THE IMPACT OF DIFFERENT STORMWATER FEE TYPES: A CASE STUDY OF TWO MUNICIPALITIES IN VIRGINIA

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Stormwater user fees (SUFs) are an increasingly popular method of generating revenue for municipalities responsible for implementing complex stormwater regulations through the NPDES permit program. These fees can be created in a multitude of ways, including a flat fee for each parcel, charging by parcel area, charging based on a runoff factor, and many others. As a case study, eight SUFs were applied to the City of Roanoke and the Town of Blacksburg, both in Virginia, to determine the effect each SUF has on how land use type impacts the revenue composition. The City of Roanoke is larger and includes more industrial areas, but less multifamily impervious areas than Blacksburg, which translates differently in the SUFs. Residential parcels comprise the highest percentage of the revenue in all eight SUFs in Blacksburg and four in Roanoke. Open space parcels don't contain much impervious area yet account for up to 27% of the revenue. Industrial parcels comprise more of the revenue in Roanoke, averaging 11.1% compared to 4.6% in Blacksburg. A detailed digitized land cover dataset was compared to Blacksburg's land cover dataset, which resulted in maximum difference of $0.02 per parcel for residential parcel fees. Exemptions of large parcels in Roanoke, like the railroad and airport, if enacted would result in a maximum increase in fees of 15% and a shift of $7,491 of the monthly revenue to the residential parcels.

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GENERAL AUDIENCE ABSTRACT

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Also, I would like to thank my family and friends, especially my fiancé Brian Fedorchak, for being with me through this journey. Brian, I could not have made it this far without you and I thank you wholeheartedly for helping me stay motivated and not lose sight of the end goal.

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1 INTRODUCTION

1.1 BACKGROUND

In 1972, the Congress of the U.S. introduced the Federal Water Pollution Control Act, commonly known as the Clean Water Act, (CWA) to protect the waters of the U.S. with programs for water quality improvements. These programs included requiring treatment for municipal and industrial wastewater, mandating permits for discharges of pollutants from point sources in navigable waters, and gave the Environmental Protection Agency (EPA) the authority to create pollution control programs (33 USC 26 - *Federal Water Pollution Control Act 1972*). This act largely focused on wastewater and industry discharges, and stormwater quality was not specifically addressed. The Water Quality Act of 1987 (WQA) amended the CWA, and created a system for permitting discharges from municipal separate storm sewer systems (MS4s) - the National Pollutant Discharge Elimination System's (NPDES) stormwater program. With this amendment, two important sections emerged: Section 303 and Section 402.

Section 303 of the CWA is the total maximum daily load (TMDL) program. This program was created to control the pollution in the nation's waters by creating regulatory limits on the amount of pollutant discharge, known as "allocations." States were first tasked with creating a list of impaired waters based on the water's designated use, developing a TMDL that the waterbody can receive without impairment, and allocating the daily loading to the various dischargers in the watershed (33 USC 26 § 303 - *Federal Water Pollution Control Act 1972*).

The NPDES program is detailed in Section 402 of the CWA. The NPDES permit program promulgated for large MS4s (population > 100,000) in 1990, and for small and medium MS4s (population < 100,000) in 1999; known as Phase I and II of the MS4 program respectively. Phase I permits require municipalities to develop a Stormwater Management Plan (SWMP) to reduce pollutants in the stormwater discharge to the "maximum extent practicable" (USEPA 1999). Tasks that need to be performed include, but are not limited to, controlling discharges from areas of development, educating the public about stormwater, and screening for illicit discharges (40 CFR § 122-124. 1990). The Phase II program requires municipalities to address six minimum control measures (MCMs): public education and outreach, public involvement, illicit discharge detection and elimination, construction site runoff control, post-construction stormwater management, and good housekeeping for municipal operations (USEPA 1999).

Regulation demands from the NPDES MS4 permits and TMDL requirements have increased the municipal responsibility for stormwater and natural stream and river quality, all of which comes at a cost. One major issue is the condition of the infrastructure; aging pipe networks, inlets, and appurtenances commonly receive maintenance only after a problem is found (WEF 2013). While Phase I requirements are relatively straightforward, Phase II municipalities often have more trouble determining what activities will meet the MCMs as described by the legislation. Aguilar and Dymond (2015) analyzed 90 MS4s in Virginia, and found that 59 different stormwater control measures were used to meet the MCMs, with municipalities reporting between 6 and 35 in their program plans. The decision of specific permit requirements are left to the states and, as the NPDES compliance is unfunded, local municipalities try to find activities that add benefit to the municipality, or try to repurpose an already funded activity (Gillespie et al. 2002).

Unfortunately, many MCMs, as well as other stormwater regulation activities, do not have a local funding mechanism.

Especially for small MS4s, completing these tasks with the existing funds can be difficult. Many municipalities trying to find more revenue for their stormwater management programs are looking at options like special service fees, fees for new development, taxes, grants, partnerships and stormwater user fees (SUFs). SUFs are fees that are paid by parcel owners to fund the operation and maintenance of stormwater utility networks, similar to a fee paid for sanitary sewer (WEF, 2013). Many methods of charging these fees exist, including flat fees, tier fees, fees charged by parcel area.

Currently, the most popular method of charging a SUF is the equivalent residential unit (ERU), with 709 recorded municipalities using this fee type (Kea 2015). The ERU is a fee type that determines the average impervious area on residential parcels in the municipality (Equation 1.1). Parcels are then billed by finding the impervious area on the property and dividing by the ERU area (Equation 1.2). Once the number of ERUs is determined, the fee charged is the number of ERUs multiplied by the assessment rate per ERU determined by the municipality (Equation 1.3).

$$\text{ERU Area} = \frac{\text{Total Residential Impervious Areas}}{\text{Number of Residential Parcels}} \tag{1.1}$$

$$\text{No. of ERUs on a Parcel} = \frac{\text{Parcel Impervious Area}}{\text{ERU Area}} \tag{1.2}$$

$$\text{SUF Fee} = \text{No. of ERUs} * \text{ERU Rate} \tag{1.3}$$

Choosing a specific type of SUF to use is usually based on a multitude of reasons, including municipality resources and data gathering and storage. However, because each fee type assesses the fee differently, the consumers are charged differently which results in different land uses being responsible for the majority of the revenue.

1.2 PROBLEM STATEMENT

Because there are so many options for SUF fee types, it may become difficult to choose which one would be the best option, and which land uses are impacted by each type. The objective of this research is to examine how eight different SUF fee types can be applied to generate the revenue needed to support the existing programs and determine which consumers (land uses) will be impacted by which SUF fee type. Two separate municipalities in Virginia will be used in this case study and the differences in the results will be compared based on the analysis factors and the municipal differences. A detailed land cover and exemptions of airport and railroad parcels were also compared to the current SUFs to see the effect these elements have on the SUF fees.

1.3 OBJECTIVES

This research will accomplish the six objectives listed below.

1. Determine the different sources of revenue used for stormwater management programs across the country, including taxes, general funds, stormwater user fees, etc.

2. Examine the different methods used for computing stormwater user fees.

3. Investigate data and personnel needs for each stormwater user fee type.

4. Calculate the stormwater user fee for two municipalities using different fee types to find changes in revenue composition.

5. Compare the consumer charges from each type of stormwater user fee to find how the land use composition is reflected in the revenue in each of the two municipalities.

6. Compare the results from both of the municipalities to find the effect of differences in municipality size and land use.

2 LITERATURE REVIEW

2.1 AMBIGUITY OF MUNICIPALITY PHASE II REQUIREMENTS

While Phase I requirements are more straightforward, Phase II municipalities have more trouble determining what activities will meet the MCMs as described by the legislation. Aguilar and Dymond (2015) analyzed 90 MS4s in Virginia, and found that 59 different stormwater control measures were used to meet the MCMs, with municipalities reporting between 6 and 35 in their program plans. The type of MS4 (whether municipality, college/university, or other) had an effect on which activities were chosen, but cultural, environmental, and economic characteristics had effects on only three stormwater control sub-measures: public seminars, children/minority stormwater education, and online illicit discharge reporting mechanisms. The decision of specific permit requirements are left to the states and, as the NPDES compliance is unfunded, local municipalities try to find activities that add benefit to the municipality, or try to repurpose an already funded activity (Gillespie et al. 2002). Unfortunately, many MCMs, like illicit discharge detection and elimination, do not have a steady, local funding mechanism.

2.2 REVENUE SOURCES FOR STORMWATER MANAGEMENT PROGRAMS

The regulatory requirements and associated economic cost of the NPDES stormwater and TMDL programs have largely been delegated to local governments, which, along with the cost of maintaining failing and aging infrastructure (WEF, 2013), has created a need for consistent funding mechanisms. Stormwater management programs have traditionally been funded through a municipality's general fund, but this is not a consistent funding source, as stormwater funding is subject to the prioritization of needs of other government programs [e.g. police and education, (WEF, 2013)]. With the increase in stormwater regulatory programs such as MS4s and TMDLs, municipal governments have had to find additional revenue streams besides the general fund, including plan review and development fees, federal or state grants and loans, dedicated taxes, special assessments, stormwater user fees (SUF), or a mix of the these funding sources (NAFSMA 2006).

SUFs have been used for over 30 years, and have become a popular choice as a steady stream of funding for stormwater management programs. State funding has been declining, and funding from property taxes also decreased during the 2008-9 recession, leaving little revenue sources for stormwater (WEF 2013). Campbell et al. (2015) found that nearly 1,500 municipalities in the U.S. are currently using SUFs. SUFs have also been used internationally; some British water companies and Sydney, Australia have a drainage charge incorporated into water bills. Also, some German consumers are charged their SUFs according to the parcel's stormwater burden (Grigg 2013), and just under 20 municipalities in Canada were recorded in the Western Kentucky University Stormwater Utility Survey in 2014 (Campbell et al. 2014). More municipalities are looking towards SUFs for a multitude of reasons, including economic pressures, increased regulations, and maintenance of aging infrastructure (WEF 2013).

