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# Assessing the arterials: environmental impacts and injustice along Poughkeepsie's east-west arterial roads

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# Assessing the Arterials:

## Environmental Impacts and Injustice along Poughkeepsie's East-West Arterial Roads

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Senior Thesis

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for the Bachelor of Arts degree in Earth Science and Society

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# Chapter 1: Production of Mobility in Poughkeepsie

If you have ever driven through Poughkeepsie, you have likely driven along Route 44/55, also called the East-West arterial. This road transects the city, running parallel on both sides of Main Street. As someone who has spent most of the past four years going to school in Poughkeepsie, the arterials are the roads I am most familiar with. I drive on them every time I come back to school, and every time I return to my home in central New York. Traveling from one side of Poughkeepsie to the other on the arterials takes about 10 minutes, and it is only necessary to slow down or stop if you hit a stoplight. The speed and ease of driving along the arterials can cause them to fade into the background for drivers. It is easy to drive by the many houses that line the arterials without thinking about the effects the arterials have on those who live near them (Figure 1).

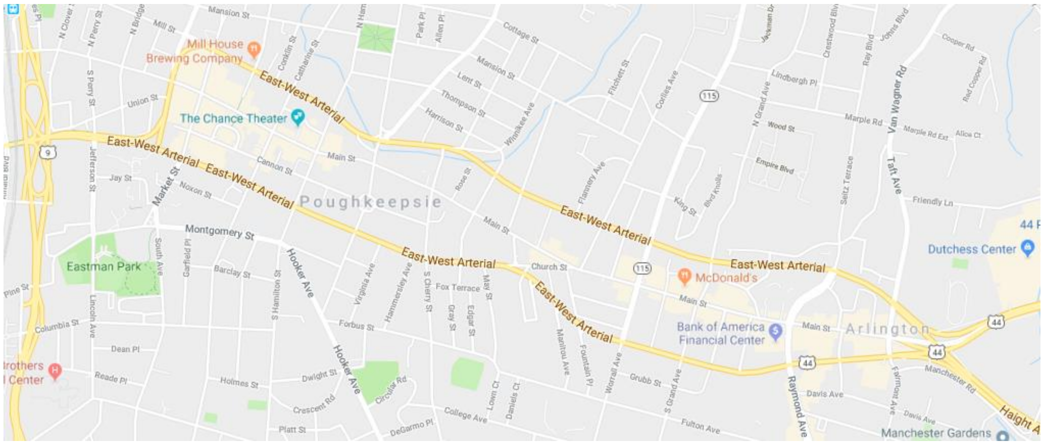


*Figure 1: The East-West Arterials, shown in yellow (Google Maps)*

The arterials dominate the transportation infrastructure of Poughkeepsie. Figure 1, taken from Google Maps, shows the prominence of the arterials as a means of transportation. They are highlighted in a different color, their labels are larger and more frequent than other roads, and the lines are larger. It shows how the arterials are different from other roads and the disruption they cause in the city landscape. The arterials are one-way three-lane streets, creating an impact similar to a six-lane highway split in half to encircle downtown Poughkeepsie and Main Street. The color represents how the arterials are an extension of Route 44/55, which is a national highway, as opposed to being city-owned. The arterials are the only roads in the city with a speed limit over 30 mph, and the 12-foot wide lanes and lack of turns makes it easy and common for vehicles to travel much faster. The arterials were created with intentions to alleviate traffic and make driving through Poughkeepsie fast and easy. ESRI's global traffic map categorizes the arterials as having "free flowing" traffic, which characterizes traffic that does not need to slow or stop 85-100% of the time (ESRI 2018). The arterials have clearly streamlined and enabled car mobility in Poughkeepsie.

However, increased car mobility can have negative health and environmental effects for people, especially when it is in proximity to residential areas. Sheller and Urry (2000) discuss how the concept of automobility, or creating infrastructure that prioritizes automobile transportation, often comes at the expense of other kinds of mobility. These and other theorists have questioned the power relationships automobility reinforces, intentionally and unintentionally. Age, ability, income, and citizenship status are just some factors that can affect a person's ability to take advantage of a landscape created for automobility (Speck 2012). Although the arterials created a route with fast and free flowing traffic, only some people are able to take advantage of it. The speed and placement of the arterials make them less useful to someone who is traveling within Poughkeepsie rather than through and across it. The unequal benefits of the arterials are in part due to the priorities that informed its creation. The significant increase in commuters from surrounding towns, in part due to the growth of IBM in the 1950's and 1960's, exacerbated traffic (Flad 2009). This primary focus on easing traffic meant the creation of the arterials was not equitable.

