Impervious Cover and Watershed Vulnerability: Bull Creek Watershed Austin, Texas

Ian Johnston
GIS in Water Resources
December 2, 2016

Summary

Within the last few years, through the use of geographic information systems (GIS), there are opportunities to "prioritize water quality improvement needs and identify structural Best Management Practice opportunities on a watershed scale", in order to decrease costs and improve water quality in an efficient manner.[1] One model that has helped in watershed management decisions is the "Impervious Cover Model" (ICM), developed by the Center for Watershed Protection (CWP).[2] The ICM takes into account average percentages of impervious cover within a watershed and classifies streams and their watersheds into three categories: sensitive, impacted, and non-supporting. Additionally, the Nonpoint Education for Municipal Officials (NEMO) program has expanded on the ICM by providing methodologies on how to conduct a zoning based, impervious surface "build out" analysis.[3] By conducting a combination of these models cities can gauge the current conditions of their streams and better plan for future impacts of development.[4]

This project examined the present health of the Bull Creek watershed in Austin through the application of the ICM. By applying NEMO methodologies, a "build out" scenario was then conducted to investigate the implications of future growth based on current zoning in the watershed. Results of this study found total impervious cover rate at levels that would qualify Bull Creek Watershed as currently "impacted" according to the ICM and on the verge of "non-supporting". "Build out" analysis has determined that if growth continues, there is the potential for the amount of impervious cover to increase and cause the Watershed to be considered "non-supporting". Based on these results, it is concluded that the overall environmental integrity of Bull Creek Watershed is vulnerable as it is currently zoned. If growth continues at its current rate, the city of Austin may need to consider more stringent impervious cover limits to prevent further degradation of the watershed.

[1] Susilo, K., Leisenring, M., Strecker, E., "Combining GIS, BMP Performance, and Strategic Planning to Support Quality Implementation Planning". World Environmental and Water Resources Congress. 2009,1

[2] Flinker, Peter. "The Need to Reduce Impervious Cover to Prevent Flooding and Protect Water Quality". AICP Dodson Associates, LTD., May, 2010. Providence, RI. Web. 21 Sept. 2016., 4

[3] Giannotti, Laurie, Prisloe, Sandy. "Do it Yourself! Impervious Surface Buildout Analysis". NEMO Project. Haddam, CT. 1998.

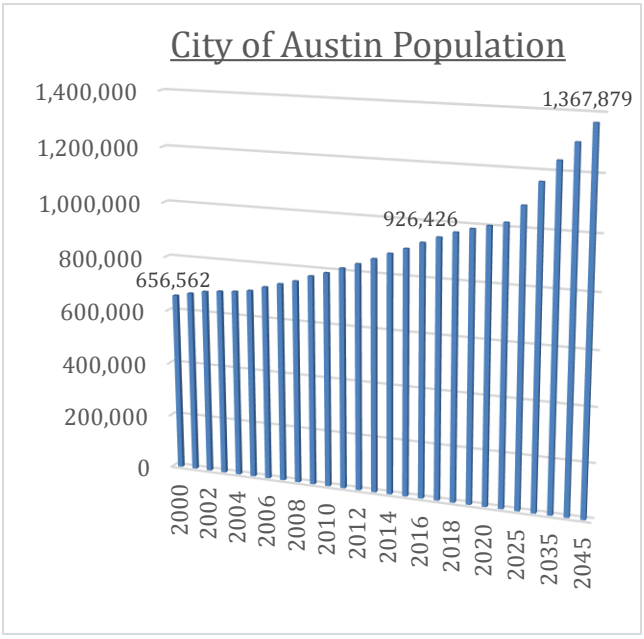
[4] Flinker, 4

Introduction

Austin and Urban Sprawl

The city of Austin has been growing at nearly an exponential rate. Just since the year 2000 the city has increased by over 300,000 people and by the year 2020 the demographer's office expects the population to exceed one million for the first time in history. This kind of growth can bring with it many positive developments for a city, including higher economic production, increased employment, and better public services, for example.[5] However, for these benefits to be realized, how this growth occurs matters. If it takes place with little planning or direction –as is often the case- this can lead to fairly undesirable developments: one of which, is sprawl. When sprawl occurs, there can be a myriad of negative repercussions related to the environment, health, and quality of life.[6] The city of Austin, is no exception. Figure 2 and Figure 3 on the following page demonstrate how the city has grown since the year 1992, as represented by impervious cover.[7] Land cover data was retrieved online from the National Land Cover Database while files on Austin's 2016 Extra Territorial Jurisdiction (ETJ) were retrieved through the city GIS database online.