2.3 STORMWATER USER FEE ORGANIZATION

Utility fees are commonly organized so that everyone charged is paying for a needed service and at a rate directly related to the cost of providing such service. The need for a SUF should be made clear early in the creation process, and made apparent to the public (McClelland 2001). McClelland believes the key to a successful SUF starts with public approval, which may be found through many facets including identifying pubic interests, holding neighborhood meetings, sending brochures, and creating an educational video about the SUF. Also mentioned was the need to identify short- and long-term goals of the stormwater program that the SUF will directly fund. Organization of SUFs vary greatly across the United States, and can be driven by local priorities and politics (Grigg 2013). When creating a fee, two factors to consider are the implementation costs and administration budget. Implementation costs are a one-time cost which may include development of ordinances, parcel information databases, and billing systems. While these implementation costs will only occur at the onset of the SUF, administration costs will be ongoing and should be assessed based on the complexity of the fee chosen and take into consideration periodic updates to the parcel database (WEF 2013).

Utility fees such as drinking water or sanitary sewer rates are typically assessed so that consumers are paying for a needed service and at a rate directly related to the cost of providing the service. SUF fees are difficult to determine using the same concept, but a number of methods to calculate them have been developed. The revenue needs to balance both the demand of service from each parcel along with the resources of data and personnel required to compute the fees. Common types of SUF fees include Flat, Tier, Equivalent Residential Units (ERUs), Residential Equivalence Factor (REF), Dual, and Parcel Area. Many others, including by water meter size, water usage, and number of parking spaces, also exist, but are not as prevalent (Kea 2015). Each fee type is calculated based on different attributes of the parcels. Table 2.1 illustrates that the ERU fee type is the most popular, followed by Tier and Flat fees.

Table 2.1. Description of Common Fee Types and Number of Municipalities Using Each (Kea 2015).

Fee Type	Description	No. of Municipalities
Equivalent Residential Unit (ERU)	Charges based on average impervious area (IA) of residential parcels	709
Tier Fee	Charged by classifying parcels into categories based on Impervious Area, land use, etc.	228
Flat Fee	One fee for all parcels	221
Residential Equivalence Factor (REF)	Calculates amount of runoff from each parcel using NRCS or Rational method	126
Dual Fee	Separate parcels into residential or nonresidential, and charges each classification differently	89
By Parcel Area	Rate based on size of parcel	32
Water Meter	Charged based on water meter size	4
Water Usage	Based on amount of domestic water used	4

Modifications can be made to the rate structure by using credits that reduce the SUF for a property for a specified reason. Reese (1996) details some of the ways these credits are determined. His research led to six categories of assessing credits: class of ratepayers, class of property, location within the watershed, activities that improve the system, reduction of property impact, and reduction of the municipality's cost of service. Because of the direct relation to the purpose of the fee, credits based on impact-reduction and cost-reduction hold the most legitimacy. Cost-reduction credits are given for properties where private investments have reduced the municipality's cost to maintain the storm sewer system. Impact-reduction credits apply to properties that reduce their impact on the storm sewer system. Both of these categories, however, are difficult to determine exactly, and many are based on a related, more easily attainable measure, like reduced peak flow (Reese 1996).

2.4 EXISTING STORMWATER USER FEES

Along with Kea, many others have compiled reports of municipality SUFs, including Grigg (2013), WEF (2013), Western Kentucky University Stormwater Utility Surveys (Campbell 2007-2013; Campbell et al. 2014), Black and Veatch Stormwater Utility Survey (Black & Veatch 2014), Florida Stormwater Association Stormwater Utilities Survey (FSA 2011), Southeast Stormwater Association Southeast Stormwater Utility Survey (SESWA 2013). Grigg researched existing SUFs by region, and found many variations in organization and rate structure across the regions and also within each region. Some states, including New Jersey and New York, do not have legislation that allows for the creation of SUFs. SESWA, FSA, and Black and Veatch all found that impervious area is the critical metric in the majority of fees surveyed, and SESWA found parcel credits reduced the rate paid by an average of approximately 25.6%. Also, it should be noted that an average 20.7 full-time employees per utility were funded through SUFs from SESWA and an average of 23.2 from FSA, not including City of Jacksonville or Miami-Dade County which fund 200 and 227 employees, respectively. Campbell, in 2014, reported the median fee for a single-family residential parcel was $4.00 per month across the country, with the maximum fee reaching $35 per month. A total of 1,479 SUFs are currently in the 2014 Western Kentucky University database, with five states having 100 SUFs or more; Florida has the most SUFs at 180, followed in decreasing order by Minnesota, Wisconsin, Washington, and Texas.

3 THE IMPACT OF DIFFERENT STORMWATER FEE TYPES: A CASE STUDY OF TWO MUNICIPALITIES IN VIRGINIA

3.1 ABSTRACT

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Along with Kea, many others have compiled reports of municipality SUFs, including Grigg (2013), WEF (2013), Western Kentucky University Stormwater Utility Surveys (Campbell 2007-2013; Campbell et al. 2014), Black and Veatch Stormwater Utility Survey (Black & Veatch 2014), Florida Stormwater Association Stormwater Utilities Survey (FSA 2011), Southeast Stormwater Association Southeast Stormwater Utility Survey (SESWA 2013), and others. Grigg researched existing SUFs by region, and found many variations in organization and rate structure across the regions and also within each region. Some states, including New Jersey and New York, do not have legislation that allows for the creation of SUFs. SESWA, FSA, and Black and Veatch all found that impervious area is the critical metric in the majority of fees surveyed, and SESWA found parcel credits reduced the rate paid by an average of approximately 25.6%. Also, it should be noted that an average 20.7 full-time employees per utility were funded through SUFs from SESWA and an average of 23.2 from FSA, not including City of Jacksonville or Miami-Dade County which fund 200 and 227 employees, respectively. Campbell, in 2014, reported the median fee for a single-family residential parcel was $4.00 per month across the country, with the maximum fee reaching $35 per month. A total of 1,479 SUFs are currently in the 2014 Western Kentucky University database, with five states having 100 SUFs or more; Florida has the most SUFs (180), followed in decreasing order by Minnesota (163), Wisconsin (120), Washington (113), and Texas (103).

Because there are so many options for SUF fee types, it may become difficult to choose which one would be the best option, and which land uses are impacted by each type. The objective of this research is to examine how eight different SUF fee types can be applied to generate the revenue needed to support the existing programs and determine which consumers (land uses) will be impacted by which SUF fee type. Two separate municipalities in Virginia are used in this case study and the differences in the results are compared based on the analysis factors and the municipal differences. A detailed land cover dataset and exemptions of airport and railroad parcels are also compared to the current SUFs to examine the effect the changes have on the SUF fees.

3.3 DATA SUMMARY

The two municipalities used in this study are Blacksburg and Roanoke, Virginia, which differ significantly in their land use composition and existing SUF fee types. Impervious cover data and parcel boundary data was obtained from both local governments. The impervious cover data separated areas of the municipality into either impervious or pervious areas. Parcel boundary data included parcel locations and the land use of the parcel. The following sections introduce each municipality and describe its current SUF.

3.3.1 Town of Blacksburg

The Town of Blacksburg is a 5151.5-hectare, 42,620-person town in southwest Virginia that encompasses the Virginia Tech (VT) campus (U.S. Census Bureau 2010). Blacksburg started discussing a possible SUF in 2012, and adopted into code the current SUF in June 2014, which became effective starting January 1, 2015. The existing SUF for Blacksburg separates parcels into six categories:

- Developed residential property
- Developed multifamily residential property
- Developed nonresidential property
- Agricultural property
- Undeveloped property, and
- Exempt property

Developed residential properties are charged a flat $6 fee per month for each unit on the parcel, with a maximum of 4 units. All other property types are subject to a monthly fee based on a tier system which determines the appropriate amount based on the parcel impervious areas (Table 3.2). Exempt properties include cemeteries, government-owned properties, and the property of Virginia Tech, as the university manages its own, separate MS4 (Code of the Town of Blacksburg, VA, § 18-700–18-707).

Table 3.2. SUF tiers for the Town of Blacksburg in 2016
(Code of the Town of Blacksburg, VA, § 18-700–18-707).

No.	Impervious Area (m^2)	Monthly Charge per Parcel
1	0 – 27.9	$0.00
2	28.0 – 631.7	$6.00
3	631.8 – 929.0	$12.36
4	929.1 – 1,858.1	$18.18
5	1,858.2 – 2,787.1	$36.36
6	2,787.2 – 3,716.1	$54.55
7	3,716.2 – 4,645.2	$72.73
8	4,645.2 – 5,574.2	$90.91
9	5,574.3 – 6,503.2	$109.09
10	6,503.3 – 7,432.2	$127.27
11	7,432.3 – 8,361.3	$145.45
12	8,361.4 – 9,290.3	$163.64
13	9,290.4 – 18,580.6	$181.82
14	18,580.7 – 27,870.9	$363.64
15	27,871.0 – 37,161.2	$545.45
16	37,161.3 – 46,451.5	$727.27
17	46,451.6 – 55,741.8	$909.09
18	55,741.9 – 69,677.3	$1,090.91
19	69,677.4 – 92,903.0	$1,363.64
20	Greater than 92,903.1	$1,818.18

3.3.2 City of Roanoke

The City of Roanoke is an 11,023-hectare locality in southwest Virginia, and has a population of 97,032 (VEC 2016). The City of Roanoke's SUF was developed in 2014, with the first revenue collected in October 2014, and uses a variation of the ERU fee method. The SUF was created to have a three-year ramp-up of fees so consumers would not be burdened with a large fee the first year. A traditional ERU fee type determines the average impervious area on residential parcels in the municipality (Equation 3.1). Parcels are then billed by finding the impervious area on the property and dividing by the ERU area (Equation 3.2). Once the number of ERUs is determined, the fee charged is the number of ERUs multiplied by the assessment rate per ERU determined by the municipality (Equation 3.3).

$$\text{ERU Area} = \frac{\text{Total Residential Impervious Areas}}{\text{Number of Residential Parcels}} \tag{3.1}$$

$$\text{No. of ERUs on a Parcel} = \frac{\text{Parcel Impervious Area}}{\text{ERU Area}} \tag{3.2}$$

$$\text{SUF Fee} = \text{No. of ERUs} * \text{ERU Rate} \tag{3.3}$$

Instead of the traditional ERU Area, the City of Roanoke uses a billing unit of 46.5 m^2 (500 ft^2) of impervious area. The parcel fees are calculated using Equation 3.2 and Equation 3.3 by replacing the ERU Area with Roanoke's billing unit, even though the billing unit is not based on

residential impervious area. Currently, the billing rate is $0.60 per billing unit, however, 2015 is the second in a three year ramp-up of fees, with the final fee of $0.90 per billing unit. Parcels that are exempt from the City of Roanoke SUF include undeveloped parcels, government property except the City of Roanoke parcels, parcels that maintain their own MS4, and public roads and street rights-of-way (City of Roanoke 2015b).

