# Stormwater Infiltration Siting for the City of Edina

## Spring 2022


**Prepared by**

Karina Anderson, Martha Burket, Noah Gallagher, and Owen Turner
*Students enrolled in CEGE 4102W: Civil Engineering Capstone*

**Capstone Advisor**

Robert Krussow
College of Science and Engineering

**Prepared in Collaboration with**

Jessica Wilson
Water Resources Coordinator, City of Edina


EDINA MINNESOTA

Resilient Communities Project
UNIVERSITY OF MINNESOTA
*Building Community-University Partnerships for Resilience*

METROPOLITAN COUNCIL

The project on which this report is based was completed in collaboration with the City of Edina and the Metropolitan Council as part of a 2021–2022 Resilient Communities Project (RCP) partnership. RCP is a program at the University of Minnesota's Center for Urban and Regional Affairs (CURA) that connects University faculty and students with Minnesota communities to address strategic projects that advance local resilience, equity, and sustainability.



**Resilient Communities Project**
University of Minnesota
330 HHHSPA
301—19th Avenue South
Minneapolis, Minnesota 55455
Phone: (612) 625-7501
E-mail: rcp@umn.edu
Web site: http://www.rcp.umn.edu

Resilient Communities Project

University of Minnesota
Driven to Discover℠

M.O.N.K. Engineering
123 Oak Street
Minneapolis, MN, 55414

April 28th, 2022

Jessica Wilson
City of Edina
7450 Metro Blvd
Edina, Minnesota 55439

Re: S22-12_ResilCmty_E Draft Report

Dear Ms. Wilson:

We have compiled a report regarding the project to create a tool consisting of maps and methodologies that evaluates the suitability of areas for infiltration-based stormwater control measures within the City of Edina. Using the United State Department of Agriculture's soil data along with MN-GEO elevation data, we were able to map the suitability of sites for infiltration stormwater control measures. This map was then compared to another map with zones where infiltration should be excluded, such as zones indicated by the City of Edina's wellhead protection plan and areas of concern identified through the Minnesota Pollution Control Agencies 'What's in My Neighborhood' tool.

The final map products are best used as a planning level tool, not as a substitute for thorough site examination. Using both maps highlights regions with excellent infiltration potential and few pollution concerns, which tend to be in the center and northwest of the city. The maps identify prime locations for infiltration-based on technical, not social, analysis. The maps do not consider public feedback on the desirability of infiltration-based stormwater control measures (SCMs) in regions identified as good candidates for infiltration SCMs. The Preliminary Infiltration Rating (PIR) map is only useful for general area evaluations, and site specific measurements will still be necessary. We recommend the PIR map be used first to screen potential neighborhoods for infiltration-based SCM suitability, then the exclusion criteria map be used to avoid areas with potential for contamination within the selected neighborhood. Following these screening steps, engineers should still conduct a typical site evaluation and take special care to include the voice of the public when finalizing construction plans.

Regards,

| | | | |
|---|---|---|---|
| Owen Turner | Karina Anderson | Martha Burket | Noah Gallagher |
| Project Manager | Project Engineer | Project Engineer | Project Engineer |
| turne962@umn.edu | and06200@umn.edu | burke781@umn.edu | galla444@umn.edu |

CC: Ms. Sarah Tschida, Dr. Vaughan Voller, Dr. Merry Rendahl, Mr. Robert Krussow
Attached: Draft Report, .zip Files Containing Final Shapefiles for the Maps

# Stormwater Infiltration Siting for the City of Edina


*Braemar Arena infiltration basin, July 2020*

**Prepared for**
Jessica Wilson, City of Edina
Sarah Tschida, U of M RCP

**by M.O.N.K. Engineering**

Martha Burket
Owen Turner
Noah Gallagher
Karina Anderson

**April 28th, 2022**

## Executive Summary

The City of Edina is experiencing rapid urban redevelopment. Stormwater infiltration is a key strategy that cities use to recharge groundwater, mitigate flood risk, and protect and improve water quality. There are many common stormwater control measures (SCMs) that may be used to manage stormwater infiltration, including rain gardens and infiltration basins. Proper placement of SCMs is crucial in order to ensure that they remain effective and sustainable.

The aim of this project is to develop a tool to identify areas within the City of Edina where stormwater infiltration is both technically feasible and protective of the quality of its groundwater, which is the city's primary drinking water source. To do so, this report expands upon the work from a 2021 University of Minnesota research paper, "Siting Surface Infiltration-Based Stormwater Control Measures Using a Geographic Information Systems Approach" (Tecca, Gulliver, and Nieber 2021). The Tecca et al. paper provides a preliminary framework for identifying viable areas for stormwater infiltration based on the hydrogeologic characteristics of an area of interest. This report applies the same framework to the City of Edina, layering various regulations, guidelines, sustainability considerations, and environmental justice concerns on top of the initial model in order to further refine the placement of stormwater infiltration facilities.

To implement the method from Tecca et al., data values for hydraulic conductivity (Ksat), depth to the water table, and Digital Elevation Model (DEM) data were collected from the USDA's web soil survey and the MnTOPO website. Large areas of the city lacked values for $K_{sat}$ and depth to the water table, so alternative methods were used to determine the relevant values from those areas. The initial Preliminary Infiltration Rating (PIR) map indicated large swathes of land in Edina which were rated as poor for stormwater infiltration, some which were moderately ideal, and a few that were excellent.

To determine additional exclusion criteria for stormwater infiltration facilities siting, several resources such as the Minnesota Stormwater Manual, The City of Edina's Wellhead Protection Plan, the Minnesota Pollution Control Agency's 'What's in My Neighborhood' database, National Pollution Discharge Elimination System (NPDES) permits, and relevant watershed district policies were consulted. Guidelines from these sources were compiled and converted into several layers in a geographic information system (GIS), which were layered over the PIR map to narrow down locations in which placement of infiltration-based SCMs was ideal. It was found that the combined PIR and EC maps covered over 70% of Edina's land area and that there are significant portions of the city in which placement of infiltration-based SCMs would both be technically feasible and protective of the City's drinking water sources and the environment. The GIS tool and methodology developed for this project have the potential for future use in other cities.

Included in this report is a discussion of recommended considerations to take into account when placing infiltration-based SCMs, including environmental justice concerns, sustainability considerations, and the importance of community input and outreach.

## Terminology and Definitions

- **ArcGIS Toolbox:** An ArcGIS Toolbox contains tools that accomplish specific GIS tasks using a consistent methodology.
- **ArcMap:** A GIS software.
- **cm:** Centimeters.
- **Depth to Water Table (DTWT):** The distance between the ground surface and the estimated water table level.
- **Digital Elevation Model (DEM):** A raster dataset containing information about the elevation of a geographic area.
- **Drinking Water Supply Management Area (DWSMA):** The surface and subsurface area surrounding a public drinking water supply well managed by an entity identified in a Wellhead Protection Plan.
- **Emergency Response Area (ERA):** The surface and subsurface area around a drinking water well corresponding to a one-year time of travel for infiltrated water.
- **Environmental Justice:** Defined by the Environmental Protections Agency (EPA) as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies."
- **Exclusion Criteria (EC):** A set of regulations, guidelines, and environmental concerns relevant to siting stormwater control measures.
- **Geographic Information Systems/Sciences (GIS):** GIS involves managing and analyzing spatial data.
- **GIS Layer:** A single GIS map can contain multiple layers. Each layer contains a single dataset.
- **mm/hr:** Millimeters per hour.
- **Preliminary Infiltration Rating (PIR):** A rating of potential for stormwater infiltration, developed by Tecca et al.
- **Saturated Hydraulic Conductivity ($K_{sat}$):** A property of a material relating to how easily water can flow through the material.
- **Soil Survey Geographic Database (SSURGO):** A dataset curated by the United States Department of Agriculture. It was collected via the National Cooperative Soil Survey.
- **Stormwater Control Measure (SCM):** A permanent structural device that is designed, constructed, and maintained to remove pollutants from stormwater runoff by promoting settling or filtration or mimicking the natural hydrologic cycle.
- **Sustainability:** Defined by the American Society of Civil Engineers (ASCE) as "a set of economic, environmental, and social conditions in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality, or the availability of economic, environmental, and social resources."
- **Web Soil Survey (WSS):** An online database of soils data produced by the National Cooperative Soil Survey.
- **Wellhead Protection Plan (WHPP):** A document that identifies drinking water wells within an area, assesses their vulnerability to certain pollutants, and outlines measures to manage and prevent groundwater issues.
- **What's in My Neighborhood (WIMN):** A visual record and database of EPA violations and possible contaminant sources using geospatial data.

## Certification Page

By signing below, the team members submit that this report was prepared by them and is their original work to the best of their abilities.

Owen Turner, Project Manager

Karina Anderson, Project Engineer

Martha Burket, Project Engineer

Noah Gallagher, Project Engineer

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# 1. Introduction

The City of Edina is experiencing population growth and undergoing redevelopment, and much of the new infrastructure is replacing development that occurred prior to the Clean Water Act. This process of redevelopment tends to incrementally increase impervious surface cover and thereby increases runoff. The redevelopment also has to adhere to modern stormwater management standards that are often stricter than those that were in place during initial development. Stormwater Control Measures (SCMs) are crucial in treating runoff resulting from impervious areas, both for water quality and quantity. Infiltration-based SCMs rely on water seeping into the soil, which both reduces peak demand on storm sewers, and can filter out particles suspended in stormwater.

Unfortunately, infiltration-based practices can have a high failure rate. SCM failure occurs when the SCM cannot infiltrate all the water it is supposed to treat. A survey of Department of Transportation officials from 8 states found failure rates ranging from zero to over 50% (CTC & Associates LLC 2018). These failures stem from two major design issues. First, if the soil is too restrictive to flow, then water will not infiltrate, resulting in long standing water periods for the SCM. Standing water that persists over 72 hours after a storm event is classified as nuisance ponding and can be a breeding ground for mosquitoes (CTC & Associates LLC 2018; New Jersey Department of Environmental Protection 2004). Second, if the SCM is situated too close to the water table or bedrock layer, then there is not enough storage capacity in the soil. The SCM fails after only infiltrating a portion of the stormwater because the soil becomes fully saturated. These failures are expensive as there is a capital cost associated with installing an SCM that does not work. There are also costs associated with excess runoff and repairing damage to the SCM and surrounding infrastructure due to flooding if it occurs. Additionally, insufficient depth to a restricting layer reduces the treatment efficiency as there is less flow depth where the water is in contact with soil (MPCA 2014).

Most failures can be prevented by proper siting of an infiltration practice. Proper siting ensures the underlying soil sits sufficiently above the water table or bedrock layer and makes certain that the soil can transmit water at an adequate rate. Site specific measurements can be costly and only apply to one specific area. Current siting procedures rely on flowcharts rather than maps and have high degrees of uncertainty. There are also areas in which infiltration could mobilize pollutants and threaten groundwater integrity. A variety of resources for identifying potentially hazardous or problematic sites exist, but no single resource is comprehensive. The infiltration limitations associated with these sites are difficult to comprehensively visualize in their separate, conventionally tabular datasets and are a part of the tedious conventional flowcharts for SCM siting.

The objective of this project is to develop a visual tool that can identify areas on the neighborhood scale well-suited to infiltration-based SCMs across the entire City of Edina. This tool is a combination of maps within an interactive mapping software that allows the user to toggle different layers of data on and off. To create the map for technical feasibility of infiltration, the procedure from "Siting Surface Infiltration-Based Stormwater Control Measures Using a Geographic Information Systems Approach" (Tecca et al. 2021) was modified. These modifications focused on expanding the applicability of the method to urban soils where the sources used in Tecca et al. may not have the required data. Tecca developed a toolbox to calculate the PIR within the geospatial information software 'ArcMap'. The toolbox was modified to produce the PIR for this project. The modifications focused on getting the toolbox to work for the Edina-specific data and making the toolbox easier to use for future users. The end result of these modifications is a map of infiltration suitability for the City of Edina, as well as a method and toolbox that can be used in other jurisdictions to generate suitability maps for their areas of interest.

To assist in identifying potential problems and pollutant mobilization concerns at a site, an additional map includes a compiled list of most potentially prohibitive areas. These include areas in which the placement of infiltration practices is prohibited by law, highly discouraged based on potential adverse environmental factors, or would require higher engineering review of a specific site. These areas exist as individual layers within the interactive mapping software that can be easily referenced to determine if there are existing concerns at a location, along with the specific nature of those concerns. This data structure is flexible and allows for modifications or updates to individual buffers without having to recreate the entire map.

Combined, these maps can assist in determining technical feasibility of a site for an infiltration-based SCM, but they do not consider social aspects of siting. These maps should not be used in a vacuum, but rather alongside considerations for community engagement, sustainable building practices, and environmental justice. Later sections of this report include some guidance on implementing environmental justice and sustainability. Further, there are several important components of groundwater infiltration that are not touched on here, such as basement flooding, financial considerations, pollution reduction capacity, etc. These were deemed beyond the scope of this technical study and are up to the discretion of the engineers who use the maps.

## 2. Background

### 2.1 City of Edina

The City of Edina is approximately 16 square miles and is located southwest of the Twin Cities. A map of the City of Edina is shown in Figure 1. Between 2010 and 2018 the population growth rate in Edina increased, and the population is projected to grow to 63,600 people in 2040 (City of Edina 2018). Edina is currently considered to be fully developed, and future growth in the city will be accommodated by redevelopment of existing properties (City of Edina 2018). As redevelopment occurs to accommodate a growing population, infiltration can be a promising strategy for managing stormwater. Additionally, much of the development of Edina predates the 1972 Clean Water Act and modern stormwater management controls. Thus, much of the stormwater infrastructure will be newly built instead of replaced or renovated.