Figure 1



Source: austintexas.gov

As evidenced by the maps below, Austin has begun to develop outward into its hinterland. This growth has taken place in a predictable manner, following major roads and highways such as I-35, Mopac, 183, or 71. Indeed, roads and highways often act as direct catalysts of sprawl[8] and the pattern we see here is one that has played out in similar ways across the United States.[9] Unfortunately, despite how dramatic this increase in impervious cover may appear, the consequences are often even greater than the spatial extent would suggest and especially in terms of environmental quality.[10]

---

[5] Bhatta, B. 2010. Analysis of Urban Growth and Sprawl from Remote Sensing. Springer. Berlin, GER. ISBN: 978-3-642-05298-9, 28
[6] Bhatta, 29
[7] Impervious cover can generally be defined as any surface that prevents water from penetrating into the ground and will include a range of materials associated with development such as rooftops, driveways or parking lots, for example
[8] Bhatta, 24
[9] Robert Patterson Interview
[10] Bhatta, 29

Figure 2

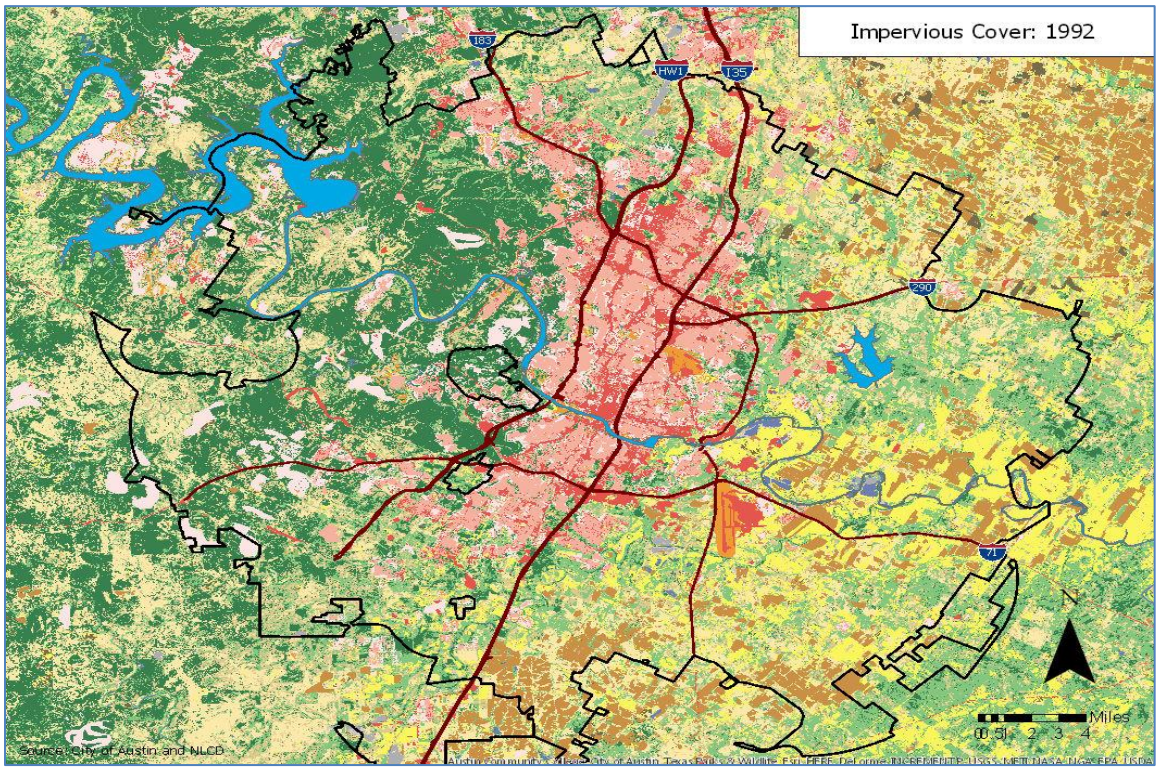
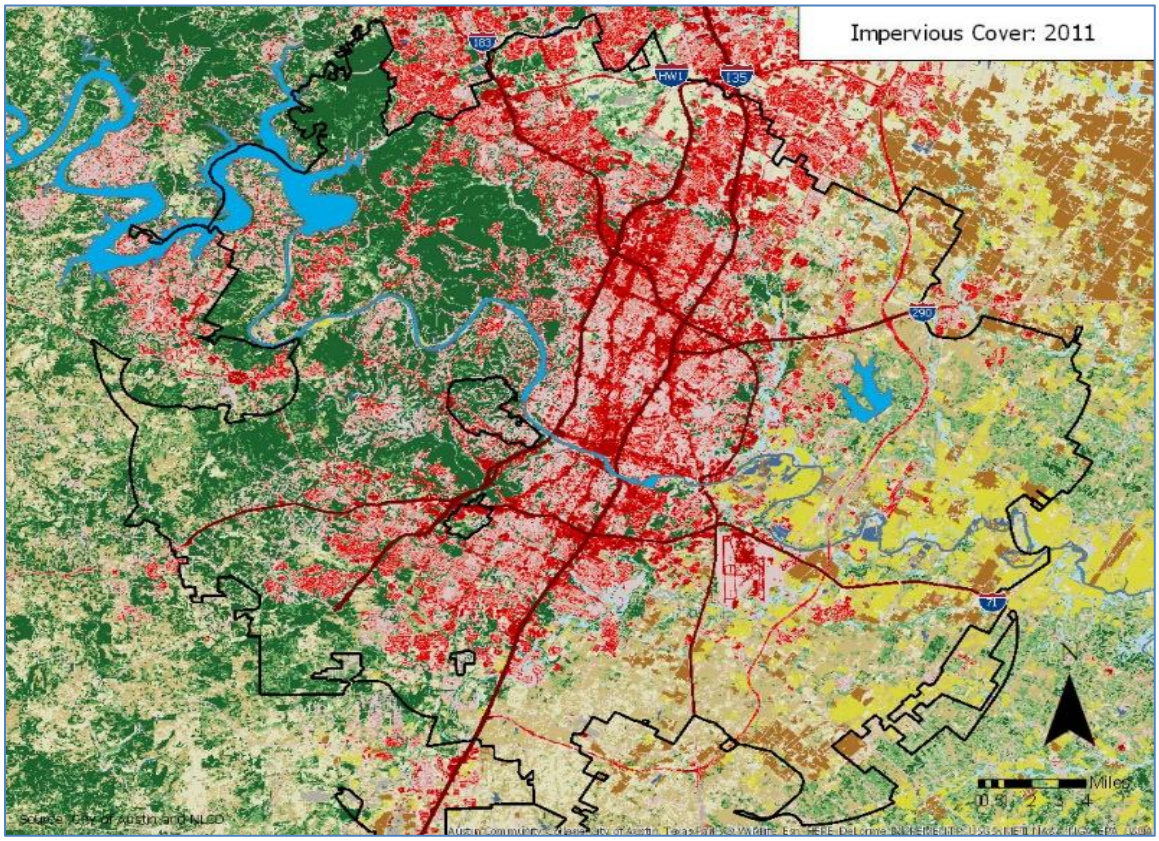