3.4 METHODS

Eight fee types were applied to both municipalities: Flat fee, ERU fee, Per Parcel Area fee, Tier fee, two types of Dual fees, and two types of REF fees. The fee rates are found by starting with the municipal monthly revenue (MMR) for Blacksburg and Roanoke and calculating backwards to find the monthly parcel fee (MPF). The MMR for this study is equal to the currently reported monthly revenue from the respective municipality for the 2015 fiscal year: Blacksburg's MMR is $44,132.08 (Town of Blacksburg 2015) and Roanoke's MMR is $170,830.25 (City of Roanoke 2015a). The MMR for Roanoke reflects the first year of a three year ramp-up of fees; the final MMR that Roanoke will reach is three times more than the revenue used in this analysis, or $512,490.75.

Using this method, equations were created to find the MPF for the eight fee types. Starting with the Flat, ERU, and Area fee types, the equations in Table 3.3 were used - note that the number of calculated ERUs for a given parcel is rounded to the nearest integer before calculating the MPF.

Table 3.3. Calculation method for Flat, ERU, and Area fee types.

Fee Type	Calculation
Flat	$$\text{MPF} = \frac{\text{MMR}}{(\text{Total No. Parcels})}$$
ERU	$$\text{ERU} = \frac{\text{SFR Impervious Area}}{(\text{Total No. SFR Parcels})}$$ $$\text{No. of ERUs on a Parcel} = \frac{\text{Parcel Impervious Area}}{\text{ERU Area}}$$ $$\text{ERU Rate} = \frac{\text{MMR}}{(\text{Total No. ERUs})}$$ $$\text{MPF} = (\text{No. Parcel ERUs}) * (\text{ERU Rate})$$
Area	$$\text{Area Rate} = \frac{\text{MMR}}{\sum \text{Parcel Area}}$$ $$\text{MPF} = [\text{Parcel Area}] * (\text{Area Rate})$$

Tier fees are based on the current Blacksburg SUF tiers. The current Blacksburg SUF includes a residential rate of $6 per unit, however that portion of the fee will not be used for the analysis; the Tier analysis will be conducted only using the tier so that it follows a true tier fee system. Each current tier fee in Table 2 was divided by the highest fee (Tier 20) to determine the tier fraction multipliers that were used to calculate the new base fee for Blacksburg and Roanoke.

Calculation of the base fee (Tier 20) is found using the number of parcels in each fee and Equation 3.4. Each tier's fee is found by multiplying the base fee by each multiplier to find the final tier fee table.

$$\text{Base Fee} = \frac{\text{MMR}}{\sum_i \text{Multiplier}_i \cdot \text{No. Parcels}_i} \tag{3.4}$$

Dual fees were calculated in two ways: the first applies a flat rate to both residential and nonresidential parcels, and the second applies a flat rate to the residential parcels and an ERU fee for the nonresidential parcels. The dual flat rate option (Dual-1) is found using a multiplier that reflects the ratio between the residential and nonresidential rates. For this research, the multiplier is calculated by dividing the residential impervious area by the nonresidential impervious area. The second option (Dual-2) uses one fee for the residential parcels and the same rate as the nonresidential ERU rate (Table 3.4).

Table 3.4. Equations to calculate the two Dual fees.

Dual Fee Type	Calculation
Dual-1	$\text{Multiplier} = \text{Non-Res. IA} / \text{Res. IA}$ $\text{Res. Rate} = \frac{\text{MMR}}{\sum_i \left[(\text{Multiplier})_i (\text{No. Parcels})_i\right]}$ $\text{Non-Res. Rate} = (\text{Res. Rate})(\text{Multiplier})$
Dual-2	$\text{Rate} = \frac{\text{MMR}}{(\text{No. Res Parcels}) + (\text{Total Non-Res. ERUs})}$ $\text{MPF} = \begin{cases} \text{Rate} & \text{for Res.} \\ (\text{Rate})(\text{No. ERUs}) & \text{for Non-Res.} \end{cases}$

REF fees are also calculated two ways: the first is based on National Resources Conservation Service (NRCS) TR-55 using a ratio of runoff factors, and the second is based on the Rational Method using an impervious factor. The NRCS method estimates runoff using curve numbers (CNs) to depict land cover and hydrologic soil group (HSG) (NRCS 1986). The CNs chosen will be based on HSG B since that is the predominant soil group for both Blacksburg and Roanoke (Table 3.5).

Table 3.5. Runoff curve numbers from TR-55 used for REF calculation.

REF Category	TR-55 Cover Description	CN
Open Space	Open Space: Fair Condition (grass cover 50% to 75%)	69
Commercial/Business	Urban Districts: Commercial and Business	92
Industrial	Urban Districts: Industrial	88
Residential	Residential districts by average lot size: ½ acre	70
Multifamily	Residential districts by average lot size: 1/8 acre or less (town houses)	85

The runoff depth for each land use is calculated using the TR-55 equation and the rainfall depth used is the 2-year, 24-hour rainfall for each of the municipalities: 7.01 cm for Blacksburg and 8.00 cm for Roanoke (U.S. National Oceanic and Atmospheric Administration, Atlas 14 Point Precipitation Frequency Estimates, Accessed January 27, 2016, <http://hdsc.nws.noaa.gov/hdsc/pfds/>). Once the runoff depth for each land use is found, the residential runoff depth is used as a unit runoff (Q_R) to find the runoff ratio. This method maintains the current practice of using the most common parcel as the runoff unit. The rate is found using Equation 3.5, and the MPF found using Equation 3.6.

$$\text{Rate} = \frac{\text{MMR}}{\sum_i [[\text{Total Parcel Area}]_i * Q_i / Q_R]} \tag{3.5}$$

$$\text{MPF} = [\text{Parcel Area}] \left(\frac{Q_{\text{Parcel}}}{Q_R}\right) (\text{Rate}) \tag{3.6}$$

The Rational Method runoff coefficient was used as impervious factors for the second REF option (REF-2). Runoff coefficients for the Rational Method are representative of the fraction of runoff to rainfall. The five categories used for this study and the associated coefficient are listed in Table 3.6.

Table 3.6. REF categories and impervious factors
based on the Virginia Dept of Transportation Drainage Manual (2014)

REF Category	VDOT Description	Impervious Factor (C)
Open Space	Parks, Cemeteries and Unimproved Areas	0.275
Commercial/Business	Business: Industrial and Commercial	0.85
Industrial	Business: Industrial and Commercial	0.85
Residential	Residential (lots ½ acre or more)	0.35
Multifamily	Apartments and Townhomes	0.7

Using these impervious factors, the REF rate is found using Equation 3.7, and the MPF is found by multiplying the parcel area, impervious factor, and REF rate (Equation 3.8).

$$\text{Rate} = \frac{\text{MMR}}{\sum_i [[\text{Total Parcel Area}]_i * C_i]} \tag{3.7}$$

$$\text{MPF} = (\text{Parcel Area})(C_{\text{Parcel}})(\text{Rate}) \tag{3.8}$$

This method was used to find the rate for all eight SUF fee types, and then the MPF for each parcel in the municipalities.

3.5 RESULTS AND DISCUSSION

The two municipalities differ considerably with regards to land use, and these differences translate into who will be paying the SUF fees. The land use and impervious area composition of Blacksburg and Roanoke are compared in Table 3.7. In both municipalities, the residential land use comprises the largest percentage of the parcel count and area, however, it does not encompass the largest percentage of impervious area in Roanoke. The high percentage of

residential parcels shows a likely source for a large percentage of SUF revenues. Roanoke has a larger percentage of industrial land use (15.5 to 6.3%), but Blacksburg has a higher percentage of imperviousness coming from multifamily units (18.2 to 6.1%). Commercial parcels in Roanoke are double the percentage of commercial parcel area in Blacksburg, whereas Blacksburg's open space is double the percentage of Roanoke's. The exempted properties in Blacksburg comprise just under 20% of the parcel area, but only 12.9% in Roanoke. It can also be noted that while Blacksburg exempts city parcels from the SUF fees, Roanoke does not, and government parcels account for 9.4% of the total parcel area and 2.4% of the impervious area. Table 3.7 illustrates how this alters the land use compositions for the SUF fee types.

Table 3.7. Land use composition for Blacksburg and Roanoke, Virginia (2016 data).This table does not include Virginia Tech parcels.