City planners envisioned the East-West arterials in 1966 as a means of ameliorating Poughkeepsie's congestion and as a crucial step in the urban renewal of the city (Flad 2009). While the surrounding suburban towns were experiencing fast population growth, Poughkeepsie was struggling with depopulation and a depleted economy (Flad 2009). Planners portrayed the arterials as a solution to the decreased downtown economy in addition to easing traffic (Flad 2009). This solution centered on bringing suburban residents (and their spending money) into Poughkeepsie. Rather than focusing on solutions that targeted city residents, the arterials prioritized the needs and actions of non-city residents. Traffic was primarily exacerbated by commuters who lived in surrounding towns who needed to drive to or through the city for work. Similarly, casting the arterials as a means of drawing suburbanites to Main Street to improve the economy identified non-city residents as the desired actors (Flad 2009). In posing automobile movement as a cure for economic depletion in Poughkeepsie, the arterials' proponents oversimplified and overlooked underlying causes of deindustrialization like job shortages and white flight. The focus on attracting outside wealth solely by convenience without also supporting intra-city means of generating wealth is a reason why the arterials, like many urban renewal projects, did not benefit Main Street.

The patterns of benefits and sacrifice from the creation of the arterials are similar to narratives of environmental justice. Those who benefit most from the arterials are car-owners in nearby towns who need to drive through the city quickly to commute. Those who face the brunt of its consequences are those who live along the arterials. As Poughkeepsie began experiencing declining population and economy in the 1950's and 1960's, the surrounding towns increased in population and affluence (Flad 2009). This relationship has continued over time, with towns surrounding Poughkeepsie having higher household income levels, as seen in Figure 2 (US Census Bureau 2010). The arterials are a creation that produce an unequal distribution of negative effects along class lines, a central tenet in studies of environmental injustice (Bullard 215).

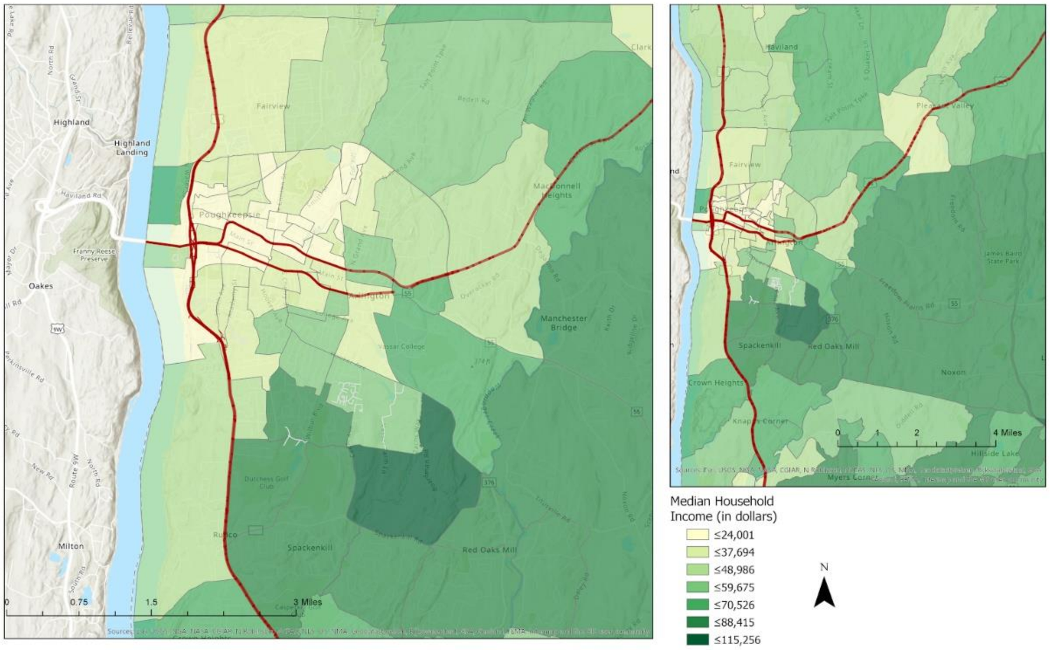


*Figure 2: showing median household income in Poughkeepsie area (left) and in part of Dutchess County (right)*