Figure 3



Impervious Cover and Watershed Health in Austin

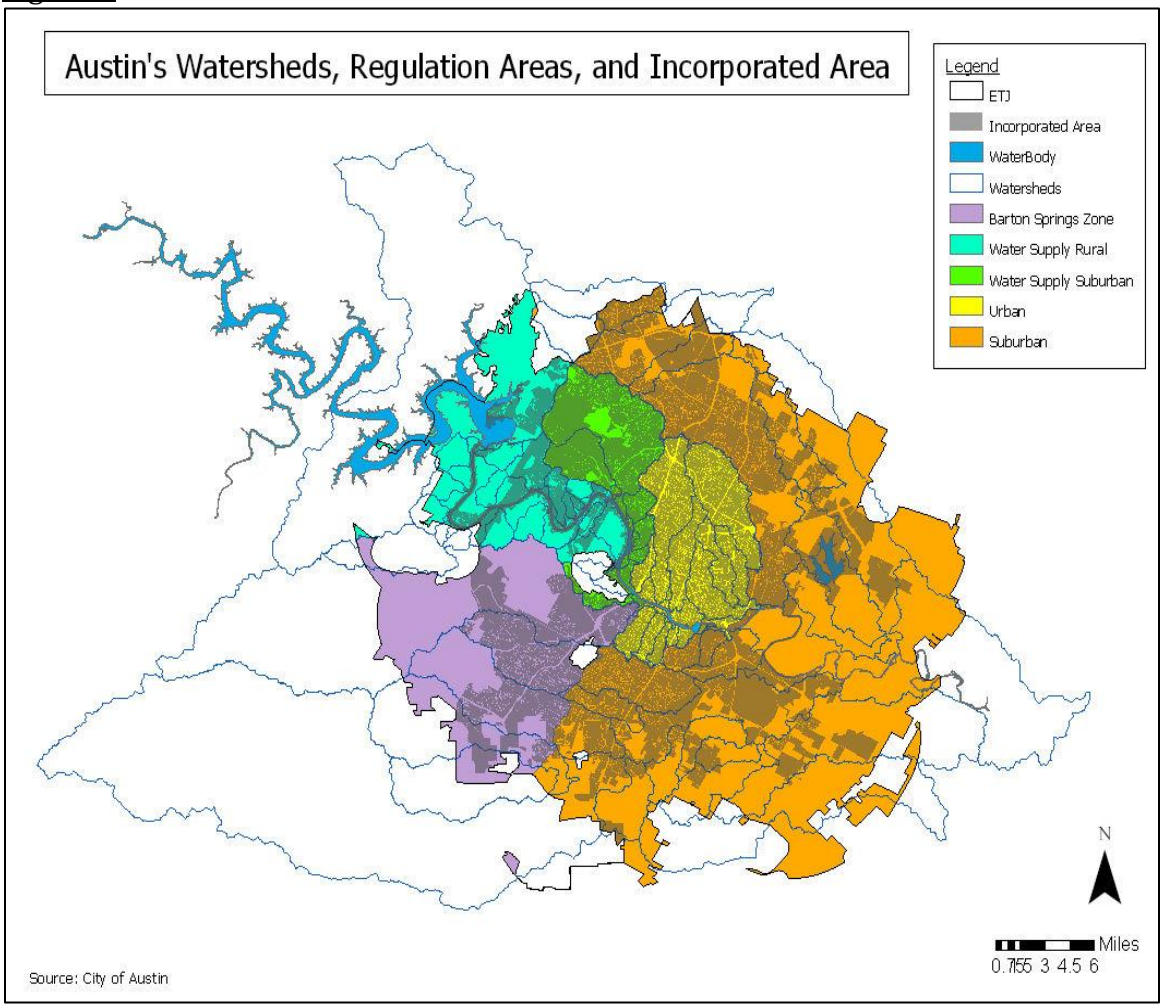
Increasing amounts of impervious cover contributes significantly to many of the water quality and quantity issues facing cities today. In short, these surfaces prevent water from infiltrating into the ground and create stormwater runoff. This runoff then carries organic matter, fertilizers, pesticides, oil and grease and other contaminants, directly into streams, water bodies, and local water supplies. Additionally, because water runs quickly off of these surfaces, the quantity and velocity of runoff is increased, the physical structure of streams become altered and eroded, and there is a greater likelihood of more frequent and larger floods.[11]

In recognition of this effect, since the mid 1970's the city of Austin has passed a series of ordinances related to flood and water quality protection that include restrictions on impervious cover.[12] Unfortunately, these ordinances have historically only applied to land uses within the incorporated city limits and not to the entirety of the city's ETJ. Due to the sprawling nature of Austin's growth therefore, a substantial amount of development occurred outside of these ordinances' jurisdiction.[13] The most recent iteration of municipal watershed planning and management however, the 2013 Watershed Protection Ordinance (WPO), extends the city's authority to regulate development to the entirety of its ETJ. Today, both the WPO and zoning within the incorporated city limits apply restrictions on impervious cover that vary according to land use (e.g residential, commercial, industrial, etc.). More specifically, zoning restrictions apply further limitations on each category of land use (for example, with residential land use there are 15 distinct classifications such as rural residential, single family, or multi-family). Figure 4 on the following page represents Austin's current incorporated city limits and the WPO as it applies to the city's ETJ.