Land Use	Blacksburg			Roanoke		
	Parcel Count	**Total Parcel Area**	**Impervious Area**	**Parcel Count**	**Total Parcel Area**	**Impervious Area**
	No. *(%)*	*ha* *(%)*	*ha* *(%)*	*No.* *(%)*	*ha* *(%)*	*ha* *(%)*
Open Space	715 (9.8)	914.0 (21.7)	16.6 (3.3)	3,407 (7.7)	799.9 (8.5)	206.2 (7.7)
Commercial	382 (5.2)	348.6 (8.3)	118.1 (23.1)	2,381 (5.4)	1,833.6 (19.6)	942.5 (35.2)
Industrial	28 (0.4)	99.1 (2.3)	32.3 (6.3)	696 (1.6)	652.8 (7.0)	414.2 (15.5)
Residential	5,965 (81.4)	1,808.3 (42.9)	207.7 (40.6)	28,995 (65.2)	3,578.8 (38.2)	764.5 (28.6)
Multifamily	115 (1.6)	221.5 (5.3)	93.3 (18.2)	2,997 (6.7)	412.3 (4.4)	163.2 (6.1)
Government	---	---	---	428 (1.0)	875.8 (9.4)	119.8 (2.4)
Exempt	124 (1.7)	827.7 (19.6)	43.2 (8.4)	5,596 (12.6)	1,212.7 (12.9)	64.9 (4.5)

The previously described SUF fee computation methods were applied to both Blacksburg and Roanoke. Figure 3.1 illustrates the fee paid by each type of land use (consumer) for every fee type for both municipalities. The figure, which is also transcribed in Table 3.8, shows that, in Blacksburg, the residential land use comprises the highest percentage of the SUF for all fee types. Multifamily parcels in Blacksburg range from paying 1.0 percent of the total revenue (in the Dual-2 fee type) to 18.3 percent (ERU). Dual-1 fees, which separate residential and nonresidential parcels into different flat rates, seem to replicate the same fee composition as the Flat fee type, with only a slight shift in revenue from residential parcels to commercial and open space parcels.

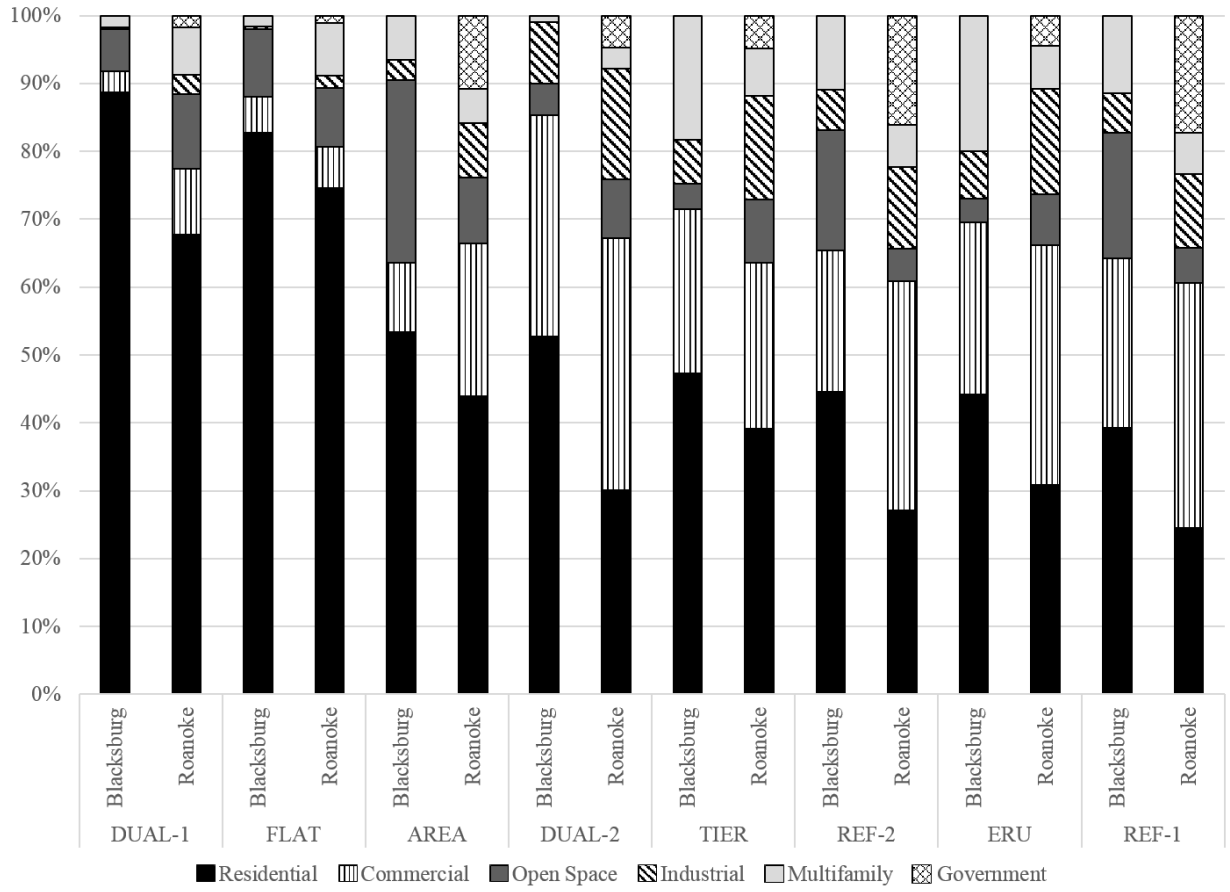

Figure 3.1. Fee composition by land use for both Blacksburg and Roanoke for the eight SUF fee types, shown in decreasing order or residential percentage in Blacksburg.

Roanoke SUFs showed some different patterns than Blacksburg. For Roanoke, the highest percentage for fee types were split between residential and commercial parcels; ERU, REF-1, REF-2, and Dual-2 have commercial as the highest paying land use while Dual-1 Flat, Area, and Tier have residential as the leading percentage. Also contrary to Blacksburg, industrial parcels account for over 10 percent of the SUF in all but three fee types (Dual-1, Flat, and Area). The REF-1, REF-2, and ERU fee types all have similar compositions, which suggests that the impervious factor and runoff ratio used in the REF fees simulate the same amount of impervious cover found on the parcels of Roanoke. Government parcels compose more than 10 percent of the monthly revenue in three fee types (REF-1, REF-2, and Area).

One notable pattern is that the REF-1 and REF-2 fee types are very similar to each other in both municipalities, even though they use different methods to determine the fees. On the contrary, Dual-1 and Dual-2 fees are different in their land use composition; Dual-1 shows a high dependence on residential parcels where Dual-2 shifts that revenue to the commercial and industrial parcels. Also, the Tier and ERU fees in Blacksburg are very similar, suggesting that the tier limits and fees were chosen for the Blacksburg SUF based on an ERU type fee. However, the Tier and ERU for Roanoke are not as similar, which would further suggest the Tier fee is based on the Blacksburg ERU, which would not fit the changed land use composition of Roanoke. Open space parcels in both municipalities do not contain much impervious area and

account for less than 10 percent of the revenue, but have the second highest revenue source in five fee types: Blacksburg's Dual-1, Flat, and Area and Roanoke's Dual-1 and Flat fee types.

Table 3.8. Percentage of monthly revenue paid by each land use for Blacksburg and Roanoke for every SUF fee type, with cells highlighted based on percentage and current fee type outlined.

Municipality	Fee Type	Residential	Commercial	Open Space	Industrial	Multi-family	Govt.
Blacksburg	Flat	82.8	5.3	9.9	0.4	1.6	---
	ERU	44.2	25.3	3.5	6.9	20.0	---
	Area	53.3	10.3	26.9	2.9	6.5	---
	Tier	47.3	24.1	3.8	6.4	18.3	---
	Dual-1	88.7	3.1	6.3	0.2	1.7	---
	Dual-2	52.7	32.7	4.7	8.9	1.0	---
	REF-1	39.2	25.0	18.5	5.9	11.4	---
	REF-2	44.6	20.9	17.7	5.9	10.9	---
Roanoke	Flat	74.5	6.1	8.8	1.8	7.7	1.1
	ERU	30.9	35.3	7.5	15.5	6.3	4.5
	Area	43.9	22.5	9.8	8.0	5.1	10.7
	Tier	39.1	24.5	9.3	15.3	7.0	4.8
	Dual-1	67.7	9.7	11.1	2.8	7.0	1.7
	Dual-2	30.1	37.1	8.7	16.3	3.1	4.7
	REF-1	24.5	36.1	5.1	10.9	6.1	17.3
	REF-2	27.1	33.7	4.8	12.0	6.2	16.1

Average fees for residential and commercial parcels for each fee type are compared to the current fee paid for those land uses in each municipality to see the effect a change in fee type has on individual parcels. For average residential fees, Blacksburg charges were compared to the current $6.00 flat rate, and Roanoke to the ERU fees (Table 3.9). For Blacksburg, two fee types result in an increase in average fees: Flat and Dual-1. The other six fee types result in a reduction of the average fee. For Roanoke, four fee types result in an increase of fees, with two types that have an increase over 100 percent (Flat and Dual-1). Of note, the Dual-2 fee type for Roanoke only has an average parcel fee decrease of 2.7%, or $0.05, from the existing fee.

Table 3.9. Average residential fees for each fee type and the percent change from the current average fee.

Fee Type	Blacksburg		Roanoke	
	Avg. Fee	*% Change*	*Avg. Fee*	*% Change*
Current	$6.00	---	$1.82 (ERU)	
Flat	$6.13	2.1	$4.39	141.2%
ERU	$3.27	-45.5	$1.82	---
Area	$3.94	-34.3	$2.59	42.1%
Tier	$3.50	-41.6	$2.31	26.6%
Dual-1	$6.56	9.3	$3.99	119.2%
Dual-2	$3.90	-35.0	$1.77	-2.7%
REF-1	$2.90	-51.6	$1.44	-20.8%
REF-2	$3.30	-45.0	$1.60	-12.2%

Average commercial fees also show both increases and decreases to the current fee. For both municipalities, the current average commercial charge is the median compared to the other seven fees (Table 3.10). Blacksburg fees increase when changed to ERU, Dual-2, and REF-1. Roanoke fees increase when changed to Dual-2, REF-1, and REF-2.

Table 3.10. Average commercial fees for each fee type and the percent change from the current average fee.