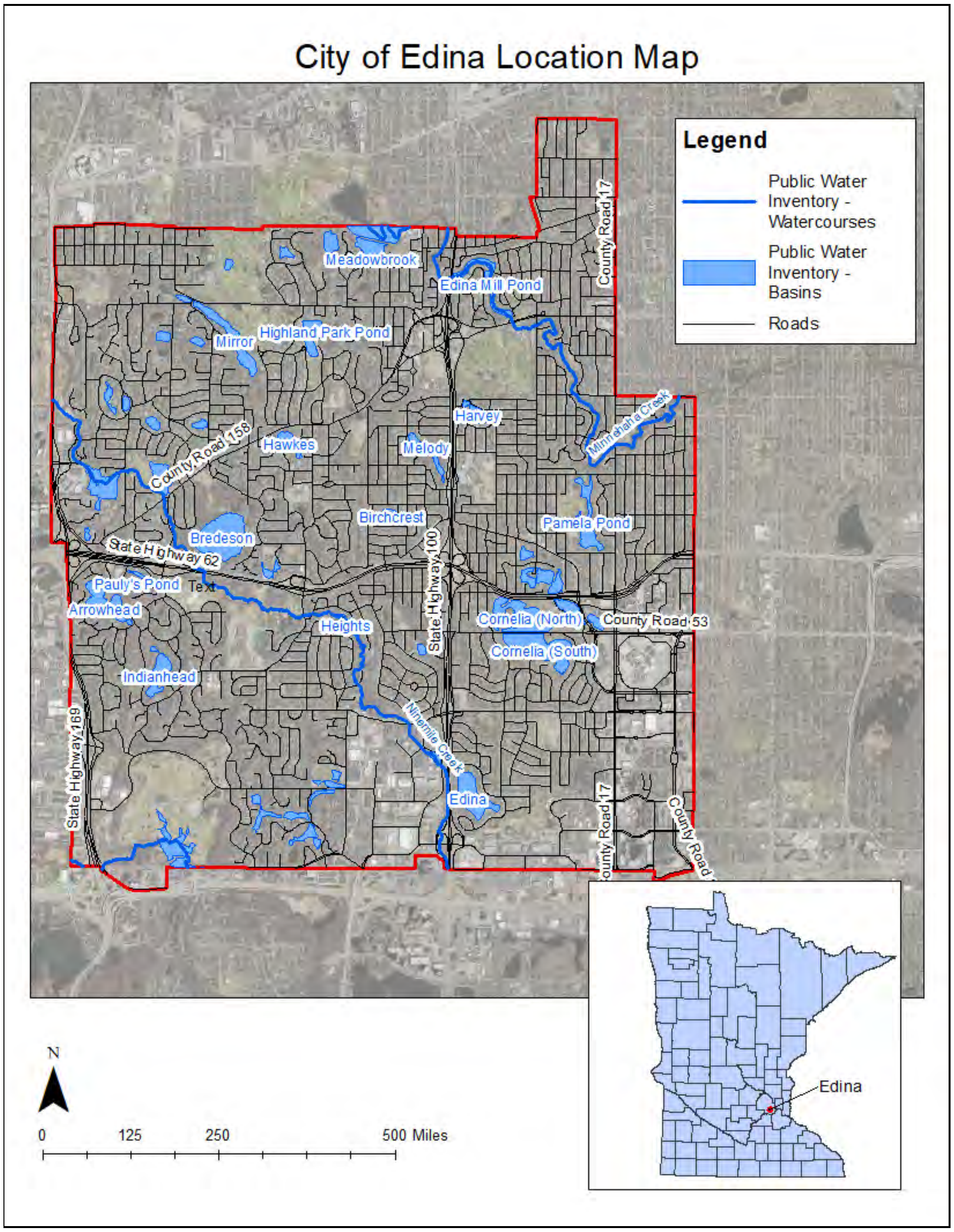


***Figure 1:*** *Overview Map of the City of Edina.*

For this project, relevant departments of the City of Edina include the departments of engineering and public works. Relevant governing plans include Edina's Comprehensive Water Resources Management Plan and the Wellhead Protection Plan. Edina falls within the Nine Mile Creek Watershed District and the Minnehaha Creek Watershed District. The other relevant governing agencies are the Minnesota Department of Health (MDH) and the Minnesota Pollution Control Agency (MPCA). The MDH is responsible for defining the Drinking Water Supply Management Areas, and the MPCA is responsible for curating the 'What's in My Neighborhood' database and issuing National Pollution Discharge Elimination System (NPDES) permits.

The population of Edina was 98.4% white in 1980 and 86.5% white in 2016 (City of Edina 2018). The median household income is $91,800, which is above regional and state values (City of

Edina 2018). These statistics are relevant to environmental justice considerations.

The land use in Edina provides some context for the level of development and feasibility of infiltration. In 2016, the top three land uses in Edina were as follows: single family detached homes (53%); park, recreational, or preserve (10%); and golf course (7%) (City of Edina 2018). Retail and other commercial is the 8$^{th}$ most common land use (3%), and industrial and utility is the 9$^{th}$ most common land use (3%) (City of Edina 2018).

### 2.2 Water in Edina

Drinking water for most residents in the City of Edina comes from groundwater. The city has eighteen total wells, nine of which are pumped year-round. Of the eighteen wells, fifteen are vulnerable to pollution from the surface (MN Department of Health 2022). The well water is treated at one of four treatment facilities in the city. The city also has a second system called Morningside which provides water to a small portion of Edina. The Morningside water is Mississippi River water that is treated at a water treatment facility located in Minneapolis. Edina maintains the distribution system for Morningside water, not the facility itself (City of Edina n.d.).

The City of Edina takes a 'One Water' approach to its water resources, including drinking water, stormwater and sanitary sewer systems. The Water Research Foundation states, "One Water is an integrated planning and implementation approach to managing finite water resources for long-term resilience and reliability, meeting both community and ecosystem needs." This manifests in a variety of water conservation efforts, as well as emphasizing crossover in treatment ideas and personnel between the separate water streams.

The reliance on groundwater provides motivation for viewing infiltration through a 'One Water' lens. To protect groundwater supplies, the City needs infiltration practices to be safe. It is important to recognize that management of stormwater has direct implications for drinking water resources. Mobilization of a pollutant into the drinking water supply could be catastrophic and would likely be expensive. In addition to groundwater quality, infiltration practices affect surface water quality by their contribution to stormwater management. Applications like rain gardens with underdrains treat stormwater by removing suspended solids before discharge to storm sewers, which are often routed to surface waters. Quantity of water is also impacted by some infiltration-based SCMs. Infiltration basins can help manage stormwater volumes by detaining runoff and thereby reduce potential floods that may occur. Infiltration can also filter out particulate matter suspended in stormwater, improving the quality of water that eventually gets discharged into surface water resources. Understanding the context for other water resources and investigating interactions between different types of water management can lead to more sustainable and overall superior outcomes.

### 2.3 Preliminary Infiltration Rating

A 2021 paper by Tecca et al. provides a method engineers can use to identify sites where infiltration-based SCMs are likely to be successful. The method uses datasets for hydraulic conductivity ($K_{sat}$), depth to water table (DTWT), and relative elevation. The paper proposes a fuzzy logic model which gives different weights to the infiltration influencing characteristics. For instance, a $K_{sat}$ value greater than 45mm/hr has a weight of 0.95 while a $K_{sat}$ value between 5 and 15 mm/hr has a weight of 0.35. The weights from DTWT, relative elevation, slope, and $K_{sat}$ are all multiplied together to give the final output value, which is then classified into one of four infiltration ratings. When implemented in a geographic information system (GIS), the model outputs a raster that can be displayed on a map. The raster displays the viability of a given area for infiltration-based SCMs on a rating scale from ‘poor’ to ‘excellent.’ This is the preliminary infiltration rating (PIR) model, and can be used to screen sites early in the design process to increase the likelihood that an SCM will remain effective for its intended life span.

### 2.4 Motivation for Exclusion Criteria

The PIR model alone accounts only for hydrogeologic information when determining viability for infiltration-based SCM placement. SCM placement must adhere to local legal and environmental regulations and best practices. To adhere to the variety of statutes and best practices, a list of ‘exclusion criteria’, which stipulate where infiltration is either prohibited or would require a higher level of engineering review, needs to be compiled. For example, the PIR does not show the human land use of any given area; while water from a residential roof would most likely be acceptable to infiltrate via a rain garden, runoff from a vehicle maintenance facility would pose a significant threat to the quality of the groundwater. Tecca et al. suggest that environmentally-sensitive areas within the region of interest can be superimposed onto the model in order to further optimize SCM placement. This is necessary because characteristics that give a location a positive rating according to the PIR may become detrimental when considering outside factors. For example, while a given location may be rated as excellent by the PIR due to the soil’s high infiltration capacity, that same characteristic would become detrimental if there were a pollutant in that soil layer that would become mobilized by stormwater infiltration. Such environmental concerns are sometimes folded into regulations set by local governing bodies or by broader authorities, and those regulatory documents, as well as emerging industry understanding and engineering judgment, must be consulted.

Some relevant factors when considering stormwater infiltration siting may not be formally regulated. Rain gardens and infiltration basins may seem like relatively harmless or even beneficial infrastructure, especially when compared to other environmental engineering structures such as waste management facilities. However, their placement can potentially pose issues to the communities in which they are placed, beyond legal or environmental concerns. These concerns must also be taken into account when compiling exclusion criteria for the placement of infiltration-based SCMs.

## 3. Methods

### 3.1 Implementation of PIR Model

The Preliminary Infiltration Rating (PIR) model was used to understand where infiltration would potentially be technically feasible in the City of Edina. The PIR model was described by Tecca et al. in their published research paper and report for MnDOT (Tecca et al. 2021a; b).

The first step of implementing the Tecca et al. procedure was to gather and process the data. The PIR model uses the following datasets: $K_{sat}$ and DTWT data derived using the USDA’s web soil survey (WSS) and elevation and slope data derived from a Digital Elevation Model (DEM) downloaded from the MnTOPO website. The Tecca et al. procedure was followed without modifications for the DEM derived data. For the WSS data, however, the Tecca et al. procedure had to be modified. Tecca et al. used a plugin for ArcMap called ‘Soil Data Viewer’ to find values for $K_{sat}$ and DTWT. There were large gaps in the $K_{sat}$ data collected using the method described, so additional data collection was necessary. Utilizing other data in the Web Soil Survey, $K_{sat}$ values were calculated from the most restrictive soil layer, and soil cores from the City of Edina were used to determine $K_{sat}$ values for locales where no conductivity data was recorded in the WSS. Appendix 1 includes more information about the $K_{sat}$ methodology. There were also gaps in the DTWT data. In this instance, the WSS data was not used at all. Instead, local data from the Nine Mile Creek Watershed District (NMCWD) was used for roughly three-quarters of the city area. In areas where the NMCWD was not available, data from the Minnesota Department of Natural Resources was used. The methodology for developing the final DTWT layer is described in more detail in Appendix 2.

The next step in implementing the PIR model is to actually calculate the PIR. Nicholas Tecca developed an ArcGIS toolbox that calculates the PIR using a model built in ModelBuilder. This toolbox was provided directly from Tecca via communication facilitated by Sarah Tschida of the Resilient Communities Project. The toolbox allows users to implement the same processing steps as Tecca et al. The toolbox required modifications in order to get it to work for the data used in this project. The modifications to the toolbox related to the input data and general file structures and did not change the actual calculations used for the PIR model. A description of the modifications is included in Appendix 3. The modified toolbox was used to produce a PIR map for the City of Edina. In-depth details on the entire process used to run the PIR are included in Appendix 4.

### 3.2 Development of Exclusion Criteria

Beyond the exclusion of various locations based on hydrogeological characteristics in the PIR model, it is necessary to rule out areas that fall within a wider net of limitations. Major categories of exclusion criteria are split up by source, including the Minnesota Stormwater Manual/National Pollution Discharge Elimination System (NPDES) permits, The Comprehensive Water Resource Management Plan and Wellhead Protection Plan from the City of Edina, and the 'What's in My Neighborhood' (WIMN) database. The full list of exclusions are included in Appendix 5.

#### *3.2.1 Minnesota Stormwater Manual/National Pollution Discharge Elimination System (NPDES) Permits*

The Minnesota Stormwater Manual was developed with the goal to "be used as a single source to guide stormwater managers through the maze of regulations, Best Management Practices (BMPs) designs, models/techniques and terminology that constitute good stormwater management" (MPCA 2017). The document compiles information from programs such as the NPDES (National Pollutant Discharge Elimination System) Phase I and II program, the TMDL (Total Maximum Daily Load) program, and runoff control programs at local and watershed levels. An NPDES General Stormwater Permit for Construction is required for the MPCA and the U.S. EPA to approve the infiltration of stormwater from construction-related activities. Such activities include landscaping clearing and soil excavation, both of which are involved in the construction of infiltration practices. Part of the Stormwater Manual describes conditions under which infiltration is not authorized under a construction stormwater permit. Those conditions would therefore prohibit the construction of infiltration-based SCMs in those areas. The exact prohibitions from Section 16 of the Construction Stormwater Permit are summarized in Appendix 5.

*3.2.2 Comprehensive Water Resources Management Plan*

When placing infiltration-based stormwater control measures, one must be aware of any specific regulations that may apply to the watershed districts in the area of interest. Edina falls within the boundaries of two watersheds: the Nine Mile Creek watershed and the Minnehaha Creek watershed. The City of Edina's 2018 Comprehensive Water Resources Management Plan (CWRMP) was developed to address the city's current and future stormwater issues, particularly those related to what is now ongoing redevelopment. The plan incorporates guidelines and regulations from both watershed districts. The plan states that the City of Edina aims to achieve "no net loss of wetlands, including acreage, function, and values" (City of Edina 2018). Placement of SCMs is prohibited within wetlands, as infiltration practices cannot physically be placed in bodies of water. It is acceptable to place an SCM within a wetland buffer zone so long as its placement adheres to all other exclusion criteria. The Groundwater section of the CWRMP states that the City will implement groundwater quality and quantity protection measures according to the City's Wellhead Protection Plan (WHPP).

*3.2.3 Wellhead Protection Plan*

The City of Edina's Wellhead Protection Plan (WHPP) contains a vulnerability analysis of each of the City's drinking water supply wells to potential sources of contamination. The WHPP delineates Edina's Wellhead Protection Areas (WHPA), Emergency Response Areas (ERA), and Drinking Water Supply Management Area (DWSMA). The DWSMA is relevant to several infiltration regulations denoted in the Minnesota Stormwater Manual and other exclusion criteria sources.

*3.2.4 'What's In My Neighborhood' Database*

The Minnesota Pollution Control Agency was founded in 1967 with the ultimate goal of protecting the environment through "ensuring that every Minnesotan has healthy air, sustainable lands, clean water, and a better climate" (MPCA 2009). In support of that effort they developed a tool that takes statewide records of pollution sources and translates them into a geospatial database that is free and widely available. Infiltration can, when not built properly, contribute to the spreading of pollutants in the groundwater. For example, an infiltration SCM located directly upstream or on top of a hazardous water site could mobilize pollutants. The 'What's in My Neighborhood' database lists all of these potential contaminant sources as pinpoints on a map. Buffer distances for infiltration SCMs around these sources do not currently exist. To provide a safe minimum distance from each potential contaminant source, the Minnesota Department of Health's Isolation Distances From a Water-Supply Well was used as a proxy (MN Department of Health 2008). While this source strictly deals with water-supply wells, it was assumed that these values are conservative when applied to infiltration basins as the consequences for contaminating drinking water wells are much more severe and are thus better protected in legislation. The WIMN database provides locations for historical sources as well as currently active sites. In the case a pollutant site was marked as 'inactive', the exclusion radius value was typically halved. However, several cases were context dependent, in which case experts like Jessica Wilson and Derek Asche were consulted (the Water Resource Managers for the cities of Edina and Maple Grove respectively). The exclusion criteria pulled from this source are listed in Table 1, and full definitions are available in Appendix 5 along with a brief explanation of exclusion radius rationale.