In addition to not situating the residents of the city as the primary beneficiaries of the arterials, the arterials negatively affected the communities surrounding them. The process of constructing the arterials caused significant disruption. This began with the road expansion necessary to make room for the three-lane streets. This process displaced 100 people, as well as 26 business. Expansion truncated front lawns to just beyond porch thresholds to make way for the roughly 30-foot-wide streets (Flad 2009). Arterial construction drastically altered the landscape of the residential areas nearby. The pedestrian environment changed with the influx of cars that accompanied the arterials. Crossing the street became dangerous in places without a stoplight. In addition to impeding mobility, increased car traffic increases pollution and affects human health. The materials and the increased pollution they bring to potentially create a micro-ecosystem of impaired air and soil quality, mobility, and health that has not been thoroughly assessed.

I grew up in an unusually walkable neighborhood. Cooperstown, NY has a year-round population of less than 2,000, with just enough cars to require a single stoplight. Friends' houses, school, work, and restaurants were all within a ten-minute walk or a five-minute bike ride. My small town ingrained in me an expectation of personal mobility, and I immediately notice when it is restricted. Upon my arrival in Poughkeepsie for college, I realized that walking to places within reasonable walking distance was a vastly different experience from my hometown. Even spaces that were designated specifically for pedestrians (such as crosswalks and sidewalks) were frequently interrupted by cars to enter drive-throughs or make right turns. The way cars dominated the built environment hindered my ability to move as a pedestrian. These experiences prompted me to think of the other ways busy roads affected pedestrians: noise and environment pollution, stress, and safety came to mind. How did busy roads, such as the arterials, affect the quality of the air and soil, and what could this mean for the health of nearby residents?

As I was formulating this thesis, I spoke with my great uncle, Robert Heifetz, about the arterials in Poughkeepsie. He became very animated and recounted his similar experience growing up before and after the construction of the Cross Bronx Expressway.

> "I used to be able to cross the street to get to my friend's house. After it was built I had to go eight blocks. It went right through my backyard. It really destroyed the neighborhood."

His story reminded me how road building through high density residential and commercial areas in the urban core was a common phenomenon. Throughout New York, in Syracuse and Buffalo, as well as in many other states including New Jersey, Connecticut, Texas, and Alabama, highways were constructed through densely developed and populated urban areas. Many of them have faced criticism and calls for their partial or complete removal (Semuels 2016). These projects have been broadly criticized, and urban highways have become associated with community division, economic stagnation, mobility restriction, and other negative effects on livability (Speck 2012, Semuels 2016). The construction of Poughkeepsie's arterials is not a unique event- similar projects have happened as part of a nation-wide trend that has prioritized car mobility over quality of life.

In this thesis, I identify and quantify several measures for the health and environmental impact from the arterials. I do this to examine the effects the built environment of the arterials has on residents by comparing mobility, soil quality, and air quality data from along the arterials with data from other streets in the city. Quantifying environmental differences between arterial and non-arterial zones can provide support to the idea that the residential areas along the arterials are a sacrifice zone of higher environmental pollution and potential negative human health impacts. In addition to assessing environmental effects, I emphasize the connection between the environment and potential impacts on human health. The health impacts of mobility, soil quality, and air quality are addressed in many studies. Focusing on potential negative impacts on human health is particularly important along the arterials, where everyday exposure to residents compounds the effects of pollution and exacerbated the effects of mobility constraints. This research sets a baseline of the effects of the large traffic load of the arterials, allowing for follow-up research on to assess change in pollution levels.

The idea of a sacrifice zone provides a conceptual framework to describe the difference in environment around the arterial roads compared to Poughkeepsie's other roads. During the Cold War researchers used the term to describe areas exposed to nuclear radiation or destroyed by nuclear testing. The term sacrifice zone reveals how the government believed these areas could best serve the country through their destruction (Little 2016). Since the Cold War, the researchers have used the term to describe areas impacted by extractive processes, like mining, drilling, and fracking, as well as areas impacted by industrial waste (Shade 2015, Little 2016, Lerner 2010). Again, the destruction of these areas fills a 'need' for the country. Oliveira and Hecht (2016) use sacrifice zone to explain the unique environmental impacts of areas used for soy production. The widening of the use of the term sacrifice zone reflects the prevalence of its occurrence. Although all of these processes will result in environmental degradation, if no one lives close enough to be affected by it, the area is not considered a sacrifice zone. Environmentalist writers have used the term to focus on the people and ecosystems that have been most heavily impacted by environmental destruction, and to contrast them with nearby areas that are not affected.