Fee Type	Blacksburg		Roanoke	
	Avg. Fee	*% Change*	*Avg. Fee*	*% Change*
Current	$27.87 (Tier)		$24.19 (ERU)	
Flat	$6.13	-78.0	$4.39	-81.9%
ERU	$29.28	5.1	$24.19	---
Area	$11.87	-57.4	$20.21	-16.5%
Tier	$27.87	---	$17.84	-26.3%
Dual-1	$3.59	-87.1	$6.93	-71.3%
Dual-2	$37.72	35.4	$25.42	5.1%
REF-1	$28.89	3.7	$32.48	34.3%
REF-2	$24.11	-13.5	$30.32	25.3%

3.6 SENSITIVITY ANALYSIS

Two sensitivity analyses were conducted to follow this research: the effect of detailed land cover in Blacksburg and exemptions of the railroad and airport parcels in Roanoke. The methods and results of these analyses are detailed below.

3.6.1 Effect of Detailed Land Cover

The data used for the SUFs influence the fees that are assessed to each parcel. To see the effect of a very detailed land cover, the Town of Blacksburg's current land cover dataset was compared to a more detailed dataset. The detailed land cover dataset (DLCD) was created using aerial photography to digitize land cover into 11 land cover categories. The latest update of the DLCD was completed from 2013 aerial imagery. The 11 categories were delineated into impervious and pervious classes (Table 3.11).

Table 3.11. Land cover categories of the Blacksburg DLCD separated into impervious or pervious classes.

Impervious	Pervious
Sidewalk Road/Parking Buildings Gravel Other Asphalt/Concrete Areas	Open Space Dirt Light Forest/Tree Canopy Dense Forest Brush/Bush Light Bush/Dirt/Mulch

The DLCD was compared to the Town of Blacksburg database (TOBD) and two minor distinctions between the datasets were found. DLCD delineates more sidewalks and driveways, and some minor additions to residential projects (Figure 3.2). However, since the last update of the DLCD was from 2013 data, new developments since that time are not captured in this dataset. The DLCD does not capture impervious area on the VT campus, however because this increase in impervious area is only found in the exempted parcels, it is not reflected in the SUF fees. These differences between the datasets do not accumulate to significant impervious differences, as illustrated in Table 3.12. When translated to the SUF, the average residential fees have a maximum difference of $0.03 per parcel and the average commercial fees have a maximum difference of $0.87 per parcel.

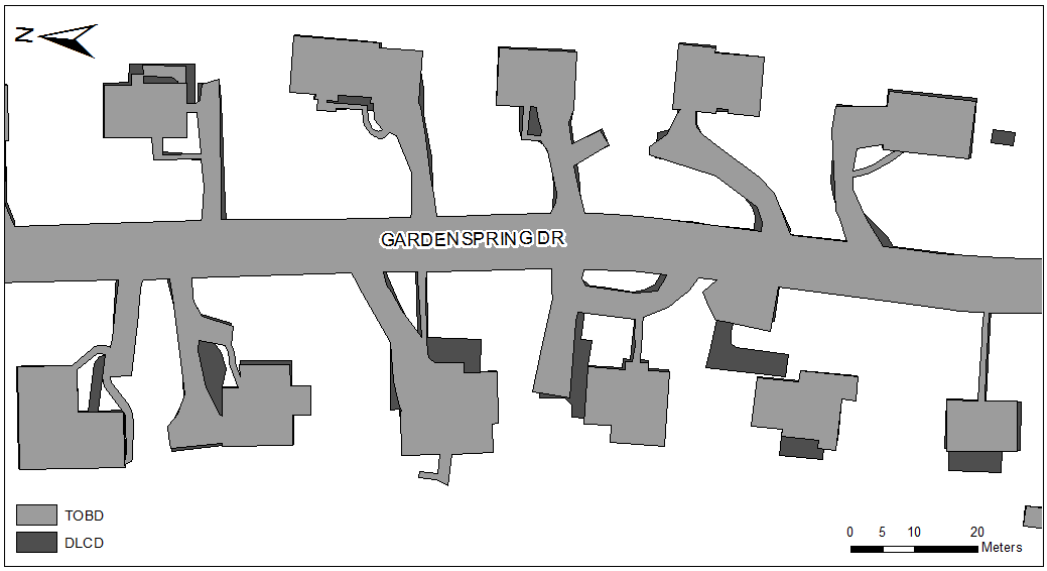

Figure 3.2. Increased impervious cover delineated with DLCD when compared to TOBD.

Table 3.12. Comparison of impervious areas found from both TOBD and DLCD.Virginia Tech parcels are included in these numbers so that the difference in impervious areas can be seen.

Land Use	TOBD Impervious Area		DLCD Impervious Area	
	m^2	%	m^2	%
Open Space	166,330	3.1	154,548	3.0
Commercial	1,181,293	21.7	1,161,306	22.6
Industrial	323,148	5.9	335,494	6.5
Residential	2,076,688	38.2	2,071,459	40.4
Multifamily	932,891	17.2	928,072	18.1
Exempt	756,979	13.9	476,325	9.3

Exploration of Airport and Railroad Exemptions

On March 11, 2016, a bill amendment that would exempt railroads from paying SUFs was removed from a bill passed by the Virginia House of Delegates (S468 2016). For the City of Roanoke, the railroad comprises 3.97%, or 3,238,155 m2, of the billable parcel area in the municipality, and currently pays in excess of $14,000 each month for SUFs. The implication that this amendment would have on the City of Roanoke's SUF was explored by simulating exemptions to both the railroad and airport parcels.

Both the Norfolk Southern Railroad and the Roanoke-Blacksburg Regional Airport have multiple parcels in Roanoke, both encompassing a considerable portion of the city (Table 3.13). By removing both entities from paying SUFs, the fee types would have to change to compensate for the loss of revenue from the parcels. The effect of this removal can be seen in the average residential and commercial fees (Figure 3.3 and Figure 3.4). As was expected, the Flat and Dual-1 fee types were not greatly affected by the removal of the railroad or the airport because they were only paying based on the number of parcels they own. The residential average fees are increased as the billable area is decreased from the removal of parcels. The average commercial fees also increase as the airport and railroad are removed, at the same rate as the increase in residential fees. The changes seen in the average residential and commercial fees range from a 0.02% increase to a 15.1% increase (Table 3.14). For the current fee type (ERU), the residential parcels have a monthly increase of $0.07 when the airport is removed, $0.17 when the railroad is removed, and $0.26 when both are removed. This amount, when applied to all 29,050 residential parcels, accounts for $7,491 of the monthly revenue lost when the airport and railroad parcels are exempted. The remainder of the lost revenue is distributed in the four other land uses. However, this shifts more of the SUF revenue to the residential customers, than to the other land uses.

Table 3.13. Proportion of Roanoke dedicated to the railroad and airport.

Owner	No. Parcels	Total Billable Parcel Area		Total Billable Impervious Area		FY14-15 Monthly Fee Paid
		ha	*% of City*	*ha*	*% of City*	
Norfolk Southern Railroad	26	323.8	3.97	229.7	8.80	$14,846.06
Roanoke-Blacksburg Regional Airport	9	291.3	3.57	104.5	4.00	$6,751.77

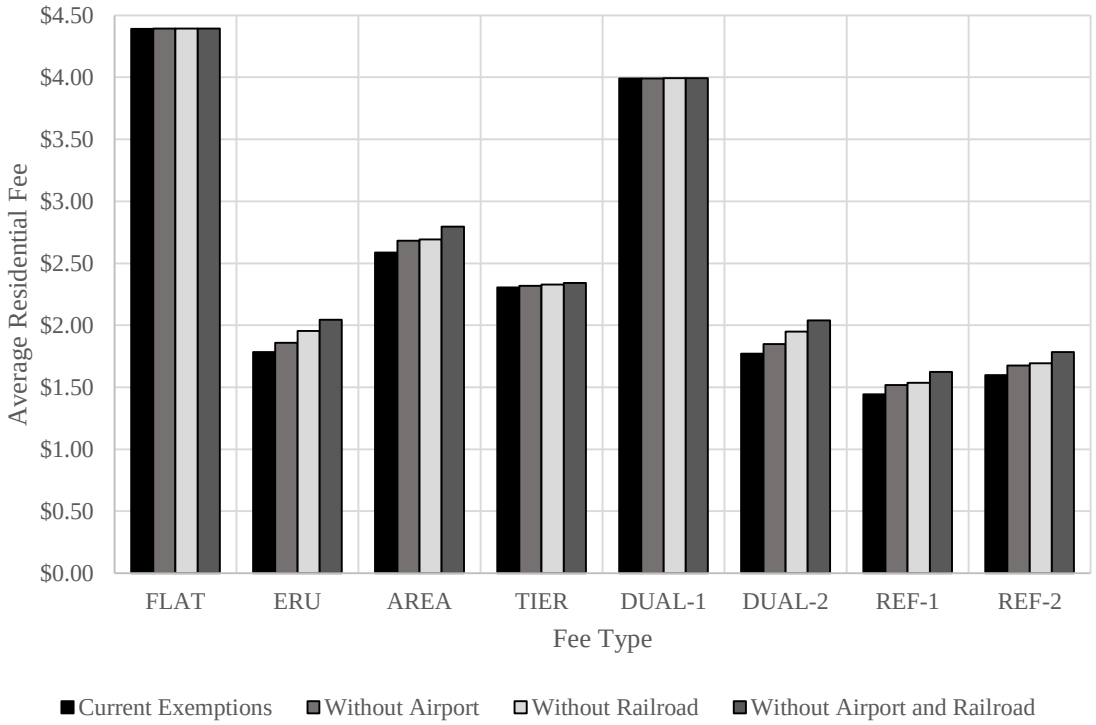

Figure 3.3. Average monthly residential fees paid for each fee type when the airport and/or railroad is removed. Current exemptions shows the fees paid in the current state of the SUF.