**Table 1: Brief Summary of WIMN** Impactful Categories**

| Category | Exclusion Radius *[ft]* | Number of Active Locations | Number of Inactive Locations |
|---|---|---|---|
| Brownfields | 100 | 95 | 8 |
| Petroleum Remediation, Leak Site | 150 | 153 | 35 |
| Solid Waste, Permitted Solid Waste Facility, Utilization Projects | 150 | 2 | 0 |
| SSTS (septic tank), Licensed Organization | 50 | 3 | 0 |
| Underground Tanks | 150 | 147 | 80 |
| Superfund, Superfund Program Non-listed Sites | 150 | 3 | 0 |
| CERCLIS Site | 150 | 5 | 0 |
| RCRA Remediation | 150 | 3 | 0 |
| Emergency Response | 0 | 2 | 0 |
| Industrial Stormwater | 0 | 12 | 11 |
| Wastewater, Industrial NPDES/SDS Permit | 0 | 3 | 4 |

***Data downloaded April 8th, 2022*

Many WIMN categories that could be found within the City of Edina were not deemed worthy of inclusion. Several were labeled 'No Impact' as they either would have no impact on infiltration or, it is assumed, are regulated by other processes or programs. These categories are listed below:

1. Aboveground Tanks
2. Air Quality
3. Construction Stormwater
4. Hazardous Waste
5. Hazardous Waste, Large quantity generator
6. Hazardous Waste, Minimal quantity generator
7. Hazardous Waste, One time generator
8. Hazardous Waste, Small quantity generator
9. Hazardous Waste, Very small quantity generator
10. MS4
11. Site Assessment

The geolocation, or where the point data appears geographically on the map, for the WIMN data is imperfect. The WIMN database uses a variety of methods to geolocate potentially polluting activities, including matching address locations, location by coordinates, internal MPCA database location, and public land survey matching. Depending on the geolocating method, the accuracy of geolocation varies. For instance, the point representing a potentially polluting activity geolocated using address matching may be geolocated to a parcel, but not the location within the parcel. Additionally, some error was introduced when converting between coordinate systems. The combination of these effects means that a displayed buffer zone may be mislocated by as much as twice the buffer width. To account for this error, if a potential infiltration site is near an exclusion buffer, a review of the true spatial location of the potentially polluting activity should be conducted. To see the exclusion criteria dataset visualized, please refer to Figure 3 in the Results section of this report.

### 3.3 Implementing Exclusion Criteria in GIS

The exclusion criteria rules are listed in Appendix 5. GIS operations were used to make layers corresponding to the exclusion criteria. Details about the GIS operations are included in Appendix Four. The GIS processes aimed to create separate layers for each EC rule that showed where infiltration would not be recommended.

The exclusion layers were organized into a folder that was shared with the City of Edina. In ArcMap, the visibility of these layers can be turned 'on' and 'off' in order to see how they overlap with each other and also the PIR. Looking at these layers individually or in combination with each other revealed regions where infiltration was not recommended by the exclusion criteria. Maintaining separate layers for each exclusion criteria rule allows for buffers to be individually revised as new guidance becomes available.

### 3.4 Environmental Justice

#### *3.4.1 Definition of Environmental Justice*

The most crucial aspect to consider when siting SCMs is the social aspect. Environmental justice (EJ), as defined by the EPA's Office of Environmental Justice, is "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (US EPA n.d.). For this project, EJ primarily pertains to the siting of the SCMs.

#### *3.4.2 Meaningful Involvement*

Stormwater infiltration practices can be viewed positively or negatively by a community. Stormwater control measures in the forms of rain gardens or infiltration basins provide many potential environmental benefits for the areas in which they are placed, including the recharging of underground drinking water sources, protection of those sources from potential pollutants, flood mitigation, and habitat for local wildlife. Rain gardens in particular also offer aesthetic benefits and are ways in which to re-introduce native flora to urbanized areas. However, there are also potential downsides to consider. When placed improperly, infiltration-based SCMs can fail well before their intended lifespan. This often means they become unable to infiltrate runoff in a timely manner, leading to stagnant water accumulation which can provide an environment for pests such as mosquitoes to breed, a potential for unpleasant odor, and may displace community gathering places (CTC & Associates LLC 2018; New Jersey Department of Environmental Protection 2004). SCMs also often require alterations to the terrain during construction and maintenance throughout their service life.

Because SCMs can be a benefit or a burden, an important first step in SCM siting is community engagement. Community engagement can be used to determine the local opinion of SCMs. SCMs should only be placed in areas where they are viewed positively. If communities have had negative experiences with SCMs in the past, then steps should be taken to try to prevent similar experiences in the future.

*3.4.3 Fair Treatment*

A critical component of EJ is that no subset of the population, whether defined by a common race, class, religion, or the like, should have either disproportionate access to environmental benefits or exposure to environmental burdens. In order to further explore this concept, this project utilized a recently published dataset by the Metropolitan (MET) Council entitled “Equity Considerations for Place-Based Advocacy and Decisions in the Twin Cities Region” (Metropolitan Council n.d.). This dataset folds in 704 census tracts to explore environmental justice as a broader concept, beyond simple economics or demographics. To see relevant components of the dataset displayed individually over the City of Edina, please refer to Figures A3 through A6 in Appendix 6.

While the MET Council dataset is much more inclusive and extensive than previous efforts, it also comes with several limitations. Chiefly, no individual is perfectly represented by larger trends. Each person has a unique set of circumstances and simply because they may live in an area with a higher median household income, for example, does not necessarily inform one of their actual income status. This dataset can and should be used to make broader, planning-level decisions and can help better inform those behind the scenes, but it is not an adequate substitute for personal knowledge of an area and the community’s input on the matter. Like most elements of this project, once a preliminary site is selected, that site’s suitability for infiltration should be followed with a more thorough exploration of that specific location's impact.

# 4. Results

## 4.1 Final Maps

Figure 2 shows the PIR map for Edina. Figure 3 is a map of the EC data for Edina.

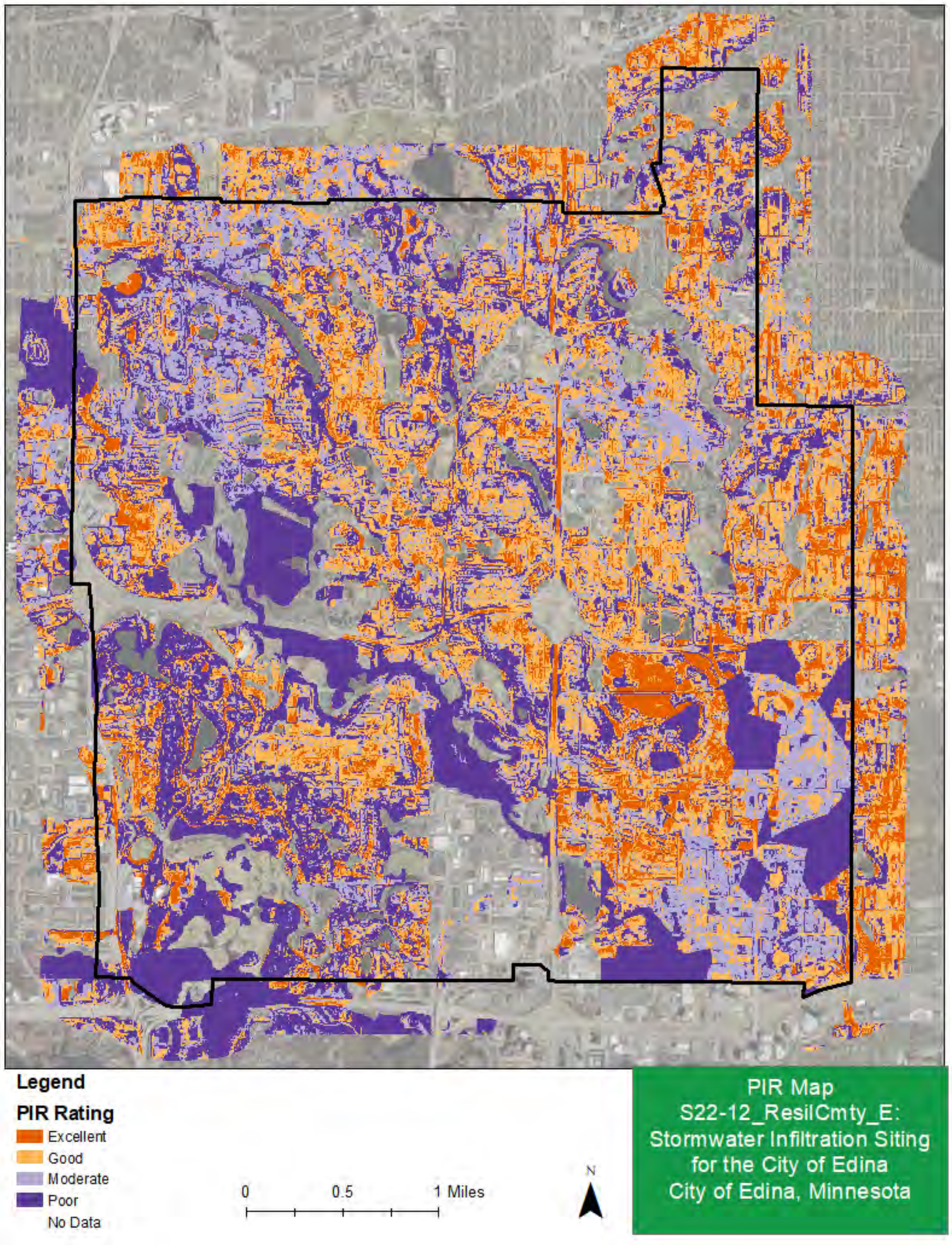


***Figure 2:*** *PIR Map for the City of Edina.*

The PIR covers 77.4% of the area of Edina, with the remaining parts of Edina having insufficient data to calculate an infiltration rating. There is a 'good' or 'excellent' rating for infiltration in 41.7% of the areas covered by the PIR. One trend of note shows a near diagonal line running from the northwest to the southeast in which most areas with data have ‘good’ or ‘excellent’ infiltration ratings. There is also a large portion of the northeast quadrant of the city that seems to have more areas rated ‘high’ or better. There are also large regions of ‘poor’ infiltration over standing water bodies.

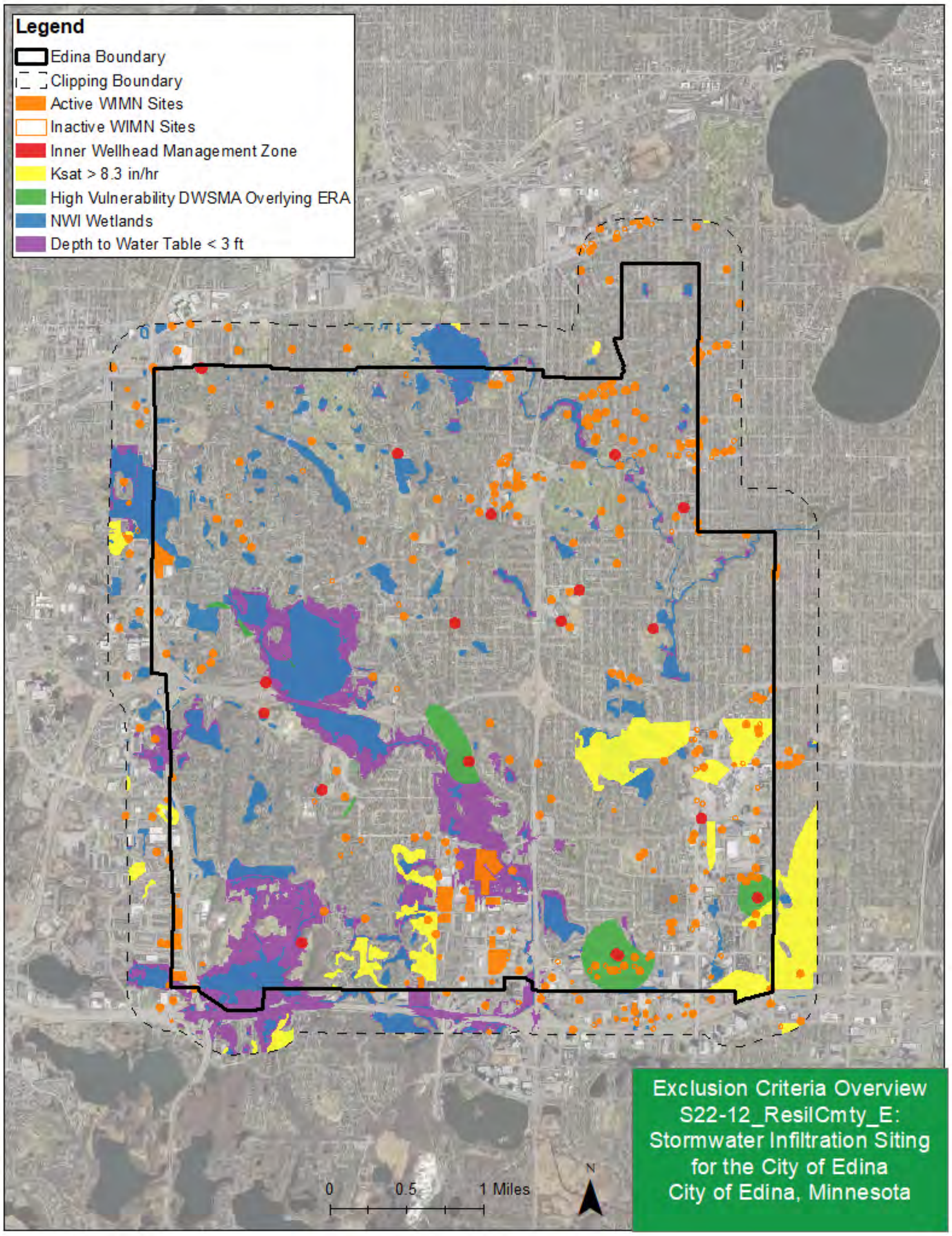


***Figure 3:*** *Exclusion Criteria Dataset Displayed Over the City of Edina. (Note that this map only includes a subset of the EC data.)*

Figure 3 showcases nearly all of the exclusion criteria that are encompassed by the City of Edina. Some areas designated as needing higher engineering review have been excluded to improve readability. Regarding infiltration feasibility, broadly speaking, there is a diagonal section between the SE-NW corners of the city that has relatively few exclusion zones. The NE corner has the highest concentration of WIMN sites, so the recommendation is that any infiltration measures placed there undergo additional higher engineering review to ensure no downstream contaminants are mobilized. 'Higher engineering review' simply means that any decision on infiltration feasibility for a specific site cannot be determined by this tool, but rather a qualified engineer should make a judgment based on other factors. Wetland and surface water make up a significant amount of the SW portion of the city, which makes placement in those neighborhoods difficult.

### 4.2 Suggested Use

The suggested use for the interactive mapping tool developed as a result of this project is as a city-wide planning stage resource to site infiltration control measures. This tool is not intended to be used as the sole factor in site selection, but rather as one element of the decision making process. Once a preliminary location has been selected, a more thorough individual-scale inspection should take place that explores the more granular aspects of stormwater infiltration design.