I argue that automobile pollution and disruption create a sacrifice zone along the arterials in Poughkeepsie and is likely manifesting itself along any heavily-trafficked residential roadway. In order to enable automobility, areas must be sacrificed to provide space for cars to drive, and then are further sacrificed through pollution and mobility restriction. Much like extraction zones, the reason for the degradation of the environment along the arterials is explained by ideas of national service. Many people depend on cars for employment, school, and obtaining food, and limiting car mobility is portrayed as limiting access to these necessities. Cars and car ownership have become a symbol of freedom, which creates a national narrative that their mobility should be preserved and prioritized at any cost (Kay 1997). Examining differences in pollution between living along the arterials and along any other road in Poughkeepsie reveals how peri-residential highways create unacknowledged sacrifice zones.

Objects and infrastructures have intended and unintended social consequences. Theories of object politics have been used by theorists like Langdon Winner (1986) to discuss how inanimate objects are capable of reinforcing and perpetuating the agendas of the structures of power that had the capabilities to create them. Winner emphasized that technologies should not only be assessed by their efficiency and potential to pollute, but also by how they can recreate types of power and authority. He illustrates this point with an examination of Robert Moses' construction of overpasses on Long Island. By making overpasses exceptionally low, in some cases with less than ten feet of curb clearance, Moses was able to control who could access the throughways he was building. In particular, these overpasses were constructed unusually low to prevent buses from being able to drive under them. Moses did this intentionally to keep people who typically used the bus, lower-income people and minorities, from being able to access the new highways Moses was building. One desired result of these actions was to keep racial minorities and low-income groups from accessing Jones Beach, Moses' "public" park that was only accessible by car (Winner 1986).

Although in a less explicitly intentional way, the arterials help to reinforce an existing power dynamic between those who live in the city and those who live in surrounding suburban towns. There are clear racial and class differences between the city of Poughkeepsie, which has a much higher minority and lower-income populations than the surrounding towns (Census 2010, Figure 2, Figure 22). City planners proposed the arterials to alleviate traffic, which most significantly affected and caused by people who did not live in the city (Flad 2009). While the arterials reduce traffic, it is at the expense of the quality of life of those who live near them. ‘Quality of life’ can be an ambiguous term that can seem subjective and immeasurable. This ambiguity allows technologies like an arterial road to benefit one group at the expense of a sacrificed zone.

In this thesis I focus on three factors associated with health and quality of life: mobility, soil quality, and air quality. I quantify these factors through sampling and analysis, and then compare values from along the arterials with averages from other roads in the city. I isolate the ways the arterials have affected the environment around them and analyze the health effects this could have on people who live along the arterials. I demonstrate the differences in environment between the arterials and most streets in the city, illustrating the potential for a more polluted sacrifice zone for residential areas near the arterials.

### ***Study Site***

Poughkeepsie, New York is a city of just under 33,000 people situated adjacent to the Hudson River about 85 miles north of New York City (US Census Bureau 2010). In the 1800 and early 1900’s, Poughkeepsie had many factory jobs and a growing immigrant population. Like many cities across the US, mid-century industrialization depleted the economy and decreased employment (Flad 2009). In 1963, IBM opened a manufacturing building in nearby Fishkill. IBM brought jobs to the surrounding area, but Poughkeepsie did not benefit as much from IBM’s presence. While nearby suburban towns grew in wealth and population, Poughkeepsie struggled with a diminished economy and higher crime rates. Since the 1990’s, the economy has begun to improve, and crime rates have decreased (Flad 2009). Some concerns of gentrification have begun to emerge, as upper-middle class people who work in New York City are increasingly moving to the Hudson Valley (Dilawar 2019, Kitchens 2018).

Assessing pollution from the arterials is particularly important in Poughkeepsie because the arterials run through residential areas. In many cases, homes are directly adjacent to the arterials (Figure 3). Proximity and length of exposure to a pollution source are two important variables that contribute to severity of health effects. Most automobile pollution is concentrated close to the road, so houses that are closer will be in zones of higher pollution. Because these are residential areas, people spend a significant amount of time within close vicinity to the arterials. Daily exposure to elevated levels of harmful pollutants increases the likelihood of negative health effects (Hassaan et al. 2016).