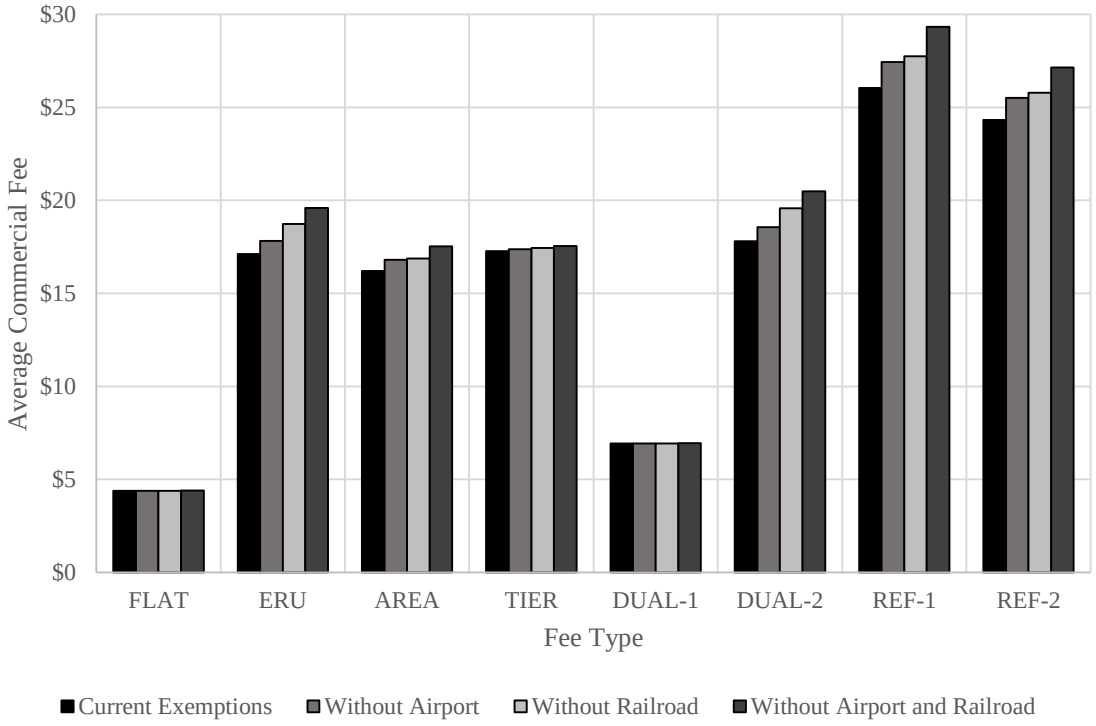

Figure 3.4. Average monthly commercial fees, not including airport or railroad parcels, paid for each fee type when the airport and/or railroad is removed. Current exemptions shows the fees paid in the current state of the SUF.

Table 3.14. Fees paid by the average residential and commercial properties, excluding the airport and railroad parcels, for each fee type under the current exemptions, and the percent change in fee through the additional exemptions.

Fee Type	Land Use Category	Current Exemptions Rate	Without Airport	Without Railroad	Without Both
Flat	Residential	$4.39	0.02%	0.05%	0.07%
	Commercial	$4.39	0.02%	0.05%	0.07%
ERU	Residential	$1.79	4.1%	9.5%	14.5%
	Commercial	$17.11	4.1%	9.5%	14.5%
Area	Residential	$2.59	3.7%	4.1%	8.2%
	Commercial	$16.21	3.7%	4.1%	8.2%
Tier	Residential	$2.31	0.6%	1.0%	1.6%
	Commercial	$17.28	0.6%	1.0%	1.6%
Dual-1	Residential	$3.99	0.04%	0.07%	0.11%
	Commercial	$6.93	0.04%	0.07%	0.11%
Dual-2	Residential	$1.77	4.3%	9.9%	15.1%
	Commercial	$17.80	4.3%	9.9%	15.1%
REF-1	Residential	$1.44	5.3%	6.5%	12.6%
	Commercial	$26.05	5.3%	6.5%	12.6%
REF-2	Residential	$1.60	4.9%	6.1%	11.6%
	Commercial	$24.32	4.9%	6.1%	11.6%

3.7 CONCLUSIONS

This study shows how applying different SUF fee types effects the imposed fee across two localities in southwest Virginia. Each fee type differs in how the fee is calculated for each parcel, and fee types chosen by municipalities are based on a number of factors including ease of calculation, availability and maintenance of data, and proportion of fees to stormwater runoff on each parcels. These different fee types will affect how much of the municipality revenue is collected from each land use, seen in this study in residential properties ranging from 88.7 percent of the revenue in Blacksburg's Dual-1 fees to 24.5 percent in Roanoke's REF-1 fees.

Large changes in land cover can greatly affect the outcome of the fees, however detailed changes to the land cover did not have much influence on the SUF revenues in this Blacksburg analysis. As seen in this study, the detailed land cover accounted for a maximum change in fee rate of $0.03 per parcel in residential parcels, which does not change the land use composition significantly. Also studied was the effect of removing significant parcels from the SUF. When these parcels, like railroads or airports, are removed from the SUF, the fees paid by both residential and commercial parcels increase and the residential fees take over the majority of the lost revenues.

The SUFs provide a steady stream of income that municipalities can use to help meet the demands of stormwater regulations. All fee types used in this study are viable options for municipalities to use, some of which require more effort to calculate the fee than others. This study does not try to suggest that there is a better or worse fee type to choose, but that there are differences between each type. Municipalities looking to choose an appropriate fee type should

take into account the differences seen within this study, but remember that each fee type will change based on the municipality land use composition.

4 CONCLUSIONS

4.1 IMPLICATIONS

This study shows how applying different SUF fee types effects the imposed fee across two localities in southwest Virginia. Each fee type differs in how the fee is calculated for each parcel, and fee types chosen by municipalities are based on a number of factors including ease of calculation, availability and maintenance of data, and proportion of fees to stormwater runoff on each parcels. These different fee types will affect how much of the municipality revenue is collected from each land use, seen in this study in residential properties ranging from 88.7 percent of the revenue in Blacksburg's Dual-1 fees to 24.5 percent in Roanoke's REF-1 fees.

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4.2 FUTURE WORK

Through the analysis of stormwater user fees, the impacts of changes in land cover detail and the effect that exemptions have on the burden of the fee was explored in this study. More exploration of these and other exemptions, including the impact of including highways or right-of-ways in the SUF fees, could be done to see what effect they have on the SUF. Those impervious areas are bound to have an impact on the land use composition of the SUF revenue and the fees that all land uses would pay.

The research in exemptions could also be translated into seeing the effect that credits have on the SUF revenue. Credits allow parcels to decrease their SUF fees based on a variety of reasons, most related to reducing quality and/or improving quality before reaching the municipal network. However, these credits do not always relate to less work that a municipality may have to do, but they do decrease the amount of revenue created from the SUF. Studying these effects could help municipalities understand the effect those credits have on both the SUF and the municipality work.

Further work can be done to see the effects of changing different attributes of the fees. Two REF fees were evaluated in this study, but there are many ways that municipalities compute REF fees, as well as many runoff coefficients and curve numbers that could have been chosen. Likewise, there are also many ways that municipalities determine the tiers for Tier fees. Blacksburg's tier was based on impervious areas, but tiers can be based on anything from parcel classification or zoning to number of parking spaces or water meter size. These differences could be further researched to see what the effect is of using different methods.

This work can also be strengthened by adding more municipalities to the study of Blacksburg and Roanoke. Municipalities of similar size to Blacksburg and Roanoke could be compared to the results of this study to see if they produce similar results. Municipalities of other sizes can also be studied to see if there are any other patterns that emerge. Because feasibility studies similar to this research cost municipalities on the order of $100-200 thousand, any potential patterns that emerge from more municipalities could help the decisions made in the creation of SUFs

4.3 FINAL COMMENTS

The SUFs provide a steady stream of income that municipalities can use to help meet the demands of stormwater regulations. All fee types used in this study are viable options for municipalities to use, some of which require more effort to calculate the fee than others. This study does not try to suggest that there is a better or worse fee type to choose, but that there are differences between each type. Municipalities looking to choose an appropriate fee type should take into account the differences seen within this study, but remember that each fee type will change based on the municipality land use composition.

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APPENDIX A SAMPLE DATA TABLES

