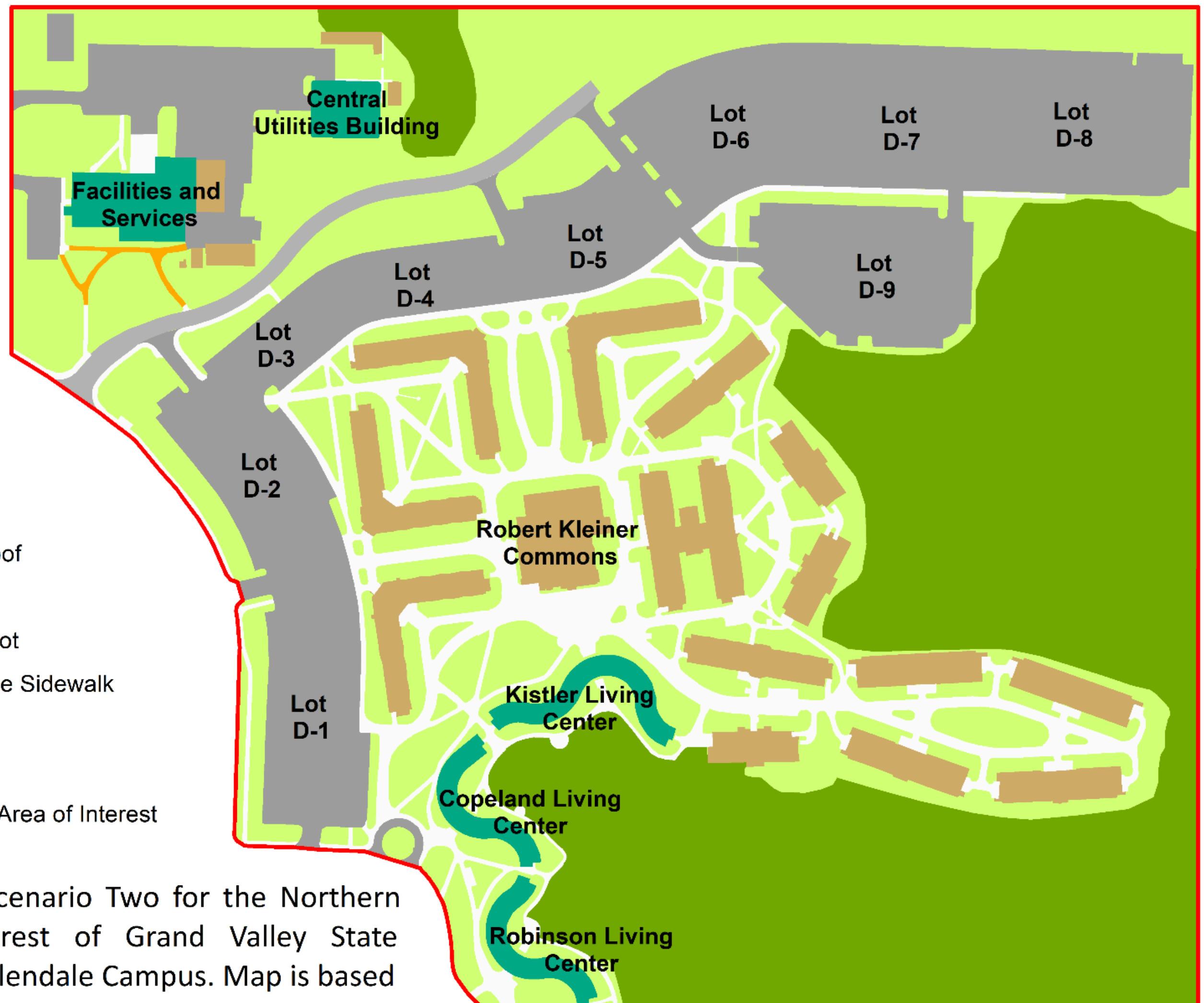


Figure 3. Scenario One for the Northern Area of Interest of Grand Valley State University's Allendale Campus. Map is based on campus conditions in 2014.