The degree of damage on watershed health will depend on many factors: on the nature of existing land uses or the particular topography, soils, and vegetation, for example. For this reason, it can be difficult to attribute environmental impairment to just one source and therefore often hard to prevent or predict. However, impervious cover, while perhaps not always the direct cause of environmental impairments, has been shown to be a good representative substitute. Numerous studies have demonstrated a correlation between impervious cover levels and the environmental integrity of streams and their watersheds and this correlation can then be used to both predict and manage water quality and watershed health.[14]

[11] Flinker,., 2
[12] Watershed Protection Department. (n.d.) Watershed Ordinance History. Watershed Protection Department. Web. 22 Nov. 2016
[13] Watershed Protection Department. (2016) Watershed Protection Master Plan. City of Austin., 23
[14] Flinker, 5

Figure 4



Methodology

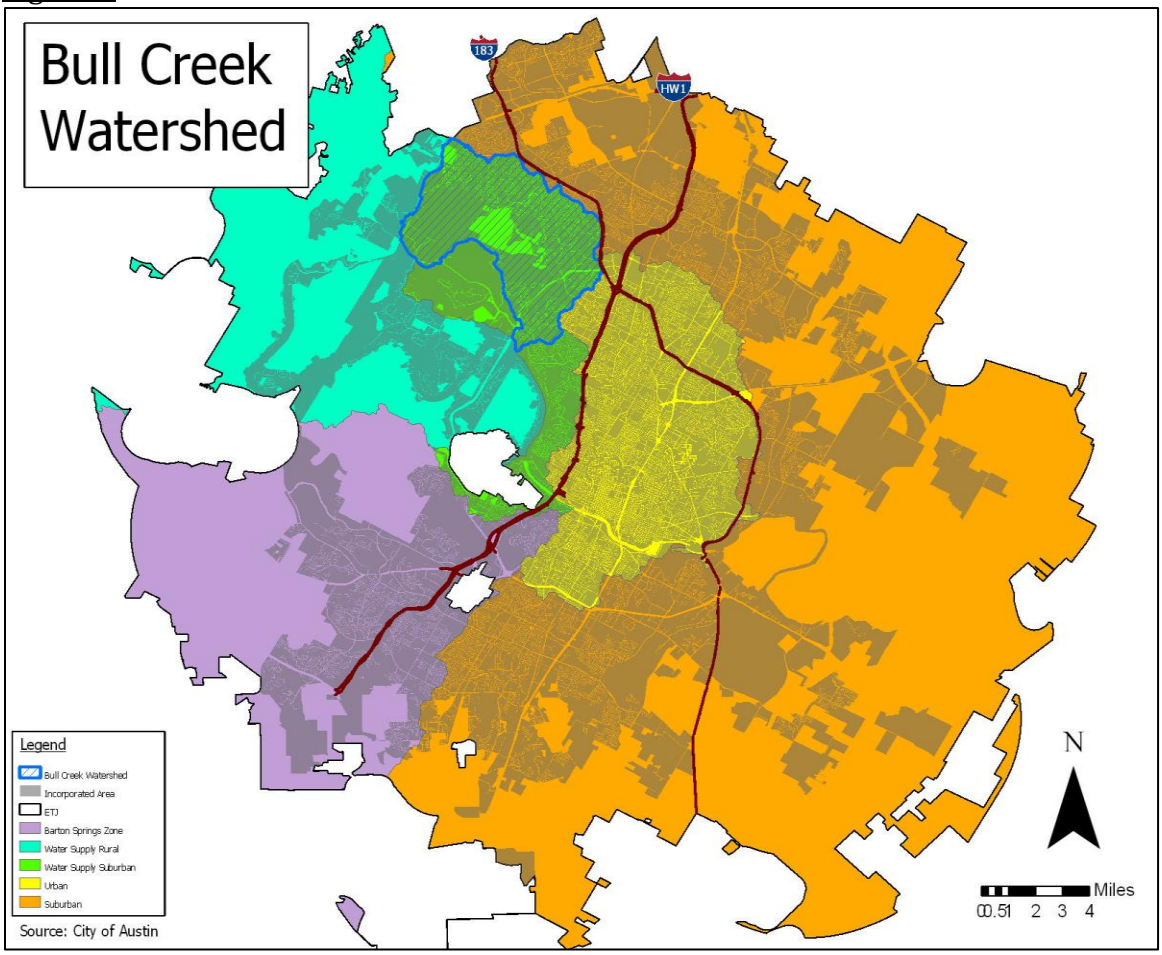
The Center for Watershed Protection (CWP), a non-profit organization that provides tools to local governments for protecting streams, lakes and rivers, has developed the "Impervious Cover Model" which is based on the average percentages of impervious cover at which stream quality declines.[15] In the development of this model the CWP has determined threshold limits when total impervious cover begins to have predictable effects on watershed health and stream environmental quality. These thresholds are then broken down into three categories: sensitive (less than 10% impervious cover), impacted (between 10 and 25%), and non-supporting (over 25%).[16] In order to predict the future impact that impervious cover may have on streams and their watersheds, the Nonpoint Education for Municipal Officials (NEMO) program then recommends using established land use-impervious cover