A.1 TOWN OF BLACKSBURG SAMPLE DATA

ID	Property Land Use	Parcel Area (SF)	Impervious Area (SF)	No. of ERUs	Rounded ERUs	Flat Fee	ERU Fee	Area Fee	Tier No.	Tier Fee	Dual Category	Dual-1 Fee	Dual-2 Fee	REF Category	REF-1 Fee	REF-2 Fee
1	Vacant	464422.70	0	0	0	$6.13	$--	$56.14	1	$--	N	$3.59	$--	A	$38.49	$36.88
2	Low Density Residential	355591.38	8632.90	2.51	3	$6.13	$9.08	$42.99	3	$6.85	R	$6.56	$3.90	D	$31.62	$35.94
3	Low Density Residential	18747.99	2358.82	0.69	1	$6.13	$3.03	$2.27	2	$2.93	R	$6.56	$3.90	D	$1.67	$1.89
4	Low Density Residential	19419.87	3299.18	0.96	1	$6.13	$3.03	$2.35	2	$2.93	R	$6.56	$3.90	D	$1.73	$1.96
5	Low Density Residential	19765.79	3669.76	1.07	1	$6.13	$3.03	$2.39	2	$2.93	R	$6.56	$3.90	D	$1.76	$2.00
6	Low Density Residential	21371.66	2897.06	0.84	1	$6.13	$3.03	$2.58	2	$2.93	R	$6.56	$3.90	D	$1.90	$2.16
7	Low Density Residential	10566.17	3041.37	0.88	1	$6.13	$3.03	$1.28	2	$2.93	R	$6.56	$3.90	D	$0.94	$1.07
8	Low Density Residential	9916.59	2691.072	0.78	1	$6.13	$3.03	$1.20	2	$2.93	R	$6.56	$3.90	D	$0.88	$1.00
9	Low Density Residential	11022.25	3088.37	0.90	1	$6.13	$3.03	$1.33	2	$2.93	R	$6.56	$3.90	D	$0.98	$1.11
10	Low Density Residential	11601.24	2789.75	0.81	1	$6.13	$3.03	$1.40	2	$2.93	R	$6.56	$3.90	D	$1.03	$1.17
11	Low Density Residential	10505.31	2681.06	0.78	1	$6.13	$3.03	$1.27	2	$2.93	R	$6.56	$3.90	D	$0.93	$1.06
12	Low Density Residential	18267.30	3706.63	1.08	1	$6.13	$3.03	$2.21	2	$2.93	R	$6.56	$3.90	D	$1.62	$1.85
13	Low Density Residential	43932.57	4067.54	1.18	1	$6.13	$3.03	$5.31	2	$2.93	R	$6.56	$3.90	D	$3.91	$4.44
14	Low Density Residential	29402.76	3438.63	1.00	1	$6.13	$3.03	$3.55	2	$2.93	R	$6.56	$3.90	D	$2.61	$2.97
15	Low Density Residential	16127.37	1795.54	0.52	1	$6.13	$3.03	$1.95	2	$2.93	R	$6.56	$3.90	D	$1.43	$1.63
16	Low Density Residential	18193.17	4202.95	1.22	1	$6.13	$3.03	$2.20	2	$2.93	R	$6.56	$3.90	D	$1.62	$1.84
17	Low Density Residential	397866.21	7113.02	2.07	2	$6.13	$6.05	$48.10	3	$6.85	R	$6.56	$3.90	D	$35.38	$40.21
18	Low Density Residential	20364.32	4148.26	1.207	1	$6.13	$3.03	$2.46	2	$2.93	R	$6.56	$3.90	D	$1.81	$2.06
19	Low Density Residential	16952.58	3914.38	1.14	1	$6.13	$3.03	$2.05	2	$2.93	R	$6.56	$3.90	D	$1.51	$1.71
20	Low Density Residential	20999.42	2426.22	0.70	1	$6.13	$3.03	$2.54	2	$2.93	R	$6.56	$3.90	D	$1.87	$2.12
21	Low Density Residential	20756.43	3594.26	1.04	1	$6.13	$3.03	$2.51	2	$2.93	R	$6.56	$3.90	D	$1.85	$2.10
22	Very Low Density Residential / Agriculture	6127641.54	18382.92	5.35	5	$6.13	$15.13	$740.77	4	$9.78	R	$6.56	$3.90	D	$544.84	$619.30
23	Low Density Residential	228247.65	9668.24	2.81	3	$6.13	$9.08	$27.59	3	$6.85	R	$6.56	$3.90	D	$20.29	$23.07
24	Undeveloped	13969.70	1341.77	0.39	0	$6.13	$--	$1.69	2	$2.93	R	$6.56	$3.90	A	$1.16	$1.11
25	Undeveloped	24149.28	2088.46	0.61	1	$6.13	$3.03	$2.92	2	$2.93	N	$3.59	$3.90	A	$2.00	$1.92

**All fees listed in this table are monthly fees.*

A.2 CITY OF ROANOKE SAMPLE DATA

ID	Property Land Use	Parcel Area (SF)	Impervious Area (SF)	No. of ERUs	Rounded ERUs	Flat Fee	ERU Fee	Area Fee	Tier No.	Tier Fee	Dual Category	Dual-1 Fee	Dual-2 Fee	REF Category	REF-1 Fee	REF-2 Fee
1	2260-Res Condo Parent	9390.49	8891.81	3.13	3	$3.95	$5.27	$1.85	3	$5.34	R	$3.64	$1.77	E	$2.48	$2.54
2	458-Comm/Indust-Other	42519.34	42297.11	14.90	15	$3.95	$26.35	$8.39	7	$30.50	N	$5.92	$26.60	B	$15.12	$13.98
3	400-Commercial/ Industrial	24962.91	24260.36	8.55	9	$3.95	$15.81	$4.92	5	$15.25	N	$5.92	$15.96	B	$8.87	$8.21
4	420-Comm/Ind-MiscImp	20332.04	19313.26	6.80	7	$3.95	$12.30	$4.01	4	$7.62	N	$5.92	$12.41	B	$7.22	$6.68
5	451-Comm/Indust-City	14288.02	14288.03	5.03	5	$--	$--	$--	X	$--	X	$--	$--	X	$--	$--
6	420-Comm/Ind-MiscImp	12773.44	12644.46	4.46	4	$3.95	$7.03	$2.52	4	$7.62	N	$5.92	$7.09	B	$4.54	$4.20
7	420-Comm/Ind-MiscImp	23001.93	22812.41	8.04	8	$3.95	$14.06	$4.54	5	$15.25	N	$5.92	$14.19	B	$8.17	$7.56
8	420-Comm/Ind-MiscImp	15999.64	15875.47	5.59	6	$3.95	$10.54	$3.16	4	$7.62	N	$5.92	$10.64	B	$5.68	$5.26
9	420-Comm/Ind-MiscImp	18809.24	18585.76	6.55	7	$3.95	$12.30	$3.71	4	$7.62	N	$5.92	$12.41	B	$6.68	$6.18
10	400-Commercial/ Industrial	18373.90	17471.36	6.16	6	$3.95	$10.54	$3.62	4	$7.62	N	$5.92	$10.64	B	$6.53	$6.04
11	458-Comm/ Indust-Other	144051.53	129455.9	45.61	46	$3.95	$80.82	$28.42	13	$76.24	N	$5.92	$81.57	B	$51.18	$47.36
12	140-Commercial Vacant	53774.03	11182.17	3.94	4	$3.95	$7.03	$10.61	4	$7.62	N	$5.92	$7.09	A	$6.23	$5.72
13	158-Vacant-Other	59179.86	40970.01	14.44	14	$3.95	$24.60	$11.68	7	$30.50	N	$5.92	$24.83	A	$6.86	$6.29
14	140-Commercial Vacant	24316.78	23081.58	8.13	8	$3.95	$14.06	$4.80	5	$15.25	N	$5.92	$14.19	A	$2.82	$2.59
15	400-Commercial/ Industrial	18760.79	18760.79	6.61	7	$3.95	$12.30	$3.70	4	$7.62	N	$5.92	$12.41	B	$6.66	$6.17
16	200-SingleFamily	2587.63	2587.63	0.92	1	$3.95	$1.76	$0.51	2	$2.29	R	$3.64	$1.77	D	$0.32	$0.35
17	200-SingleFamily	1554.26	1554.26	0.55	1	$3.95	$1.76	$0.31	2	$2.29	R	$3.64	$1.77	D	$0.19	$0.21
18	400-Commercial/ Industrial	3242.23	3240.10	1.14	1	$3.95	$1.76	$0.64	2	$2.29	N	$5.92	$1.77	B	$1.15	$1.06
19	400-Commercial/ Industrial	2742.55	2733.93	0.96	1	$3.95	$1.76	$0.54	2	$2.29	N	$5.92	$1.77	B	$0.97	$0.90
20	400-Commercial/Industrial	4523.78	4520.80	1.59	2	$3.95	$3.51	$0.89	2	$2.29	N	$5.92	$3.55	B	$1.61	$1.49
21	451-Comm/ Indust-City	4521.29	4521.29	1.59	2	$--	$--	$--	X	$--	X	$--	$--	X	$--	$--
22	451-Comm/ Indust-City	4401.81	4401.81	1.55	2	$--	$--	$--	X	$--	X	$--	$--	X	$--	$--
23	400-Commercial/ Industrial	4662.66	4661.94	1.64	2	$3.95	$3.51	$0.92	2	$2.29	N	$5.92	$3.55	B	$1.66	$1.53
24	400-Commercial/Industrial	5299.82	4807.19	1.69	2	$3.95	$3.51	$1.04	2	$2.29	N	$5.92	$3.55	B	$1.88	$1.74
25	451-Comm/Indust-City	3022.47	2692.82	0.95	1	$--	$--	$--	X	$--	X	$--	$--	X	$--	$--

**All fees listed in this table are monthly fees.*

APPENDIX B LAND USE CATEGORY ASSIGNMENTS

Land Use Category	Blacksburg Land Use Category	Roanoke Land Use Category
A – Open Space	• Open Space/Private • Park Land/Open Space • Private Open Space • Undeveloped • Vacant	• 100 – Vacant Land* • 140 – Commercial Vacant* • 151 – Vacant-SFR-City* • 155 – Vacant-Religious* • 156 – Vacant-Charitable* • 158 – Vacant-Other* • 159 – Vacant Land-SCC*
B – Commercial	• Civic • Commercial • Mixed Use • NSF • Professional Office	• 400 – Commercial/Industrial† • 420 – Comm/Ind-MiscImp† • 451 – Comm/Indust-City† • 455 – Comm/Indust-Religious† • 456 – Comm/Indust-Charitable† • 457 – Comm/Indust-Educational • 458 – Comm/Indust-Other† • 459 – Comm/Indust-SCC† • 460 – Commercial Condo
C – Industrial	• Industrial • Research & Development/ Light Industrial	• 400 – Commercial/Industrial† • 420 – Comm/Ind-MiscImp† • 451 – Comm/Indust-City† • 455 – Comm/Indust-Religious† • 456 – Comm/Indust-Charitable† • 458 – Comm/Indust-Other† • 459 – Comm/Indust-SCC†
D – Residential	• Low Density Residential • Medium Density Residential • SF • Very Low Density Residential/ Agricultural	• 200 – SingleFamily • 220 – Res-NonlivingArea • 251 – SFR-City • 255 – SFR-Religions • 256 – SFR-Charitable • 258 – SFR-Other
E – Multifamily Residential	• High Density Residential	• 2260 – Res Condo Parent • 300 – Multifamily • 355 – Multifamily-Religious • 356 – Multifamily-Charitable • 358 – Multifamily-Other

Land Use Category	Blacksburg Land Use Category	Roanoke Land Use Category
X – Exempt	• Town-Owned • Right-of-Way • University • Cemetery	• 152 – Vacant-State • 153 – Vacant-Federal • 154 – Vacant-Regional • 252 – SFR-State • 253 – SFR-Federal • 254 – SFR-Regional • 353 – Multifamily-Federal • 354 – Multifamily-Regional • 452 – Comm/Indust-State • 453 – Comm/Indust-Federal • 454 – Comm/Indust-Regional

* Open space parcels in Roanoke that have no impervious area were considered unimproved, and therefore exempt.