This scenario proposes the installation of 13 rain gardens around the freshman living centers of north campus



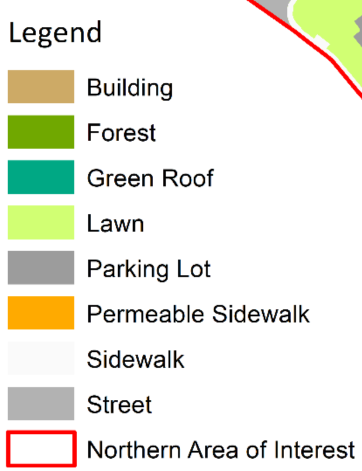
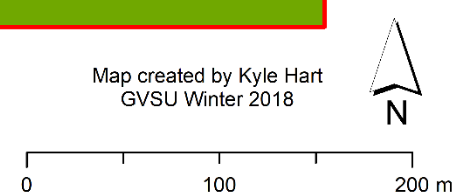


Figure 4. Scenario Two for the Northern Area of Interest of Grand Valley State University's Allendale Campus. Map is based on campus conditions in 2014.

This scenario proposes the construction of five rooftop gardens on existing flat roofed buildings



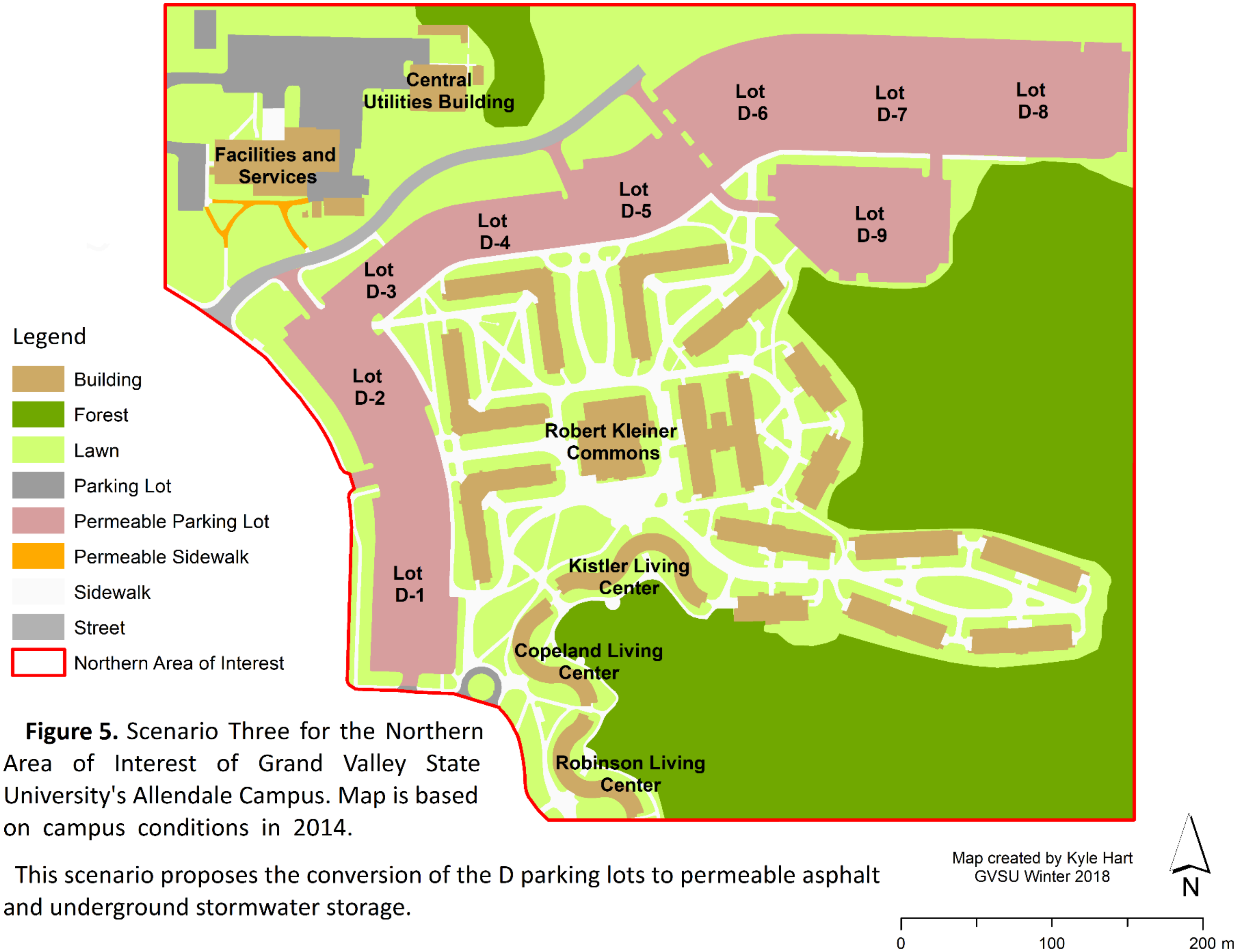


Figure 5. Scenario Three for the Northern Area of Interest of Grand Valley State University's Allendale Campus. Map is based on campus conditions in 2014.