[15] Center for Watershed Protection. (n.d.). About. Center for Watershed Protection. Web. 25 Nov. 2016
[16] Millar, S. (n.d.) Impervious Cover and its Effects on Water Quality. Rhode Island Department of Environmental Management., 1

relationships. By modeling a future scenario where impervious cover reaches the maximum build-out conditions allowed under current land use regulations, the potential future environmental quality of a watershed can be anticipated.[17]

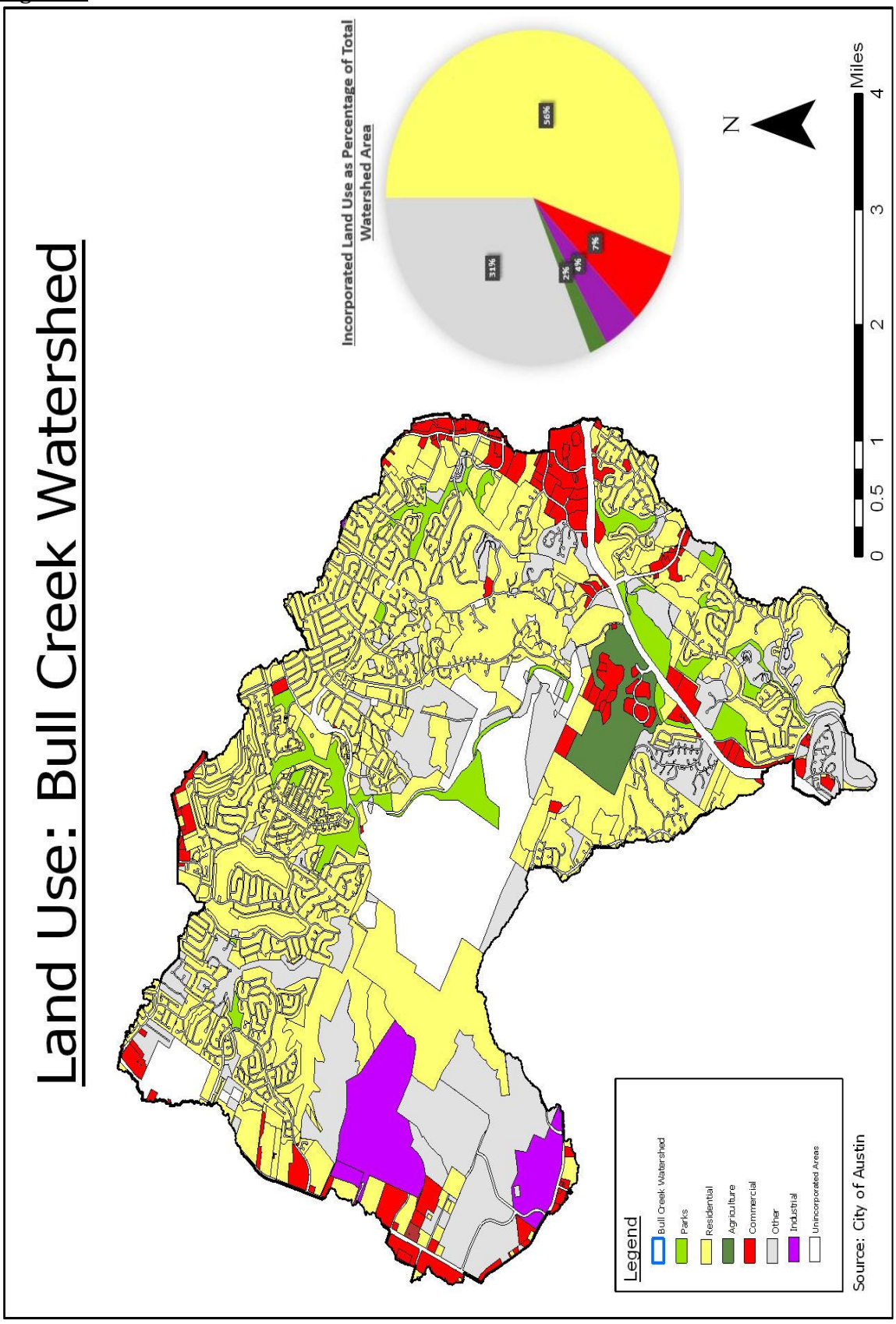
For this study, one particular watershed was chosen to perform a "build-out" scenario: Bull Creek Watershed. It is a watershed that has experienced significant development pressures in recent history –its population alone has increased by 60 percent since the year 2000[18]- and this trend is likely to continue given its proximity to Mopac Highway and Highway 183. The total impervious cover rate currently stands at 20.9%, which therefore qualifies the watershed as "impacted" and at the threshold of going beyond 25%, or what would constitute a "non-supporting". The following Figure 5 demonstrates where Bull Creek Watershed is in relation to the city of Austin. On the following page, Figure 6 details the land use breakdown of the incorporated areas within the watershed (from 2014, the most recent data available from the city).