The PIR portion of the tool works best at coarse resolutions, and the smallest scale at which the tool can be applicable is likely neighborhoods rather than individual land parcels. Special attention should be paid to the quality of the data used to generate the PIR when interpreting the results. The input data determines the resolution of the results, and unless a municipality has very granular soils data, the soils data from the USGS is the resolution limiting data source. When viewing data on the interactive USGS website, a warning appears stating that the soil data for Edina was mapped using a scale of 1:12,000. This makes the tool most useful at a planning level, where identifying areas ill-suited to infiltration can prevent unnecessary expenditure on site specific soil testing that will likely be fruitless.

There is one exception to the neighborhood level use case for the PIR map. When a neighborhood is identified as primarily good/excellent capacity for infiltration, the cells marked 'excellent' likely have better elevation characteristics than the surrounding 'good' areas and may be more suitable for infiltration. Such siting is acceptable only when the underlying soil data spans the whole neighborhood. For the Soil Survey Geographic Database (SSURGO) data, this means the 'good' and 'excellent' classifications fall within the same polygon boundary for soil type. This makes comparisons of suitability feasible as the underlying soil type is the same, and variations in classification stem from water table, elevation or slope differences which come from data sources with finer spatial resolutions. The underlying SSURGO data is provided in the attached .zip files.

The exclusion criteria map can be used at a finer resolution once a neighborhood has been identified. Data sources for the exclusion criteria have a resolution best suited for parcel scale analysis such as the 'What's in My Neighborhood' data, which identifies parcels of land with potentially polluting activities.

The overall workflow for using these maps should start with identification of average neighborhood-level infiltration suitability. Next, the exclusion criteria map should be consulted to determine if there are any causes for concern within the neighborhood. If exclusion criteria exist within the selected neighborhood, the geolocation of the criteria should be verified and infiltration SCMs sited in accordance with any buffer distance requirements. Then after a potential site is confirmed to avoid exclusion zones, a site review should be conducted where infiltration suitability is confirmed based on site measurements.

In order for this model to be useful, the information passed through it must be up-to-date. Ideally, all sources would be updated as soon as new, more accurate or encompassing information is released. At a minimum, all the data should be redownloaded once a year to ensure sources are up-to-date.

### 4.3 Sustainability Considerations

When building any project, from a football stadium to a community rain garden, it is vitally important to consider sustainability throughout both the design and construction phases. All projects impact their communities, and forward-thinking project stakeholders understand the importance of promoting green building practices and pushing for harmony between people and place. Sustainability, as defined by ASCE, is working with a triple bottom-line that equally weighs people, profit, and the planet (ASCE 2021). The City of Edina has dedicated themselves to this goal, most recently with the passing of their Climate Action Plan, a living document charter that lays out a variety of environmental goals and the timeline to achieve them (Pale Blue Dot LLC 2021). While our project scope is limited to siting strategy for infiltration measures, we have several recommendations to ensure sustainability throughout the design and construction process.

#### *4.3.1 People*

Sustainability comes in many shapes and forms and is easiest to implement early in the design and planning process, but continues to be relevant all the way through construction. A contractor that uses local, unionized vendors to source all material and labor reduces carbon emissions involved in transportation, stimulates the local economy, and ensures a safe and equitable work environment. During construction itself, being receptive to the comfort and safety of the community by minimizing heavy machinery, offsetting work hours to avoid major disruptions to residents, and implementing an active feedback loop for incremental improvements endears a project to a community.

#### *4.3.2 Profit*

Furthermore, by developing a strategy to site SCMs on soil that is suitable for infiltration, this project contributes to sustainability by potentially increasing the success rate of SCMs. Using this tool, municipalities should be able to decrease the failure rate of stormwater control measures as it is heavily impacted by the depth to restraining layer and $K_{sat}$ values, both of which are inputs in the PIR model. Reducing the chances that an SCM will fail reduces total cost as there is an increased chance an SCM will make it to the end of its service life without requiring extra maintenance or needing to be completely reconstructed.

#### *4.3.3 Planet*

Infiltration itself is sustainable as it helps to restore the natural water cycle by retaining rainfall and letting water drain directly into the local subsurface rather than be carried away by other stormwater control systems. It is also recommended that planting native species that require little upkeep is both prudent and sustainable. Excellent siting strategies will also impact the planet bottom line by reducing the disruptions to the environment caused by reconstruction of failed stormwater control measures.

## 4.4 Next Steps

While this project may have reached its conclusion, there are several possible next steps to take. The scope of this project was mainly to translate the Tecca et al. methodology into a map-based resource for the City of Edina. While some discussion and thought went into how these ideas and methodology could be scaled, it was beyond this paper to take concrete steps in that direction. If other communities follow the methodology of this project, issues related to scaling, sharing, and society may arise as those concepts were not fully explored here.

### *4.4.1 Issues in Scale*

This project was localized to the City of Edina but its methodology and applicability are valid anywhere the relevant data can be found. Many sources used to create the PIR model and develop exclusion criteria are statewide or national databases and otherwise have local counterparts. For this project, the coarsest dataset was the WSS data, and the resolution of the PIR results is thus limited to the resolution of the WSS data. Though the resolution of WSS data varies, it is generally applicable at a scale of roughly a mile. Thus, the PIR can be used to determine approximate trends for a region, but it cannot give information on the scale of an urban parcel. On the other hand, some of the EC data has a much finer scale. As the EC layers are kept separate from each other (and also the PIR layers), in some cases the EC data can be applied for a small site. This applicability depends on the scale of the EC data source. The environmental justice (EJ) data also operates on a wider scale, but can be meaningfully broken down to about the size of a neighborhood. One future application of this work could be looking at a larger-scale map of the EJ data (something that encompasses Edina and the surrounding cities) and inspecting that for meaningful trends.

### *4.4.2 Issues in Sharing*

A possible extension of the work here could be the creation of an independent, free-to-access, widely available webpage (similar to the WIMN tool) that hosts the PIR toolbox and a description of the methodology. Under such a system, communities that seek to implement this model in the future would not have to rely on the availability of authors and rudimentary communication tools like email. The project in its entirety would be posted online for all to see. Utilizing our association with the City of Edina, this paper and the GIS toolbox will be hosted on their Water Resource Library website.

### *4.4.3 Issues in Societal Involvement*

There is also a need for more social and community engagement. This project excludes locations based on technical attributes and a limited number of environmental considerations, but has little emphasis on the wants and needs of a local community. It is likely that a location that provides excellent drainage and interacts with no controlled zones or pollutants should still not be selected because it is, for example, in a historically marginalized space and the further loss of land for development will be met with backlash. To mitigate such circumstances, local community leaders and organizations should be consulted early in the process. Some communities may even find a rain garden desirable and offer incentives for placement, while others may outline areas that would not be served by such a project. In either case, community engagement is key, and it is recommended that a community engagement plan be developed before any implementation of this model.

## 5. Conclusion

The methodology from Tecca et al. was used to create a Preliminary Infiltration Rating map for the City of Edina. GIS layers of exclusion criteria were also made. These layers factored in various regulations, guidelines, and environmental factors to further refine the decision-making process when determining suitable locations for infiltration-based stormwater control measures. The resulting toolbox and methodology have the potential for use by other municipalities in order to better manage stormwater infiltration in an increasingly urbanized world. The exclusion criteria proved to be a necessary addition to the Tecca et. al. PIR process, as it excluded many areas in Edina that the PIR rated highly for infiltration potential.

It is important to note that in order to create a PIR, there needs to be soils data that adequately covers the given area of interest. This project required a significant amount of supplementary data to be compiled through various methods, and if a future municipality would wish to implement this methodology, it is highly recommended that their soil data sets cover as much land area as is feasible. It is recommended that the final map products be used as a preliminary planning tool, and not as a substitute for a more thorough site evaluation. Due to the varying resolution of the datasets, it is recommended that the PIR map first be used on a broader scale to identify potentially suitable neighborhoods (or areas of land on that scale), and then to use the exclusion criteria map to exclude potentially problematic areas on a parcel scale. Further community outreach and environmental justice evaluations should then take place before the placement of infiltration-based SCMs.

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# Appendices

## Appendix 1: $K_{sat}$ data collection

This appendix contains descriptions of the methods by which $K_{sat}$ data was collected and the motivations for choosing one set of data over another when multiple exist.

### A1.1 Introduction

For the development of a Preliminary Infiltration Rating (PIR) model, saturated hydraulic conductivity ($K_{sat}$) values are required. Tecca et al. presents a method for extracting $K_{sat}$ values from United States Geological Survey (USGS) data using Soil Viewer, but in particularly urban areas like much of Edina this method is often insufficient. The soil viewer software is only able to automatically extract the 'representative value' for $K_{sat}$ if such a value is recorded. Fortunately, in instances where a representative value is not available, there are often other values that can act as proxies for $K_{sat}$ that do get recorded. This report identifies a set of proxy values and compares them to a set of known representative values in order to determine the best proxy to use for soils where $K_{sat}$ values are not available.

### A1.2 Data Gathering

The first potential proxy available from the USGS is the hydrologic soil group. This measure is a letter grade based system that estimates how well a soil drains, and the range of reasonable $K_{sat}$ values for such soil groups are documented in the Hydrology National Engineering Handbook (Hoeft et al. 2009). The soil group categorization for each soil was determined by accessing the USGS Web Soil Survey (WSS), selecting the area of interest, then accessing the soil map. From there, each soil map unit could be accessed along with the associated data, where the hydrologic soil group was listed under 'Interpretive Groups'. The second potential proxy is the $K_{sat}$ of the most restrictive soil layer. This soil attribute can act as a conservative proxy because infiltration will occur more rapidly until the wetting front reaches the most restrictive layer, at which point the process will be primarily governed by flow through that layer. This data could similarly be accessed through the WSS (it is listed under 'Properties and Qualities' for each soil map unit), and the data is presented as a range. This data was downloaded on the 29th of January 2022.

In regions where WSS data carried no information regarding $K_{sat}$, soil cores were collected through the City of Edina for analysis. The data was primarily composed of contractor reports which categorized soil type with depth bounds on that soil type. The region where soil cores were provided was the southeast corner of the city. This data was downloaded on February 28th, 2022.

### A1.3 Proxy Comparison

In order to compare the proxy performance, all data points were converted into micrometer/s units. Then, residuals for the proxy measures were computed for the high, mean, and low values of the proxy range using the representative values for 71 soil map units as the 'true' $K_{sat}$ values. This analysis found that the most conservative proxy was the minimum value from the restrictive layer $K_{sat}$ range. The next most consersvative proxies were the minimum value from the soil group and the mean value from the most restrictive layer.

For the soil cores, there was no data for comparison, as soil core data was only given for sections without WSS data.

### A1.4 Motivations for Final Decisions on Data

For our PIR we chose to use the mean value from the most restrictive layer because, of the three 'conservative' proxies, it had the lowest average residual and lowest average standard deviation. Additionally, when the residuals were visualized in histograms, it had the tightest grouping around zero. While the selected method had more instances of overestimation (where the residual is below zero), the overestimation was a small one.

For the soil cores, an assumption that the first foot of soil would be removed during SCM installation, and that the first five feet of soil control infiltration was made and the data was trimmed to these depths. Then each soil description contained within that depth range was assigned a $K_{sat}$ value using the median values for such soil type as determined by García-Gutiérrez et al. (García-Gutiérrez et al. 2018). The minimum value between one and five feet of depth was then assigned to the soil boring. To spatialize the data, Thiessen polygons were generated using the geolocated soil core spots, and the restrictive layer $K_{sat}$ value was assigned to the polygons.

### A1.5 Statistical Tables and Figures

**Table A1: Residual Statistics for $K_{sat}$ Values Derived from Hydrologic Soil Group and from Most Restrictive Layer Analysis**

| | Ksat from Hydrologic Soil Group | | | Ksat from Most Restrictive Layer | | |
|---|---|---|---|---|---|---|
| | min | max | mean | min | max | mean |
| Mean | 17.5 | -7.3 | 5.1 | 27.6 | 3.8 | 15.7 |
| Standard Deviation | 38.2 | 37.3 | 37.1 | 39.9 | 28.8 | 32.0 |
| Instances of a Residual less than 0 | 20.0 | 55.0 | 36.0 | 0.0 | 41.0 | 22.0 |
| Minimum Residual | -13.4 | -53.4 | -33.4 | 2.4 | -49.4 | -4.4 |

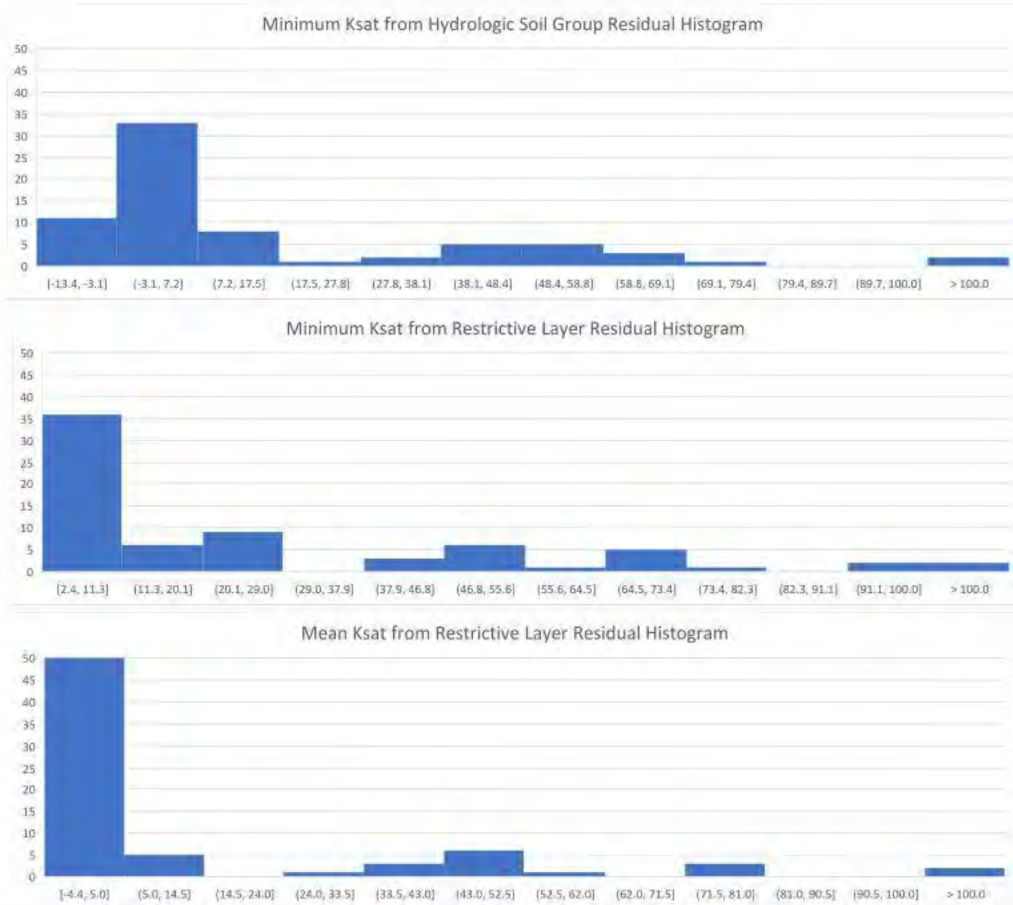


*Figure A1: Selected Histograms of Residual values.*

## Appendix 2: Depth to Water Table Supplementary Data

This appendix describes the procedure used to fill in missing depth to water table data.