This scenario proposes the conversion of the D parking lots to permeable asphalt and underground stormwater storage.

South Campus

Table 2

Land use types for the Southern Area of Interest of Grand Valley State University's Allendale Campus.

Land Use Type	Area (m^2)	% of Developed Land	% of AOI
Building	80160	24.70%	9.55%
Detention Pond	764	0.24%	0.09%
Green Roof	780	0.24%	0.09%
Parking Lot	133047	40.99%	15.86%
Permeable Sidewalk	1473	0.45%	0.18%
Rain Garden	1595	0.49%	0.19%
Retention Pond	2672	0.82%	0.32%
Sidewalk	63073	19.43%	7.52%
Street	41036	12.64%	4.89%
Total Developed Land:	324600	100.00%	38.69%
Lawn	239078	*N/A*	28.49%
Forest	276024	*N/A*	32.90%
Total Green Space:	515102	*N/A*	61.39%
Area of Interest	839060	38.69%	100%

Table 3

Peak discharge estimates for south AOI of Allendale Campus of Grand Valley State University using the *Rational Runoff Equation* and current land use types

Land Use Type	Runoff Coefficient[1] (c)	Rainfall Intensity[2] (in/hour)	Area (m^2)	Estimated Peak Discharge (m^3/sec)	Estimated Peak Discharge (cfs)
Building	0.85	4.5	80160	2.16	76.4
Buildings and Sidewalks draining into Rain Gardens*	0.25	4.5	20205	0.16	5.66
Green Roof	0.25	4.5	780	0.01	0.22
Parking Lot	0.85	4.5	133047	3.59	127
Permeable Sidewalk	0.50	4.5	1473	0.02	0.83
Rain Garden	0.25	4.5	1595	0.01	0.45
Sidewalk	0.85	4.5	63073	1.70	60.1
Street	0.85	4.5	41036	1.11	39.1
Lawn	0.25	4.5	239078	1.90	67.0
Forest	0.25	4.5	276024	2.19	77.4
Totals:	*N/A*	*N/A*	856471	12.9	454

*Area was calculated by the total amount of impermeable land uses surrounding the rain gardens whose discharge would be mitigated.

[1]Runoff coefficients are from Michigan Department of Transportation (MDOT, 2006)

[2]Rainfall intensity is from the *Rainfall Frequency Atlas of the Midwest* (Huff and Angel, 1992).

North Campus

Table 4

Land use types for the Northern Area of Interest of Grand Valley State University's Allendale Campus.

Land Use Type	Area (m^2)	% of Developed Land	% of Total Area
Building	30262	24.07%	10.06%
Parking Lot	65601	52.17%	21.82%
Permeable Sidewalk	446	0.35%	0.15%
Sidewalk	26340	20.95%	8.76%
Street	3088.0	2.46%	1.03%
Total Developed Land:	125737	100.00%	41.81%
Lawn	86040	*N/A*	28.6%
Forest	89369	*N/A*	29.72%
Total Green Space	175409	*N/A*	58.33%
Area of Interest	300701.00	41.81%	100.00%

Table 5

Peak discharge estimates for the Northern Area of Interest of GVSU using the *Rational Runoff Equation* and current land use types

Land Use Type	Runoff Coefficient (c)	Rainfall Intensity (in/hour)	Area (m^2)	Estimated Peak Discharge (m^3/sec)	Estimated Peak Discharge (cfs)
Building	0.85	4.5	30262	0.82	28.8
Parking Lot	0.85	4.5	65601	1.77	62.5
Permeable Sidewalk	0.50	4.5	446	0.01	0.25
Sidewalk	0.85	4.5	26340	0.71	25.1
Street	0.85	4.5	3088	0.08	2.94
Total Developed Land:	***N/A***	***N/A***	**125737**	**3.39**	**120**
Lawn	0.25	4.5	86040	0.68	24.1
Forest	0.25	4.5	89369	0.71	25.1
Total Area of Interest:	***N/A***	***N/A***	**301146**	**4.78**	**169**

Scenario One

Table 6

Scenario One: peak discharge estimates using the *Rational Runoff Equation* & land use types. Land use changes are italicized.