Figure 5



[17] Zielinski, J. (2002). Watershed Vulnerability Analysis. Center for Watershed Protection. Ellicott City, MD., 3
[18] Environmental Integrity Index. Bull Creek Watershed: Summary Sheet. Watershed Protection Department. Austin, TX., 1

Figure 6


Land Use: Bull Creek Watershed
Incorporated Land Use as Percentage of Total Watershed Area
56%
31%
2%
4%
7%
N
0 0.5 1 2 3 4
Miles
Legend
Bull Creek Watershed
Parks
Residential
Agriculture
Commercial
Other
Industrial
Unincorporated Areas
Source: City of Austin

The majority of land in this watershed is within Austin's incorporated limits though portions are not (these areas are within the ETJ and would instead fall under the Water Supply Suburban category of the WPO). For purposes of this study, only the land within the incorporated city limits will be used to model a future build out. The relevant zoning land use breakdown therefore is predominantly residential (56%), followed by commercial (7%), industrial (4%), and agriculture (2%). The 31% of land represented as "other" in Figure 6 consists of "special purpose" land uses, and will not be included in the model as the city does not have designated impervious cover limits for these uses. Within the categories of residential, commercial, and industrial there are subcategories, each with their own maximum allowable impervious limits. The following Tables 1, 2, and 3, lists those subcategories within the residential, commercial, and industrial zones, that are found in the Bull Creek Watershed. Their total land coverage and the associated maximum impervious cover limits are also included.

Table 1

Commercial Subcategory	Total Area (ft2)	Max Impervious Limit
CH	28,234.23	.85
CR-CO	152,293.53	.6
CS	690,198.4	.95
CS-1	193,654.60	.95
CS-1-CO	2,823.47	.95
CS-CO	979,736.00	.95
GO	2,085,392.41	.8
GO-CO	4,243,612.39	.9
GR	9,982,485.76	.9
GR-CO	9,570,101.70	.9
GR-MU	296,625.24	.9
LO	12,066,288.80	.7
LO_CO	3,777,892.52	.7
LO-MU-CO	17,573.39	.7
LR	2,096,544.39	.8
LR-CO	1,265,533.47	.8
LR-MU-CO	1,500.92	.8
NO	11,392.11	.6
NO-CO	33,928.57	.6
W/LO-CO	420,402.83	.7

Table 2

Residential Subcategory	Total Area (ft2)	Max Impervious Limit
I-RR	47,318,616.98	.25