The depth to water table (DTWT) was initially derived using the ArcMap 'Soil Data Viewer' plugin.When this method was used, there were many values of 201 cm. According to the 'Soil Data Viewer' user guide, this is the null value for DTWT (NRCS 2015). Because there were so many null values, alternative data for DTWT was required.

The City of Edina provided DTWT data from the Nine Mile Creek Watershed District (NMCWD). This dataset did not cover the entirety of Edina, so a dataset from the Minnesota Department of Natural Resources (MNDNR) was also used. To create the final layer used for the PIR model, the NMCWD data was used where it was available, and the MNDNR data was used when the NMCWD data was not available.

Note that this method contrasts with the method used for the $K_{sat}$ data. For the $K_{sat}$ data, the Tecca et al. procedure was used when possible, and for DTWT the Tecca et al. procedure was not used at all. This difference is due to the fact that there were alternative sources of DTWT data that were likely more accurate than the Tecca et al. procedure, whereas for $K_{sat}$ data there were not alternative sources that were necessarily more accurate.

## Appendix 3: ArcMap Toolbox Modifications

This appendix describes the modifications made to an ArcMap toolbox that runs the PIR.

Nicholas Tecca produced an ArcMap toolbox that contains a model to calculate the PIR. This toolbox was modified for this project, with the dual aims of 1) producing a PIR map for Edina and 2) creating an updated toolbox that would be easier to use.

The inputs to the model for this project were different from those used by Tecca et al. because both the $K_{sat}$ and depth to water table (DTWT) were modified to account for missing data. Several steps in the model were changed to account for these differences. The model originally converted $K_{sat}$ to mm/hr, but this step in the model was deleted because the input data was already in mm/hr. The 'Value field' for the 'Polygon to Raster' steps (for both the $K_{sat}$ data and DTWT data) was also changed in order to match the appropriate field name for the input data. The cell size in the 'Polygon to Raster' and 'Resample' steps was decreased. This change was necessary because the coordinate system of the data for this project was different from the coordinate system that Tecca et al. used. Steps were added so that areas with no $K_{sat}$ data would be labeled as 'No Data' in the output PIR map. All of these changes were specific to the data used for this project. Future users of the toolbox may need to make similar changes in order to modify the toolbox for their unique datasets.

The toolbox was also modified so that it would be easier to use. The toolbox was changed so that it used relative file paths instead of absolute paths. This modification makes it easier to share the toolbox between different computers. The model was also modified so that the output layer would be a polygon labeled with the infiltration rating instead of a numerical value.

## Appendix 4: GIS Methodology

The GIS work for this project was split into the following steps: 1) pre-process data for the PIR model, 2) implement the PIR model, 3) process data for the EC model. A detailed description of each step is listed below. The work here is based on the procedure developed by Tecca et al. (Tecca et al. 2021a; b). When possible, the PIR procedure is written in a general manner so that it could be applied to different municipalities or datasets. The procedure for the EC data is more specific to the City of Edina because the ECs are generally specific to the city. If a jurisdiction chooses to use similar exclusion criteria or the same datasets, then the procedures listed will apply.

1. Pre-process data for the PIR model
    a. Study region
        i. Create a polygon for the region of interest ('study_region').
        ii. Generate a buffer around the 'study_region.' This new polygon will be referred to as 'buffered_study_region.' This step is done because some of the EC rules could pertain to sites outside of the Edina boundary. For this project, a 1500 foot buffer was typically used.
    b. Soils data
        i. Navigate to the Web Soil Survey (WSS) and select the area of interest
        ii. Download, unzip and import the data into ArcMap
        iii. Open the Soil Data Viewer plugin and select the imported data
        iv. For $K_{sat}$ data use aggregation method 'Dominant Component' and layer option 'all layers'
        v. For 'depth to water table' (DTWT) use the aggregation method 'Dominant Component', 'Lowest' for tie-breaker, and 'January' and 'December' as the beginning and ending month.
        vi. Project and save the $K_{sat}$ and DTWT polygons to desired coordinate system (suggested coordinate system: WGS 1984)
        vii. In some cases (such as for this project) the $K_{sat}$ and DTWT data has missing data within the study area. Various procedures can be used to fill in the gaps in the data. See Appendices 2 and 4 for the methodology used for this project.
        viii. Prior to using the PIR model, ensure that both the $K_{sat}$ and DTWT data are stored as shapefiles. The units of $K_{sat}$ should be in mm/hr and the units of DTWT should be in cm. Note that the PIR toolbox will interpret all values of $K_{sat}$ = 0 mm/hr to be 'No Data'
    c. DEM data
        i. Download the 3-meter DEM data from the MnTOPO website.
        ii. Clip the DEM data to 'buffered_study_region.'
        iii. Project the DEM data to the same coordinate system as the soils data.
        iv. Export the DEM data as a .tif file
2. Implement the PIR model
    a. Download the modified PIR toolbox (see Appendix 3 for details on toolbox modifications) from the Edina Water Resources Library. The toolbox will have a .tbx extension.

b. Open up a map in ArcMap. Make a new folder in the map. Place the toolbox in this folder.
c. Create a file geodatabase within the folder labeled ‘PIR_Data.gdb’.
d. Add the DEM data (.tif file), Ksat data (.shp file), and water table data (.shp file) to the folder with the toolbox. The required file structure is shown below in Figure A2.

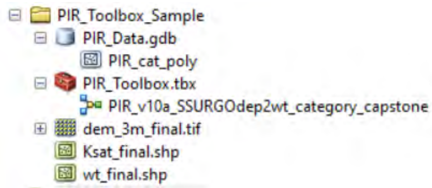


***Figure A2:*** *Sample File Structure for the Folder with the PIR Toolbox.*

e. Modify the toolbox so that it works with the input data. To modify the toolbox, right click on the model and say ‘Edit.’ Note that the toolbox is currently set up to work for 3 specific shapefiles for the City of Edina (see shapefiles in Figure A2). If these 3 shapefiles remain unmodified, then this step can be skipped.
   i. There should be three blue ellipses on the left hand side of the model labeled ‘Input_Ksat_polygon,’ ‘Input_wt_polygon,’ and ‘Input_DEM_raster.’ Double click on each ellipse and select the input data for $K_{sat}$, DTWT, and DEM.
   ii. Double click on the ‘Polygon to Raster’ steps (directly after the $K_{sat}$ and DTWT inputs). Change the ‘Value field’ to correspond to the appropriate data field (e.g., the field that contains $K_{sat}$ in mm/hr).
   iii. If the data is not in WGS 1984, adjust the cell size in all ‘Polygon to Raster’ and ‘Resample’ steps. The cell size is measured in the units of the coordinate system, and the cell size should be smaller than the study area.
f. To run the toolbox, right click on the ‘PIR_v10a_SSURGOdep2wt_category_capstone’ file and select ‘Open.’ Press ‘OK.’
g. The output polygon will show up in ‘PIR_Data.gdb’. The polygon is named ‘PIR_cat_poly’, and the PIR rating is included in the ‘PIR_rat’ field.

3. Process data for the EC layers
   a. For each rule, the data was clipped using a buffer of 1500 ft from city boundary
   b. EC Rule I: ‘What’s in My Neighborhood’ (WIMN) Data
      i. Download the WIMN data: [https://gisdata.mn.gov/dataset/env-my-neighborhood](https://gisdata.mn.gov/dataset/env-my-neighborhood)
      ii. Split by Activity (Toolbox → Analysis Tools → Split)
      iii. Sort out no impact Activities
      iv. Create multiple instances for Multiple_Activities
         1. Open the attribute table, export the data. (You may have to export as .dbf, just convert to csv once exported)

2. Open the data in excel, delete all columns except objectID and activity_l
3. Use text to columns with the semicolon delimited to place the multiple activities into their own columns.
4. Rename the columns, activity_1, activity_2, …activity_n
5. Import the new .csv data and join it to the Multiple Activities Layer
6. Use copy features layer to permanently merge the .csv attributes into a feature
7. Split by each activity
8. Merge multiple instances of each activity type into one layer
9. Use Data Management Tools -> Fields -> Alter Field to ensure the merged multiple activity points have their 'active_fla' field actually written as **exactly** 'active_fla'
10. Merge the multiple activity merges with the corresponding non-multiple activity layers of the same activities.

v. Create bufferable fields for each site type
1. Create a new field in the final merged layer titled 'buffer' of type float
2. Select python as the language and check the 'Show codeblock' option
3. In Pre-logic Script Code enter **(Note: the 3.28 is to convert from ft to m, where the buffer distances are in ft and the coordinate system units are in m)**

```
def myCalc(status):
    if (status=='Y'):
return (Active site buffer distance)/3.28
        else:
return (Inactive site buffer distance)/3.28
```

4. In the 'buffer = ' field enter
   myCalc( !active_fla!)
5. Repeat for all relevant layers

vi. Identify industrial stormwater and Wastewater sites addresses in the attribute table

vii. Download the parcel data: https://gis-hennepin.hub.arcgis.com/datasets/hennepin::county-parcels/about

viii. Modify Parcel Data for identified sites
1. Added a field titled 'Concern' and for each industrial stormwater or wastewater site wrote 'Ind-SW' or 'WW' respectively.

2. Change symbology to identify visually their locations.

c. EC Rule II: Wetlands
   i. EC Rule IIA: Wetlands
      1. Download the wetland data: https://gisdata.mn.gov/dataset/water-nat-wetlands-inv-2009-2014
      2. Clip the 'statewide_NWI' layer from the NWI dataset to the 1500 ft buffer of the city boundary

d. EC Rule III: Stormwater Manual/NPDES
   i. EC Rule IIIA: Discharge from vehicle fueling and maintenance
      1. Assumed this rule was accounted for with WIMN data, so no new GIS layer was created.
   ii. EC Rule IIIB: Bedrock and Depth to Water Table
      1. Assumed groundwater was the controlling surface, so only considered DTWT table data.
      2. Copied the DTWT data used for the PIR model and made a new field called 'wt_class'.
      3. Used 'Select by Attribute' to select the data each EC rule. Then used the 'Field Calculator' to label the data in the 'wt_class' field. For example, all of the data with DTWT < 3 ft was selected and then labeled as 'Do not place in' in the 'wt_class' field.
      4. To produce the final layer, the data labeled 'Do not place in' and 'Needs higher engineering review' was exported to a shapefile.
   iii. EC Rule IIIC: Industrial Facilities
      1. Assumed none of these facilities were present based on conversations with City of Edina professionals (Jessica Wilson and Ross Bintner)
   iv. EC Rule IIID: Contaminant Mobilization
      1. Assumed this rule was accounted for with WIMN data, so no new GIS layer was created.
   v. EC Rule IIIE: Hydrologic Soil Group D
      1. Went to the Web Soil Survey website. Pressed 'Start WSS' and defined an 'Area of Interest' around Edina. Then navigated to Soil Data Explorer → Soil Properties and Qualities → Soil Qualities and Features → Hydrologic Soil Group → View Rating.

2. Confirmed that there were no Hydrologic Soil Group D soils in Edina.

vi. EC Rule IIIF: Karst

1. Assumed no karst in Edina based on conversations with City of Edina professionals (Jessica Wilson and Ross Bintner)

vii. EC Rule IIIG: DWSMAs and ERAs

1. Download the DWSMA data: https://gisdata.mn.gov/dataset/water-drinking-water-supply
2. Download the ERA data: https://gisdata.mn.gov/dataset/water-emergency-response-areas
3. Calculated the union of the DWSMA layer and ERA layer (‘DWSMA_ERA_union’)
4. Used ‘Select by Attribute’ to find the areas of ‘DWSMA_ERA_union’ that were both high vulnerability and an ERA area. Exported these areas to a new layer. Repeated for moderate vulnerability areas.
    a. Note that the DWSMA vulnerability layer included data from multiple cities. In cases of overlap, the most severe vulnerability rating was used. Also note that some of the areas of moderate vulnerability are for cities other than Edina.

viii. EC Rule IIIH: High Infiltration

1. Copied the $K_{sat}$ data for the PIR to a new layer. Used ‘Select by Attribute’ to identify areas of $K_{sat} > 8.3$ in/hr. Exported the data to a new layer.

e. EC Rule IV: Guidance from the city

i. EC Rule IVA: Wells with ERAs

1. Use the layer for the inner wellhead management zone provided by Edina

ii. EC Rule IVB: Extra DWSMA considerations

1. Downloaded the parcel data. At the time of download, the data had been last updated on 4/17/22.
2. Select the parcels with land uses that are ‘INDUSTRIAL-PREFERRED’, ‘INDUSTRIAL-NON PREFERRED’ and ‘LAND-INDUSTRIAL.’ Export the data to a new layer.

iii. EC Rule IVD: Surface Waters

1. Assume this layer is redundant and covered by Rule IIA.

## Appendix 5: Exclusion Criteria Masterlist

This appendix will encompass the whole exclusion criteria list divided up by source. Each component will have a name, basic definition, the exclusion zone, and brief rationale of that value. 'No Impact' sites were determined in conversation with Jessica Wilson. For more complete information on the WIMN sources, downloaded April 8th, 2022, please refer to the WIMN glossary on their website.