† Roanoke commercial and industrial land uses were separated based on zoning map.

APPENDIX C FEE TYPE RATES

Fee Type			Blacksburg	Roanoke
Flat			$6.13	$4.39
ERU		ERU Area (m^2)	319.3	263.7
		Rate	$3.03/ERU	$1.69/ERU
Area			$0.00130/$m^2$	$0.00210/$m^2$
Tier	Amount of Impervious Area (m^2)	0 – 27.9	$0.00	$0.00
		28.0 – 631.7	$2.93	$2.19
		631.8 – 929.0	$6.85	$5.11
		929.1 – 1,858.1	$9.78	$7.29
		1,858.2 – 2,787.1	$19.56	$14.59
		2,787.2 – 3,716.1	$29.34	$21.88
		3,716.2 – 4,645.2	$39.11	$29.18
		4,645.2 – 5,574.2	$48.89	$36.47
		5,574.3 – 6,503.2	$58.67	$43.77
		6,503.3 – 7,432.2	$68.45	$51.06
		7,432.3 – 8,361.3	$78.23	$58.36
		8,361.4 – 9,290.3	$88.01	$65.65
		9,290.4 – 18,580.6	$97.79	$72.94
		18,580.7 – 27,870.9	$195.57	$145.89
		27,871.0 – 37,161.2	$293.36	$218.83
		37,161.3 – 46,451.5	$391.15	$291.78
		46,451.6 – 55,741.8	$488.93	$364.72
		55,741.9 – 69,677.3	$586.72	$437.66
		69,677.4 – 92,903.0	$733.40	$547.08
		Greater than 92,903.1	$977.87	$729.44
Dual – Two Flat Fees		Multiplier	0.547	1.738
		Residential	$6.56	$3.99
		Commercial	$3.59	$6.93
Dual – Flat/ERU		Residential	$3.90	$1.77
		Commercial	$3.90/ERU	$1.77/ERU
REF – TR-55		Rainfall (m)	0.07	0.08
		Rate	$0.000957/$m^2$	$0.00117/$m^2$
REF – Rational Method			$0.00311/$m^2$	$0.00368/$m^2$

APPENDIX D EFFECTS OF RAINFALL EVENTS ON REF-1 RATIOS

The REF-1 fee system uses the TR-55 manual for calculating runoff from parcels with different land uses. The most common hydrologic soil group (HSG) is usually chosen along with runoff curve numbers appropriate for different land uses. Since both Blacksburg and Roanoke have predominantly HSG B soil, the appropriate runoff curve numbers for different land uses are given in Table D.1. In the TR-55 method, the rainfall at the beginning of a storm that does not end up as surface runoff is referred to as the initial abstraction (I_a). This initial abstraction can be captured by vegetation, soaked into the ground, or held by surface tension. The value for I_a is related to the curve number through Equation D.1 and Equation D.2.

Table D.1. Initial abstraction for each land use category given previously chosen CNs.

REF Category	CN	S	I_a
Open Space	69	4.49	0.90
Commercial/Business	92	0.87	0.17
Industrial	88	1.36	0.27
Residential	70	4.29	0.86
Multifamily	85	1.76	0.35

$$S = \frac{1000}{CN} - 10 \tag{D.1}$$

$$I_a = 0.2S \tag{D.2}$$

where

S = potential maximum retention after runoff begins (in)
CN = curve number
I_a = initial abstraction (in)

In a REF-1 system, the ratio of runoff from a property with a given land use to that of a single-family residential property is used to determine the fee. Runoff is calculated using Equation D.3 for when precipitation is larger than I_a. If precipitation is less than I_a, then there is no runoff.

$$Q = \frac{(P - I_a)^2}{P + 0.8S} \tag{D.3}$$

The precipitation that is chosen when calculating the runoff will change the ratio used for the SUF fees. In 2014, Campbell et al. suggested that annual rainfall from several years should be analyzed for the different land uses to determine the ratio. This was done for Bowling Green, Kentucky, Escondido, California, and Las Vegas, Nevada. For Bowling Green and Escondido, which have very different climates, a standard rainfall of about 1.6 inches simulated the average number of REFs seen from the annual rainfall values, and therefore could be used for REF ratios. However, the value of rainfall for the very arid Las Vegas never settled to a constant value.

For some cities with a long rainfall record, a reasonable standard storm rainfall that adequately reflects the relative runoff from parcels can be found. When this is possible, it should be used as a fair method of calculating fees for nonresidential properties.

For when this cannot be used, an analysis was done to see the effect changing the precipitation would have on the runoff ratios. Figure D.1 plots the ratio for various land uses as a function of storm rainfall.

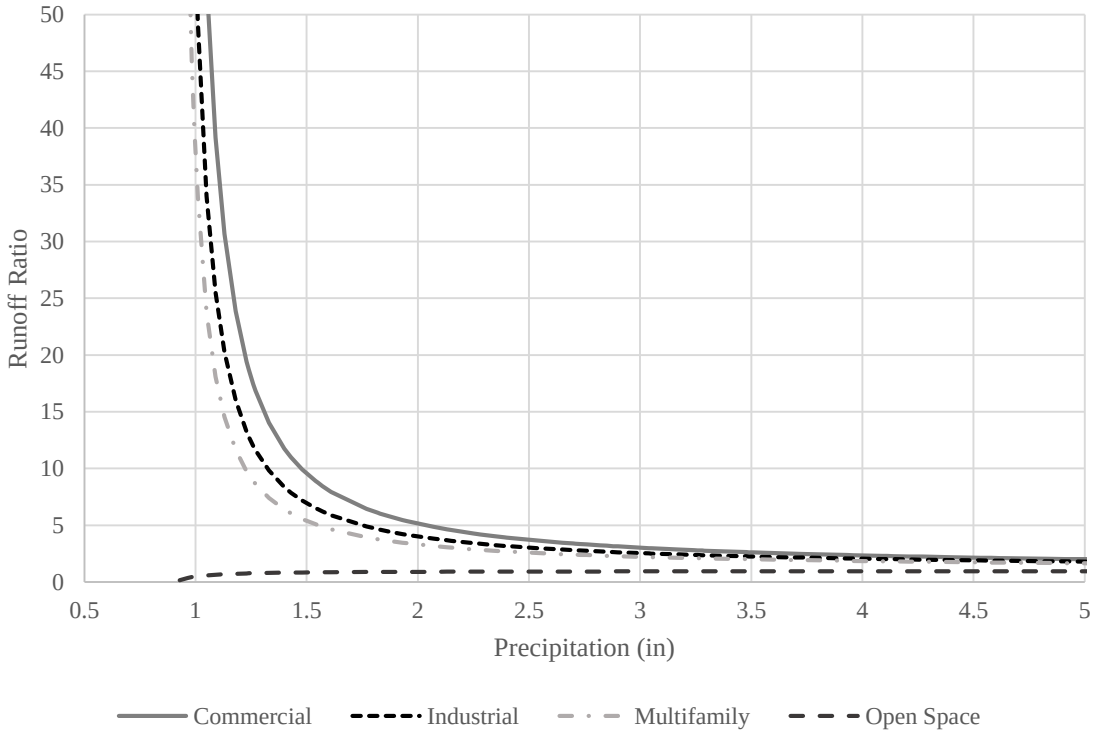

Figure D.1. Detailed graph of runoff ratio versus precipitation depth.

Figure D.1 shows a clear vertical asymptote where the precipitation is equal to the initial abstraction for residential parcels. To show why this occurs, first Equation D.2 and Equation D.3 is combined to rewrite the equation for runoff in terms of precipitation and initial abstraction (Equation D.4).

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} = \frac{(P - I_a)^2}{(P + 4I_a)} \tag{D.4}$$

For the runoff ratio used in REF-1, this can also get rewritten as:

$$\frac{Q_{Parcel}}{Q_R} = \frac{\frac{(P - I_{a\text{-}Parcel})^2}{(P + 4I_{a\text{-}Parcel})}}{\frac{(P - I_{a\text{-}R})^2}{(P + 4I_{a\text{-}R})}} = \frac{(P - I_{a\text{-}Parcel})^2}{(P + 4I_{a\text{-}Parcel})} \cdot \frac{(P + 4I_{a\text{-}R})}{(P - I_{a\text{-}R})^2} \tag{D.5}$$

When the precipitation equals the initial abstraction of residential parcels, the runoff ratio denominator reaches zero, which makes an asymptote in the graph (Equation D.6).

$$\lim_{P \to I_a} \left(\frac{(P - I_{a\text{-}Parcel})^2}{(P + 4I_{a\text{-}Parcel})} \cdot \frac{(P + 4I_{a\text{-}R})}{(P - I_{a\text{-}R})^2} \right) = \frac{(P - I_{a\text{-}Parcel})^2}{(P + 4I_{a\text{-}Parcel})} \cdot \frac{(P + 4I_{a\text{-}R})}{0} = \frac{(P - I_{a\text{-}Parcel})^2 (P + 4I_{a\text{-}R})}{0} = \infty \tag{D.6}$$

Figure D.1 also shows the ratios follow a horizontal asymptote once reaching a precipitation depth of 0.09 meters. This horizontal asymptote of 1 is found when precipitation is increased to infinity (Equation D.7).

$$\lim_{P\to\infty}\left(\frac{(P - I_{a\text{-}Parcel})^2}{(P + 4I_{a\text{-}Parcel})}\cdot\frac{(P + 4I_{a\text{-}R})}{(P - I_{a\text{-}R})^2}\right) = \left(\frac{(P)^2}{(P)}\cdot\frac{(P)}{(P)^2}\right) = 1 \tag{D.7}$$

Because of this occurrence, a rainfall depth too high will favor the non-residential properties because all ratios will be closer to 1. If the rainfall depth used for the REF-1 is low, the ratios for other properties will be high which favors the residential properties.