I-SF-2	5,183,795.79	.45
I-SF-3	106694.39	.45
I-SF-6	254,806.15	.55
MF-1	581,323.23	.55
MF-1-CO	8,662,544.00	.55
MF-2	10,184,243.91	.6
MF-2-CO	8,528,320.93	.6
MF-3	4,098,563.79	.65
MF-3-CO	677,307.39	.65
RR	28,926,932.07	.25
RR-CO	3,149,192.22	.25
SF-1	50,455,670.76	.4
SF-1-CO	3,197,769.36	.4
SF-2	143,538,894.28	.45
SF-2-CO	6,508,424.22	.45
SF-3	31,542,895.39	.45
SF-4A	24,304.85	.65
SF-4A-CO	210,661.43	.65
SF-6	21,462,805.94	.8
SF-6-CO	2,290,481.47	.8

Table 3

Industrial Subcategory	Total Area (ft2)	Max Impervious Limit
R&D	7668229.99	.5
R&D-PDA	19,421,584.64	.5

By multiplying the maximum allowable impervious limits for each of these subcategories to the total amount of area over which the zoning regulations apply, a future scenario can be modeled. This projection can serve as a forecast of the total impervious cover that could be expected under very significant development pressures. In other words, it is a worse-case-scenario build out model of what could be, based on what is allowed under current impervious cover restrictions. The following Table 4 presents this breakdown for commercial, residential, and industrial land uses.

Table 4

Land Use	Total Impervious Cover (ft2)	Total Impervious Cover as % of Total Watershed Area
Commercial	38,931,528.03	5.74
Residential	164,117,861.80	24.21
Industrial	13,544,906.80	2.00

Conclusion

The results of this build out model demonstrate that under significant development pressure and current zoning restrictions, there is the potential for total impervious cover to reach or exceed the 25% threshold limit of when a watershed transitions from "impacted" to "non-supporting". For example, if *only* residential land use were to reach the maximum allowable impervious cover limits, this would entail that 24.21% of the total area of Bull Creek Watershed would then be impervious. In the case of commercial land use, this would equate to 5.74% of the total land area. If these build-out scenarios were to also include the existing impervious cover on those lands that were designated as "special-purpose" or those areas that were within the ETJ but outside of Austin's incorporated limits, the results would be even more dramatic.

Of course, this model represents a worst-case scenario, where not only is it assumed that dramatic development occurs but also that in each of these parcels all available land will be utilized for the sake of this development. That being said, the historical patterns of Austin's growth and the particular location of the Bull Creek Watershed would indicate that development pressure will only increase. Furthermore, the WPO has designated this watershed as part of the "Water Supply Suburban" area, indicating that any localized environmental consequences as a result of an increase in impervious cover will also have an effect on the water that Austin drinks. Given this, the "build-out" analysis demonstrates that current zoning restrictions on impervious cover may not go far enough. The city of Austin would be wise to consider either adjusting these restrictions or planning for other strategies that could mitigate for further increases in impervious cover.

References

Bhatta, B. 2010. Analysis of Urban Growth and Sprawl from Remote Sensing. Springer. Berlin, GER. ISBN: 978-3-642-05298-9

Center for Watershed Protection. (n.d.). About. Center for Watershed Protection. Web. 25 Nov. 2016

Environmental Integrity Index. Bull Creek Watershed: Summary Sheet. Watershed Protection Department. Austin, TX

Flinker, Peter. "The Need to Reduce Impervious Cover to Prevent Flooding and Protect Water Quality". AICP Dodson Associates, LTD., May, 2010. Providence, RI. Web. 21 Sept. 2016.

Giannotti, Laurie, Prisloe, Sandy. "Do it Yourself! Impervious Surface Buildout Analysis". NEMO Project. Haddam, CT. 1998.

Millar, S. (n.d.) Impervious Cover and its Effects on Water Quality. Rhode Island Department of Environmental Management.

Patterson, Robert. Personal Communication. 24 Nov. 2016.

Susilo, K., Leisenring, M., Strecker, E., "Combining GIS, BMP Performance, and Strategic Planning to Support Quality Implementation Planning". World Environmental and Water Resources Congress. 2009

Watershed Protection Department. (n.d.) Watershed Ordinance History. Watershed Protection Department. Web. 22 Nov. 2016

Watershed Protection Department. (2016) Watershed Protection Master Plan. City of Austin.

Zielinski, J. (2002). Watershed Vulnerability Analysis. Center for Watershed Protection. Ellicott City, MD.