I. From 'What's In My Neighborhood'
    A. Active
        1. Brownfields, Petroleum Brownfield - **100ft**
            a) *Definition:* A brownfield is a potentially contaminated site designated by the Minnesota Pollution Control Agency (MPCA)
            b) *Rationale:* Value based on the drinking water well value for hazardous zones with safeguards
        2. Brownfields, Petroleum Brownfield and Voluntary Investigation and Cleanup - **100ft**
            a) See 'Brownfields, Petroleum Brownfield' definition and rationale
        3. Brownfields, Voluntary Investigation and Cleanup - **100ft**
            a) See 'Brownfields, Petroleum Brownfield' definition and rationale
        4. Petroleum Remediation, Leak Site - **150ft**
            a) This is a confirmed leak site of a petroleum product
            b) Value based on the drinking water well rules for a petroleum tank with no safeguards
        5. Solid Waste, Permitted Solid Waste Facility, Utilization Projects - **150ft**
            a) A solid waste facility that uses certain waste materials instead of depositing them in landfills
            b) Value determined by halving the drinking water well rules for a landfill of mixed waste
        6. SSTS, Licensed Organization - **50ft**
            a) A subsurface sewage treatment system (SSTS), or septic tank, is an underground sewage treatment system
            b) Value based on drinking water well rules for a potential contaminant that may drain into soil
        7. Underground Tanks - **150ft**
            a) Any underground tank, all are assumed to store hazardous materials unless otherwise specified
            b) Value based on the drinking water well rules for an underground hazardous substance tank with no safeguards
        8. Superfund, Superfund Program Non-listed Sites - **150ft**

        a) Superfund sites that are being processed for official listing or were voluntarily addressed before meeting contamination requirements to be listed
        b) Value based on the drinking water well rules for an underground hazardous substance tank with no safeguards
    9. CERCLIS Site - **150ft**
        a) A site listed on the Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS). These sites are suspected of being contaminated.
        b) Value based on the drinking water well rules for an underground hazardous substance tank with no safeguards
    10. RCRA Remediation - **150ft**
        a) A site designated by the Resource Conservation and Recovery Act (RCRA) as a possible hazardous waste spill
        b) Value based on the drinking water well rules for an underground hazardous substance tank with no safeguards

B. Inactive ***the active values were halved for inactive values based off input from Jessica Wilson*
    1. Brownfields, Petroleum Brownfield - **50ft**
    2. Brownfields, Petroleum Brownfield and Voluntary Investigation and Cleanup - **50ft**
    3. Brownfields, Voluntary Investigation and Cleanup - **50ft**
    4. Petroleum Remediation, Leak Site - **75ft**
    5. Solid Waste, Permitted Solid Waste Facility, Utilization Projects - **75ft**
    6. SSTS (septic tank), Licensed Organization - **25ft**
    7. Underground Tanks - **75ft**
    8. Superfund, Superfund Program Non-listed Sites **- 75ft**
    9. CERCLIS Site - **75ft**
    10. RCRA Remediation - **150ft**

C. No Impact
    1. Aboveground Tanks
        a) Any aboveground tank over a certain size.
    2. Air Quality
        a) Locations of air quality permits.
    3. Construction Stormwater
        a) Locations of construction stormwater permits.
    4. Environmental Review
        a) A review of the possible environmental ramifications of a project before construction.
    5. Hazardous Waste (HW)
        a) Sources of substances that may be corrosive, explosive, toxic, or a fire hazard.
    6. Hazardous Waste, Large quantity generator
        a) Over 2,200lbs of HW per month.

7. Hazardous Waste, Minimal quantity generator
    a) Under 100lbs HW per year.
8. Hazardous Waste, One time generator
    a) Less than 2,200lbs HW as a one-time event.
9. Hazardous Waste, Small quantity generator
    a) Between 220-2,200lb HW per month.
10. Hazardous Waste, Very small quantity generator
    a) Less than 220lbs per month.
11. MS4
    a) A Municipal Separate Storm Sewer System (MS4).
12. Site Assessment
    a) A location of a past MPCA investigation.
13. Toxics Reduction
    a) Any location that pays pollution prevention fees to the MPCA.
14. Wastewater
    a) Used water runoff from domestic/commercial/industrial use.
15. Wastewater, Municipal Collection System
    a) A city sewer system.

D. Special Considerations
1. Emergency Response - Reference point (radius value of zero)
    a) Any chemical spill that requires immediate and significant cleanup efforts
    b) Reference point designation due to the rarity and apparent low impact of events in Edina
2. Industrial Stormwater - Reference parcel (whole parcel excluded)
    a) Potential sources of contamination where stormwater runoff may come in contact with hazardous materials
    b) Reference parcel designation because non-uniform response is required. Each case is highly unique and should be dealt with using higher engineering review.
3. Wastewater, Industrial NPDES/SDS Permit - Reference parcel
    a) Industrial facilities that discharge directly into surface water
    b) Reference parcel designation because non-uniform response is required. Each case is highly unique and should be dealt with using higher engineering review.

II. From Watersheds
A. Wetlands
1. DO NOT PLACE IN
B. Wetland Buffers
1. No Impact

III. From MN Stormwater Manual/ National Pollution Discharge Elimination System (NPDES) permits
A. Infiltration prohibited in:

1. Areas that receive discharge from vehicle fueling and maintenance
    a) Assume all gas stations have underground tanks and are therefore covered by the WIMN data
2. Areas w/ less than a 3-foot separation between bottom of hypothetical infiltration system and level of seasonally saturated soils/bedrock (Dataset used: depth to water table)
    a) <3ft DO NOT PLACE IN
    b) 3-5 ft HIGHER ENGINEERING REVIEW
    c) >5ft GOOD PLACEMENT
3. Areas that receive discharge from industrial facilities that are not authorized to infiltrate industrial stormwater; need a NPDES/SDS Industrial Stormwater Permit issued by MPCA
    a) Sector A (SIC 2491) - wood preserving.
    b) Sector K - hazardous waste treatment, storage, or disposal facilities
    c) Sector M - automobile salvage yards
    d) Sector N - scrap waste materials
    e) Sector S - air transportation with deicing
        (1) None in Edina
4. Areas where high levels of soil and/or groundwater contaminants will be mobilized by infiltrating stormwater
    a) Assume these areas are accounted for by the WIMN data
5. Areas of predominantly Hydrologic Soil Group D (clay) soils
        (1) None in Edina
6. Areas within 1,000 ft up-gradient or 100 ft down-gradient of active karst features
        (1) None in Edina
7. DWSMAs (MN CSW Permit)
    a) High/very high vulnerability **and** overlying an ERA
    b) Moderate vulnerability **and** overlying an ERA **UNLESS** an MS4 higher engineering review provides a preventative treatment system
8. Soils with very high infiltration rates (greater than 8.3 in/hr; typically well-sorted, medium to coarse sands and gravels)

IV. From City
- A. Wells w/ ERAs
    1. DO NOT PLACE IN inner wellhead management zone
- B. DWSMA not overlaying ERAs - Overlaid with zoning map (see MN Stormwater Manual section for fully prohibited areas)
    1. Industrial/Otherwise Potentially Hazardous - HIGHER ENGINEERING REVIEW NECESSARY
- C. City owned property
    1. GOOD TO PLACE IN
- D. Surface waters
    1. DO NOT PLACE IN

## Appendix 6: Environmental Justice Data maps

This appendix showcases the various maps created using the MET Council Environmental Justice dataset, entitled "Equity Considerations for Place-based Advocacy and Decisions Dataset." The MET Council dataset provides census data for a wide variety of considerations. While many are relevant, a select few are displayed below in Figures A3 through A6. For full definitions and the complete dataset please refer to the MET Council's Place-based Equity Research initiative.

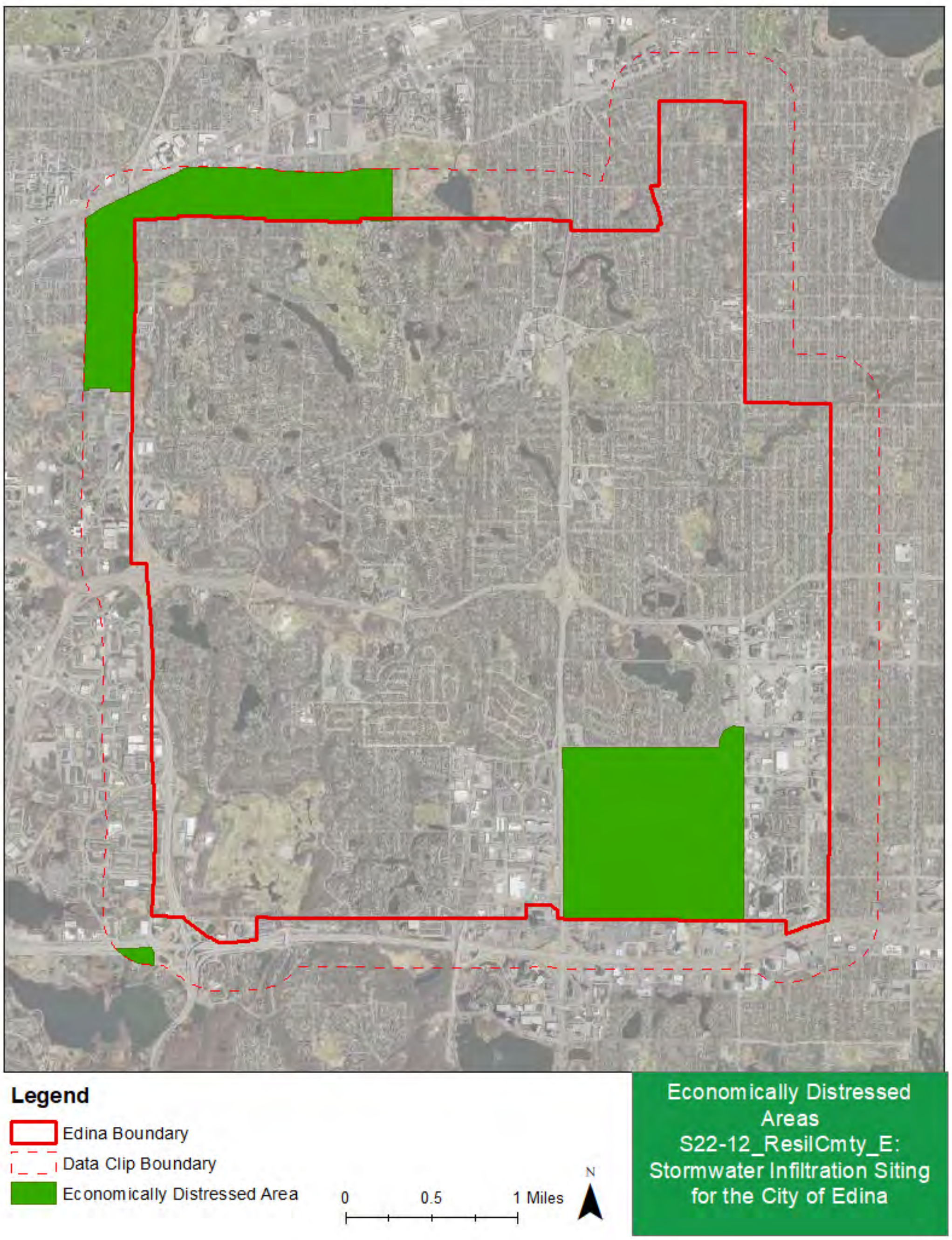


***Figure A3:*** *Economically Distressed Areas within the City of Edina.*

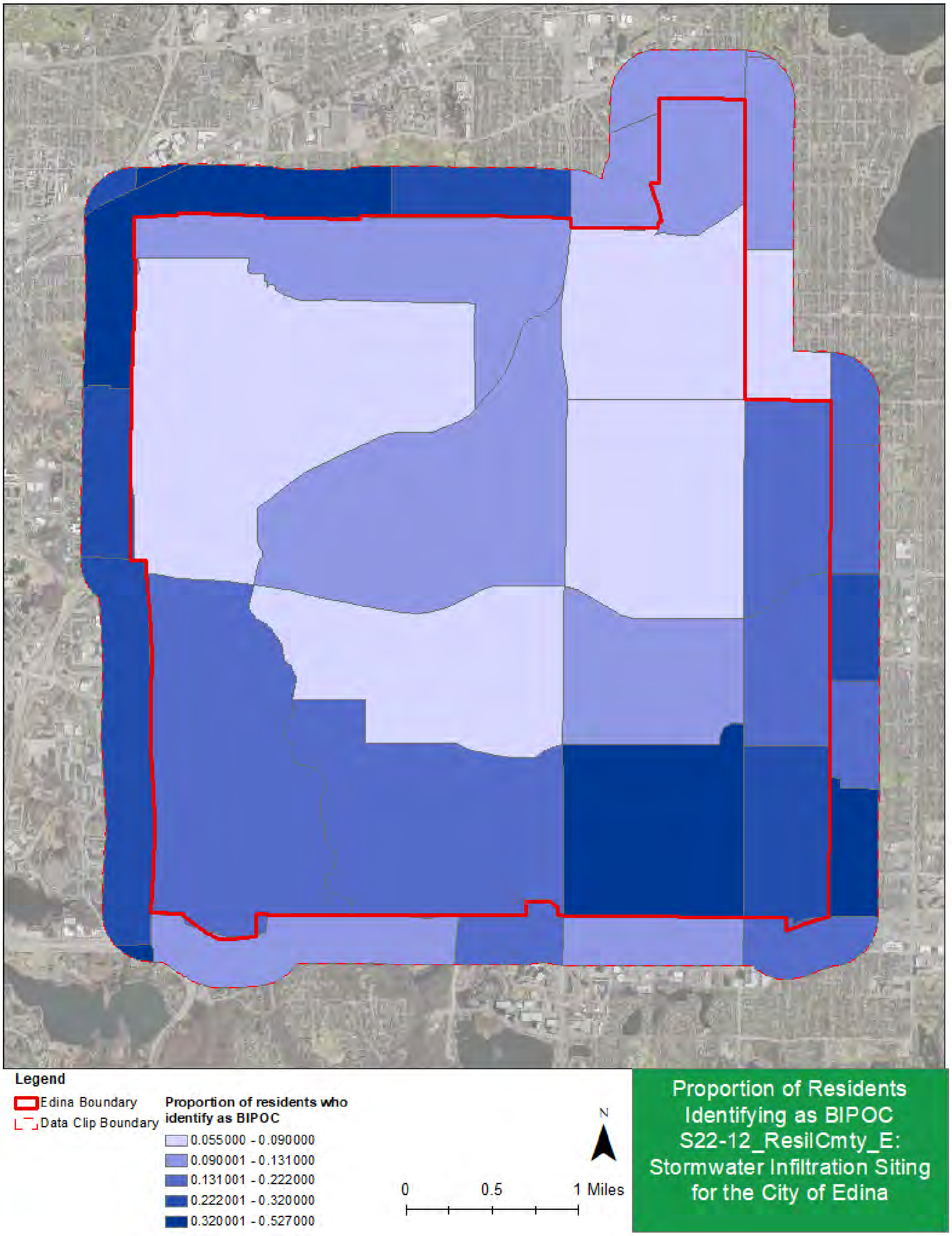


***Figure A4:*** *Proportion of Residents who Identify as BIPOC (Black, Indigenous, or Person of Color) Within the City of Edina.*