Land Use Type	Change in Area	Runoff Coefficient (c)[1]	Rainfall Intensity (in/hour)[2]	Area (m^2)	Estimated Peak Discharge (m^3/sec)	Estimated Peak Discharge (cfs)
Building	-51.22%	0.85	4.50	14762	0.40	14.07
Parking Lot	0.00%	0.85	4.50	65601	1.77	62.52
Permeable Sidewalk	0.00%	0.50	4.50	446	0.01	0.25
Sidewalk	-58.64%	0.85	4.50	10894	0.29	10.38
Street	0.00%	0.85	4.50	3088	0.08	2.94
*Rain Garden**	+100%	0.20 to 0.40	4.50	30946	0.20 to 0.39	6.94 to 13.9
Developed Land Totals:	**N/A**	**N/A**	**4.50**	**125737**	**2.75 to 2.94**	**97.1 to 104**
Lawn	0.00%	0.20	4.50	81454	0.52	18.3
Forest	0.00%	0.20	4.50	89369	0.57	20.0
Area of Interest Totals:	***N/A***	***N/A***	***N/A***	**301146**	**3.84 to 4.03**	**135 to 142**
					Reduction of Peak Discharge from Current Conditions:	13.09% to 18.85%

*Area for proposed stormwater management practices is calculated by the total amount of impermeable land uses surrounding the feature whose discharge would be mitigated.

[1]Runoff coefficients are provided by Michigan Department of Transportation [2]Rainfall intensity is based on a 25-year 24 hour rain event for Allendale Michigan

Scenario Two

Table 7

Scenario Two: peak discharge estimates using the *Rational Runoff Equation* & land use types. Land use changes are italicized.

Land Use Type	Change in Area	Runoff Coefficient (c)[1]	Rainfall Intensity (in/hour)[2]	Area (m^2)	Estimated Peak Discharge (m^3/sec)	Estimated Peak Discharge (cfs)
Building	-24.53%	0.85	4.50	22839	0.62	21.8
Parking Lot	0.00%	0.85	4.50	65601	1.77	62.5
Permeable Sidewalk	0.00%	0.50	4.50	446	0.01	0.25
Sidewalk	0.00%	0.85	4.50	26340	0.71	25.1
Street	0.00%	0.85	4.50	3088	0.08	2.94
*Rooftop Garden**	+100%	0.20 to 0.40	4.50	7423	0.05 to 0.09	1.66 to 3.33
Developed Land Totals:	**N/A**	**N/A**	**4.50**	**125737**	**3.23 to 3.28**	**114 to 116**
Lawn	0.00%	0.20	4.50	86040	0.55	19.3
Forest	0.00%	0.20	4.50	89369	0.57	20.0
Area of Interest Totals:	***N/A***	***N/A***	***N/A***	**426883**	**4.35 to 4.40**	**154 to 155**
					Reduction of Peak Discharge from Current Conditions:	3.13% to 4.52%

*Area for proposed stormwater management practices is calculated by the total amount of impermeable land uses surrounding the feature whose discharge would be mitigated.

[1]Runoff coefficients are provided by Michigan Department of Transportation [2]Rainfall intensity is based on a 25-year 24 hour rain event for Allendale Michigan

Scenario Three

Table 8

Scenario Three: peak discharge estimates using the *Rational Runoff Equation* & land use types. Land use changes are italicized.

Land Use Type	Change in Area	Runoff Coefficient (c)[1]	Rainfall Intensity (in/hour)[2]	Area (m^2)	Estimated Peak Discharge (m^3/sec)	Estimated Peak Discharge (cfs)
Building	0.00%	0.85	4.50	30262	0.82	28.8
Parking Lot	-86.78%	0.85	4.50	8670	0.23	8.26
Permeable Sidewalk	0.00%	0.50	4.50	446	0.01	0.25
Sidewalk	0.00%	0.85	4.50	26340	0.71	25.1
Street	0.00%	0.85	4.50	3088	0.08	2.94
*Permeable Parking Lot**	+100%	0.25	4.50	56931	0.45	16.0
Developed Land Totals:	**N/A**	**N/A**	**4.50**	**125737**	**2.30**	**81.4**
Lawn	0.00%	0.25	4.50	86040	0.68	24.1
Forest	0.00%	0.25	4.50	89369	0.71	25.1
Area of Interest Totals:	***N/A***	***N/A***	***N/A***	**301146**	**3.70**	**131**
				Reduction of Peak Discharge from Current Conditions:		32.01%

*Area for proposed stormwater management practices is calculated by the total amount of impermeable land uses surrounding the feature whose discharge would be mitigated.

[1]Runoff coefficients are provided by Michigan Department of Transportation [2]Rainfall intensity is based on a 25-year 24 hour rain event for Allendale Michigan