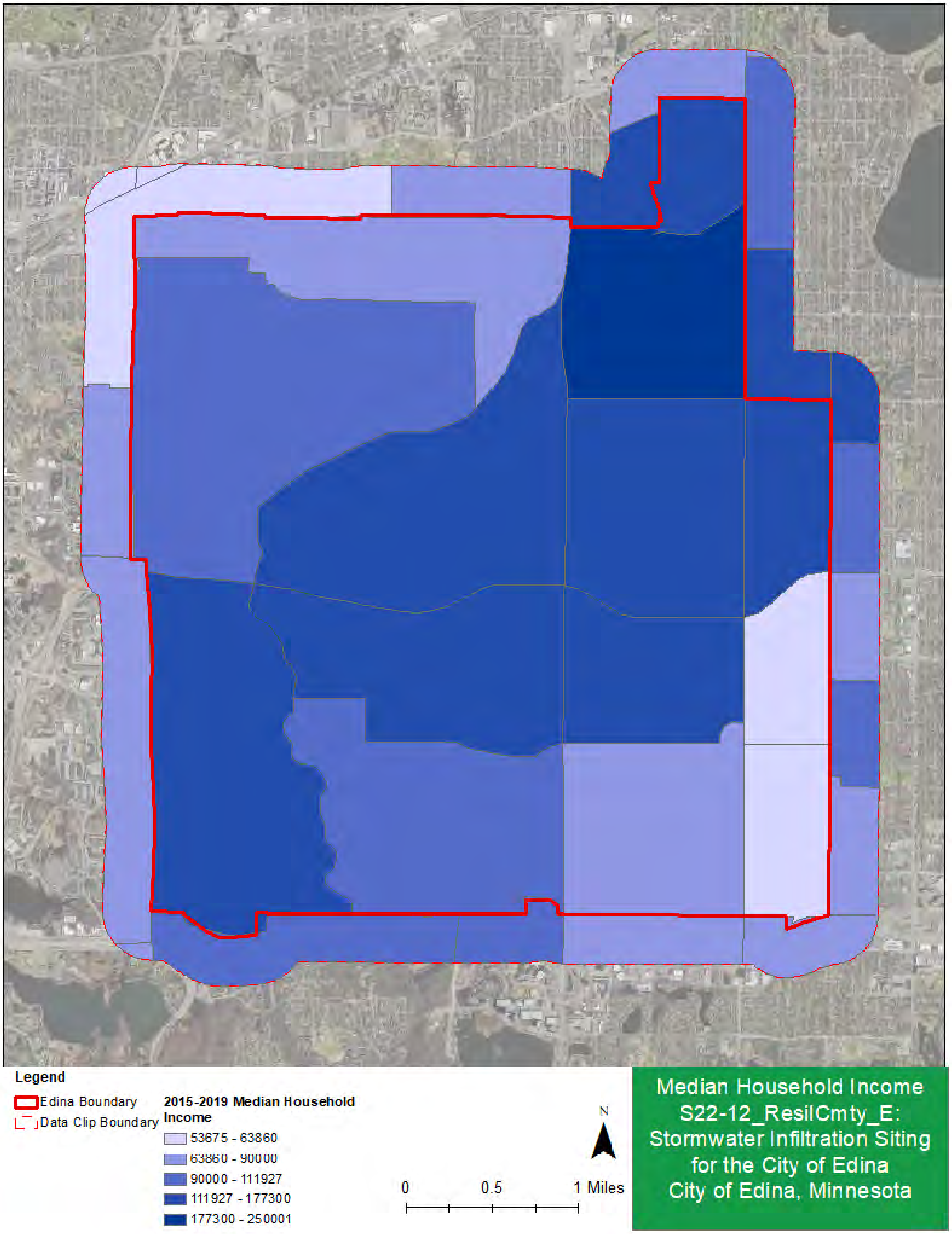


***Figure A5:*** *Median Household Income dataset within the City of Edina.*

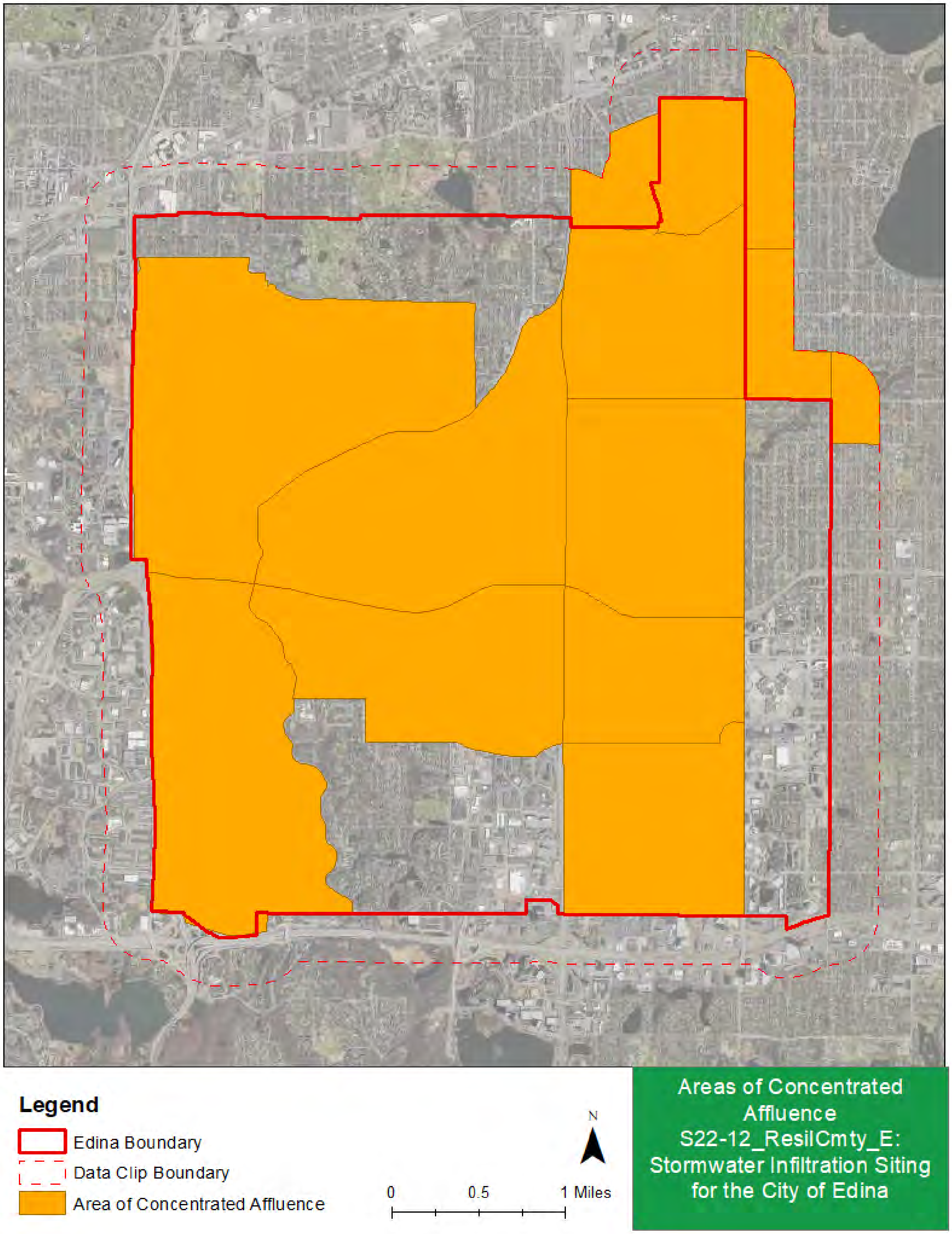


***Figure A6:*** *Areas of Concentrated Affluence within the City of Edina.*

## Appendix 7: Intermediate PIR Maps

This appendix contains intermediate maps from the GIS processing steps.

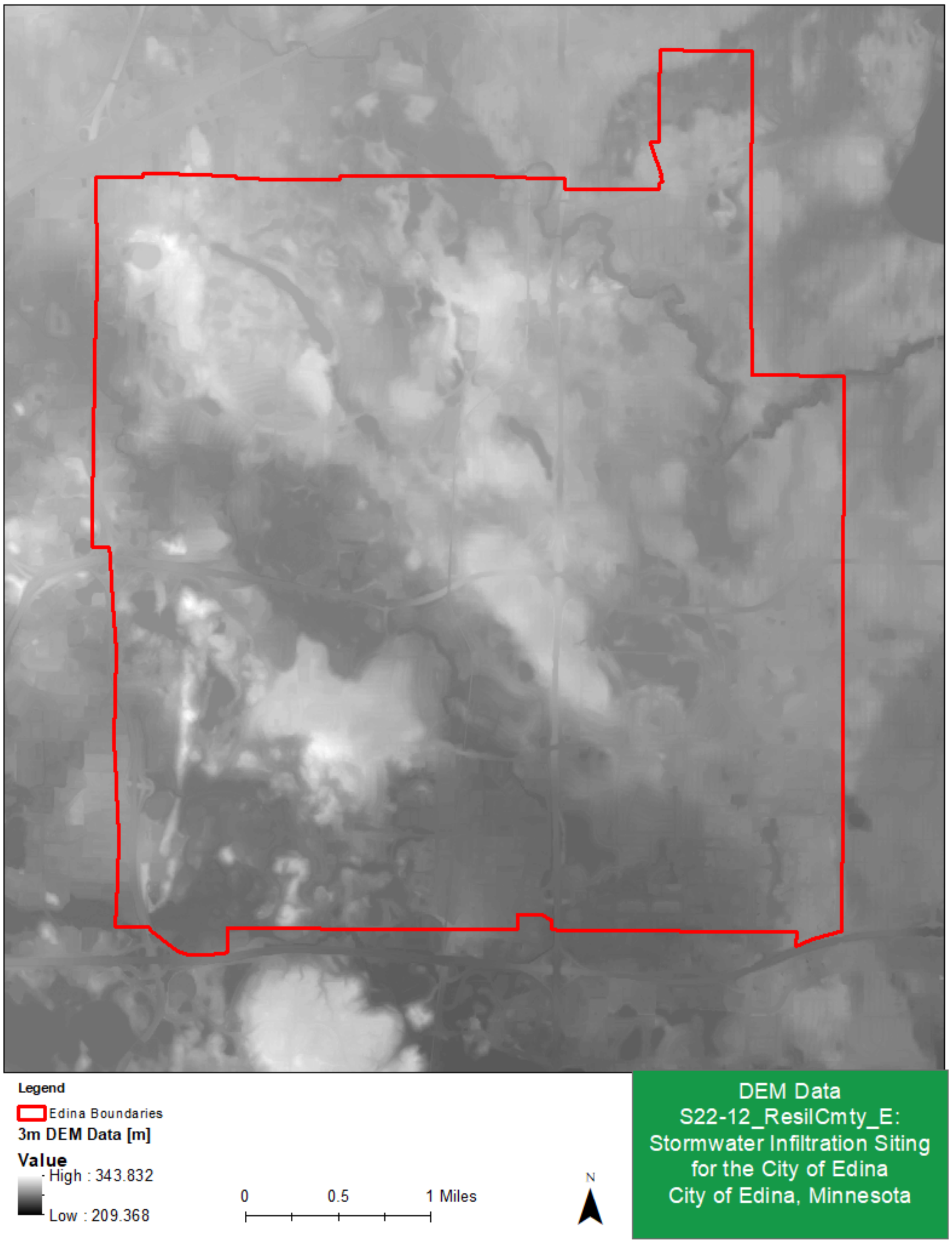


***Figure A7:*** *Digital Elevation Model for the City of Edina and surrounding region.*

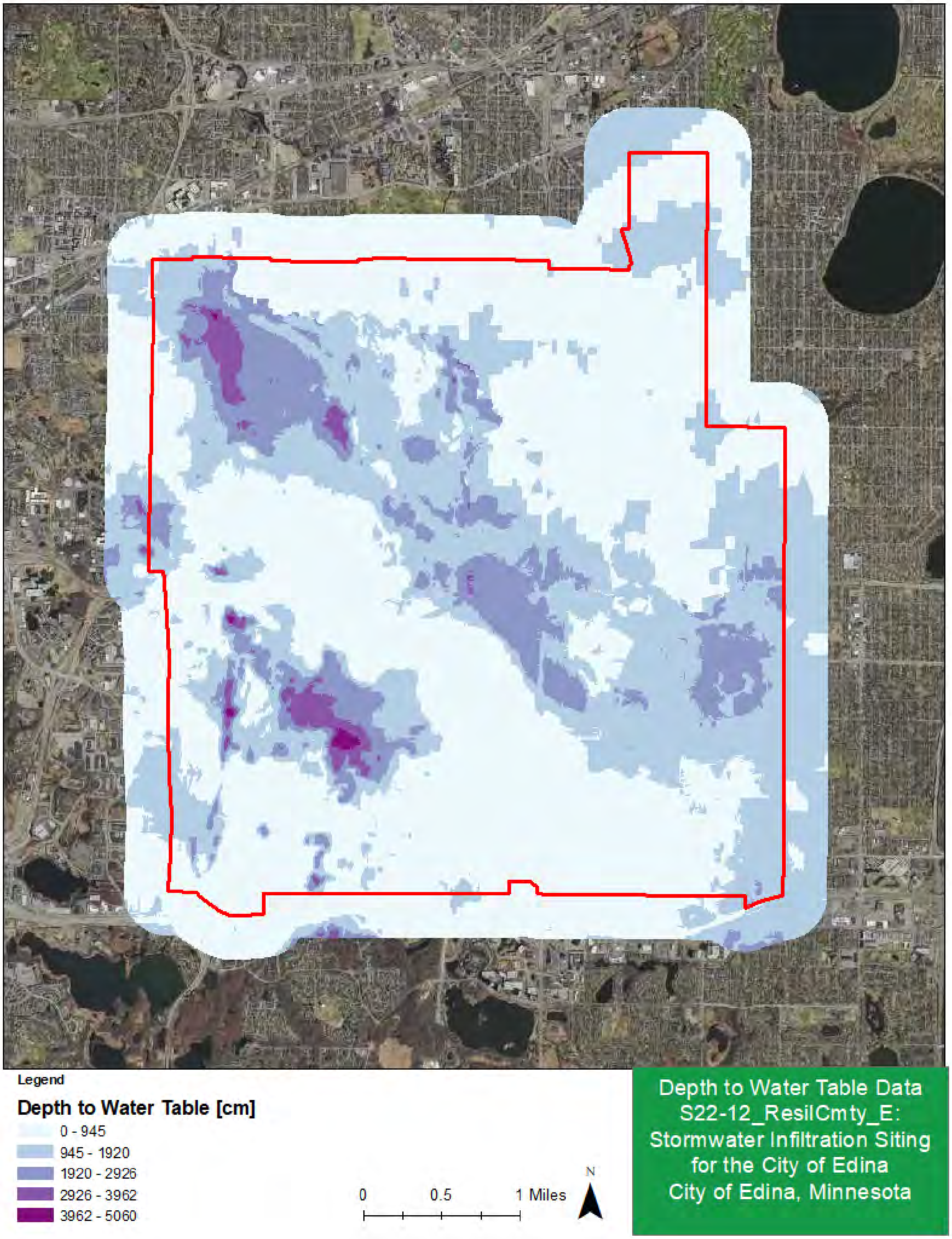


***Figure A8:*** *Depth to Water Table for the City of Edina and surrounding region.*

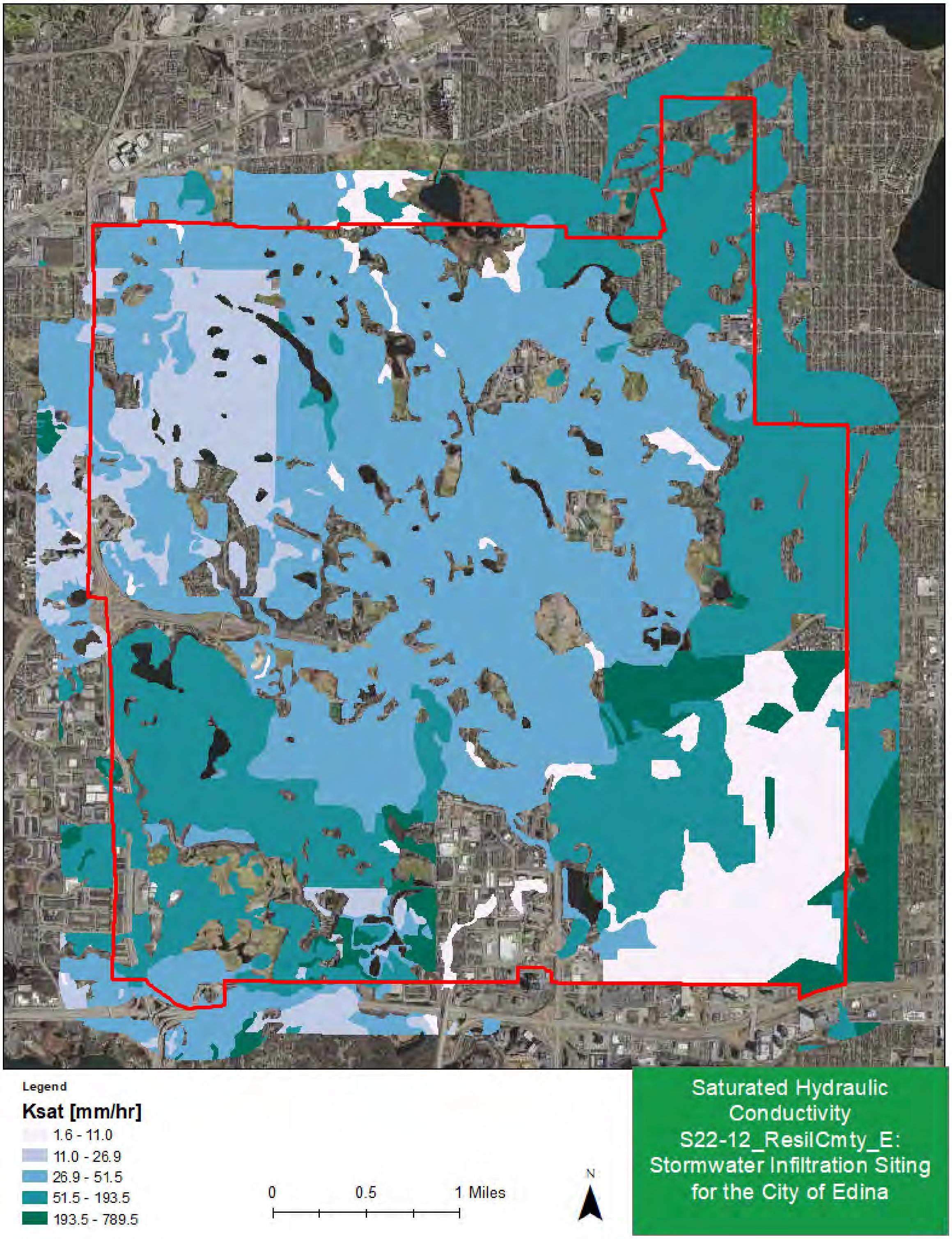


***Figure A9:*** *Saturated Hydraulic Conductivity for the city of Edina and surrounding area.*

## Appendix 8: Schedule and Budget

This appendix will have the finalized schedule and budget for this project as the final TPR graphs and budget table.

**Table 3: Team Member Billing Rate**

| No. of Team Members | 4 |
|---|---|
| **Team member** | **Hourly billing rate *[USD]*** |
| Karina Anderson | 80 |
| Martha Burket | 80 |
| Noah Gallagher | 80 |
| Owen Turner | 80 |
| **Average hourly billing rate** | 80 |

**Table 4: Final Budget**

| Project Task | Final time expenditure *[hrs]* | Final cost | Responsible team member |
|---|---|---|---|
| Project Plan (PP) | 25.75 | $2,060.00 | O |
| Meet with Mentor(s) | 39.5 | $2,370.00 | M |
| Biweekly Project Reports | 16.75 | $1,005.00 | N |
| Report 1st Draft | 21 | $1,260.00 | K |
| Report 2nd Draft | 12.25 | $735.00 | O |
| Final Report | 33 | $1,980.00 | M |
| Midterm Presentation | 16.5 | $990.00 | O |
| Final Presentation | 9 | $540.00 | N |
| Ethics Case Studies & Paper | 0 | $0.00 | _ |
| Task #1: Data Gathering | 30.5 | $1,830.00 | M |
| Task #2: Data Processing | 5 | $300.00 | N |
| Task #3: Implement PIR Model | 19 | $1,140.00 | N |
| Task #4: Identify Exclusion Criteria | 10.5 | $630.00 | O |
| Task #5: Define Exclusion Criteria | 14.75 | $885.00 | K |
| Task #6: GIS Processing of Exclusion Criteria | 14 | $840.00 | M |
| Task #7: Combine Exclusion Criteria with PIR Model | 7.75 | $465.00 | N |
| Task #9: Water Resources Conference Prep | 2.25 | $135.00 | K |
| | Total: | $17,030.00 | |
| **TOTAL** | 275.25 | | |
| **(Avg. Per Person)** | 68.8125 | | |

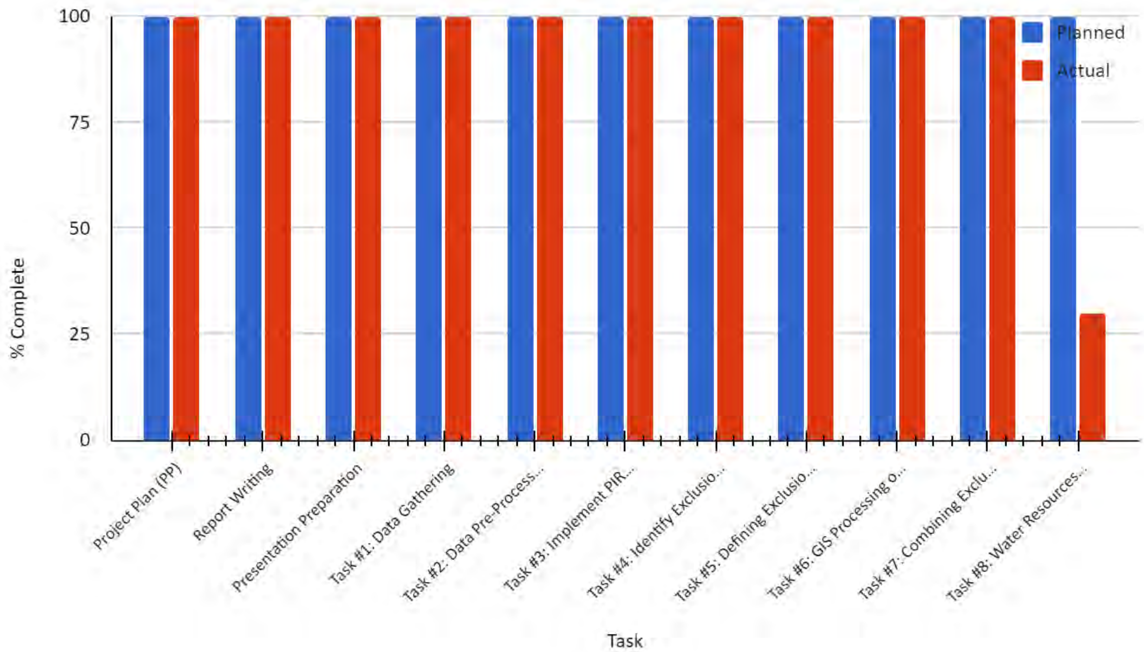


***Figure A10:*** *Final Percent Complete Comparison for Each Task.*

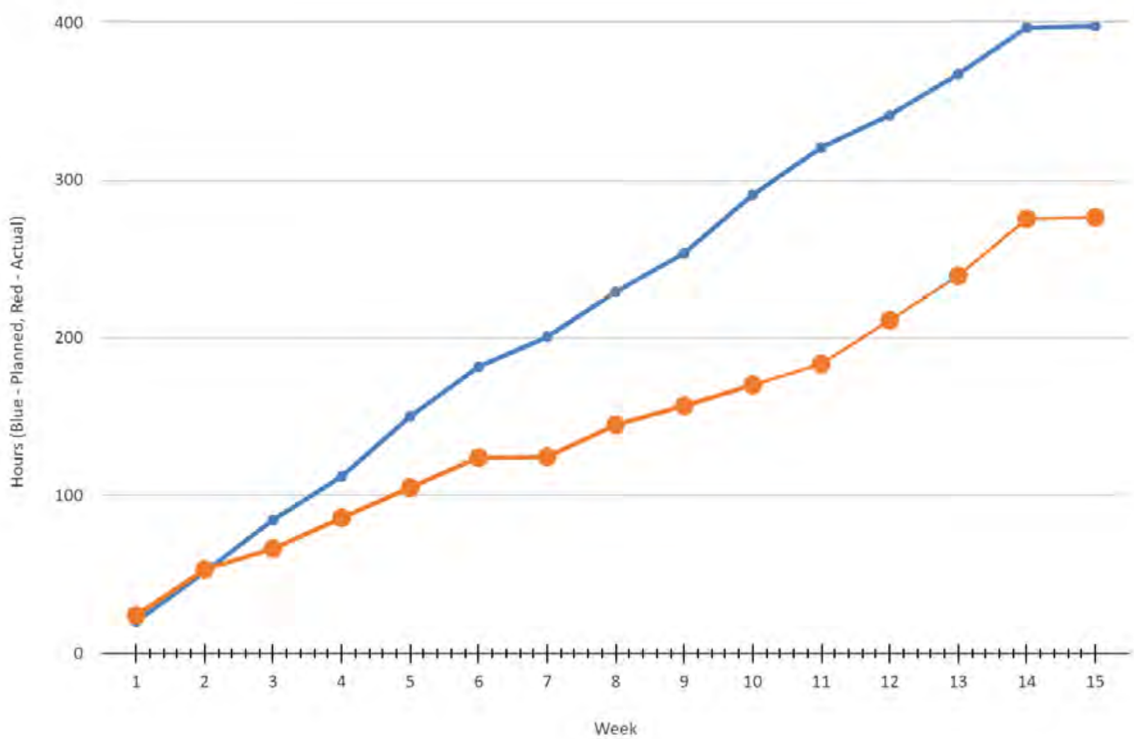


***Figure A11:*** *Final Planned vs. Actual Hours*

## Appendix 9: Summary of Tasks and Hours Spent

This appendix is a final summary of each task our group worked on as well as the hours dedicated to each task. There is also a brief description of work yet to be completed.

**Table 5: Tasks Summary**

| Task | Description | Hours Spent |
|---|---|---|
| Data Gathering | Data is needed for the PIR and for the ECs. The data will come from a variety of online sources, including the Minnesota Geospatial Commons, MnTOPO, and USDA websites. Data will also come from the City of Edina. | 30.5 |
| Data Pre-Processing | All data will be brought into ArcMap. Data pre-processing will include clipping the data to the City of Edina boundaries and re-classification of fields (if needed). | 5 |
| Implement PIR model in ArcMap | Implement the PIR model using the process described by Tecca et al. Troubleshoot any issues that arise when adapting the model to the City of Edina. | 19 |
| Identify exclusion criteria | Exclusion criteria will be used to determine areas where infiltration basins should not be constructed. In this task, mentors and other resources will be consulted in order to determine what criteria to include. | 10.5 |
| Quantitatively define exclusion criteria | In order to work with the ECs in GIS, there must be a quantitative description for the areas that should be excluded. Use background research, policies, engineering judgment, and meetings with mentors to define these criteria. | 14.75 |
| GIS processing of exclusion criteria | ArcMap will be used to turn the Exclusion criteria rules into geospatial data layers. A spatial operation (intersection) will be performed to simplify the dataset. | 21.75 |
| Water Resources Conferences (WRC) Prep | Submit abstract to MN Water Resources Conference. Design poster to present at conference. | 2.25 |

The final task of creating a WRC poster still needs to be completed. The abstract was submitted but the poster itself is incomplete.

## Appendix 10: Writer and proofreader responsibilities

This section contains a table of writer and proofreader responsibilities.

**Table 6: Writer and Proofreader Responsibilities**

| Section | Author | Reviewer | Reviewer Intial |
|---|---|---|---|
| Letter of transmittal | N | K | K |
| Executive Summary | K | O | O |
| Terminology and Definitions | MONK | O | O |
| Certification Page | MONK | K | K |
| Table of Contents | K | O | O |
| List of Tables | K | O | O |
| List of Figures | K | O | O |
| 1. Introduction | K | M | M |
| 2.1.1 Water in Edina | N | K | K |
| 2.1.2 Preliminary Infiltration Model | M | N | N |
| 2.1.3 Motivation for Exclusion Criteria | K | O | O |
| 2.3 City of Edina | M | K | K |
| 3.1 Implementation of PIR Model | N, M | N | N |
| 3.2 Development of Exclusion Criteria | O | M, K | M, K |
| 3.2.1 Minnesota Stormwater Manual | K | O, M | O |
| 3.2.2 Comprehensive Water Resources Management Plan | K | O, M | O |
| 3.2.3 Wellhead Protection Plan | K | O, M | O |
| 3.2.4 “What’s In My Neighborhood” Database | O | N, K | N, K |
| 3.3 Implementing Exclusion Criteria in GIS | M | N | N |
| 3.4 Environmental Justice | OK | M | M |
| 3.4.1 MET Council dataset | O | K | K |
| 4.1 Final Maps | O, N | M | M |
| 4.2 Suggested Use | O, N | K | K |
| 4.3 Sustainability Considerations | O | K | K |
| 4.4 Next Steps | O | M | M |
| 5. Conclusion | K | O | O |
| 6. References | M | K | K |

| | | | |
|---|---|---|---|
| List of Appendices | K | O | O |
| Appendix 1: GIS Methodology | M, N | O | O |
| Appendix 2: Ksat data collection | N | M | M |
| Appendix 3: Exclusion Criteria Masterlist | O, K | M | M |
| Appendix 4: Intermediate PIR Maps | M | N | N |
| Appendix 5: Schedule and Budget | O | K | K |
| Appendix 6: Depth to Water Table Supplementary Data | M | N | N |
| Appendix 7: ArcMap Toolbox Modifications | M | N | N |
| Appendix 8: Environmental Justice Data maps | O | M | M |
| Appendix 9: Summary of Tasks and Hours Spent | O | M | M |
| Appendix 10: Writer and proofreader responsibilities | K | O | O |