*Figure 3: Google maps image showing homes adjacent to the arterials. In this picture, the house fronts are about 10 meters from the road*

The arterials illustrate problems with urban renewal, automobility, and distribution of environmental impacts. The arterials are often seen as a necessity because of their benefits to car mobility, and their negative effects on those who live near them are downplayed or ignored. I was unable to find any previous studies that assessed pollution or other human health effects from the arterials. By quantifying levels of air pollution, soil pollution, and mobility restriction along the arterials, and comparing them to non-arterial levels, I show how the arterials affect their surrounding environment. Because this kind of study has yet to be done to the arterials in Poughkeepsie, results from this thesis will provide a first benchmark that could be measured against in the future if the arterials change and can be used to assess the current risk to environmental and human health.

In my next section, I present relevant literature, including an overview of important studies that have set precedent for pollution testing and background on social movements and theories that have impacted the arterials. I then have a methods and results section, detailing sampling and data I collected in Poughkeepsie. In my discussion, in addition to analyzing my data, I connect its implications to social theoretical contexts, like the power dynamics of automobility, environmental justice and the sacrifice zone, and national trends in mobility infrastructure. Since the beginning of my thesis, it was important to me to approach potential issues of pollution in Poughkeepsie in an interdisciplinary way. By combining new environmental data with related social theory, I provide a more complete picture of the arterials.

# Chapter 2: Automobility's Environmental Impacts and Injustices

Part of understanding the effects of the arterials is connecting them to broader national movements of urban renewal, environmental justice, and sacrificed zones. Environmental assessment of a sacrifice zone involves ideas from diverse literature; this section reviews the background of urban renewal, its emphasis on automobility, and the consequent loss of other forms of mobility. Following that I review past observations of soil and air contamination in urban areas. I connect the health effects of automobility-oriented landscape through mobility restriction and air and soil pollution.

## *Urban Renewal, Automobility, and Environmental Justice*

The urban renewal movement, which has been defined by Avila and Rose (2009, 339) "a series of radical interventions on the urban built environment", swept across the United States beginning in the 1950's and continuing into the 1970's. The movement was a reaction among urban planners to the social and economic problems many cities faced due to deindustrialization, depopulation, and depleted employment in the Northeast and Midwest (Avila and Rose 2009). Proponents of the urban renewal movement argued that freeways were a necessary prerequisite for urban prosperity. Policy makers advocated that new highway systems were the only way to create a connected and rejuvenated economy with easy movement of goods and consumers. These economic and social arguments for highways helped prioritize automobility-oriented infrastructure in areas of urban decline, leading to a pattern of arterial-like roads in deindustrialized cities (Sheller and Urry 2000). The engineers behind urban renewal movement perpetuated the narrative that they were an apolitical force solely responding to the neutral numerical results, such as traffic counts, congestion rates, and economic returns (Avila and Rose 2009). Because they did not consider a broader social context for urban decline, like redlining and white flight, solutions centered on automobility could not ameliorate social problems faced by deindustrialized cities. The urban renewal movement was influential enough to receive significant federal funding with the Interstate Highway Act of 1956 (Avila and Rose 2009). Federal backing completed the urban renewal movement's powerful combination of government funding, policies enabling property acquisition for public use through eminent domain, and a narrative that modernization was a numbers-based, 'apolitical', and therefore uncontestable, movement.

The decisions of Poughkeepsie's city planners reflect these national trends. Characteristics of deindustrialization included downsized businesses, a depleted Main Street, significant population decline, and rising rates of poverty and crime (Flad 2009). Poughkeepsie was also experiencing congestion as suburban workers traveled through the city to their jobs. The arterials were packaged as a boon for Main Street that would bring suburban populations to downtown businesses (Flad 2009). Without the national urban renewal movement that increased federal funding, the arterials, which relied significantly on federal funding, might have never been built (Flad 2009).

Automobility is a term that encompasses a number of ideas about the ways how the built environment prioritizes car mobility over others. Zoning laws and prioritization of automobile infrastructure show how the government perpetuates the 'matrix of automobility' at the expense of other forms of mobility. High traffic roads in residential areas, defunded limited bus routes, an absence of bike lanes are examples of factors in the matrix of automobility (Sheller and Urry 2000, Kay 1997). It has been a prominent force in the shaping of cityscapes since the creation of the car. Because automobiles are so integral to a majority of people's lives, expanding and prioritizing their infrastructure can seem to be an expected and neutral decision (Kay 1997). However, critics of automobility have shown the often unintended and usually unacknowledged costs it entails. Creating the physical space needed for cars is a process that necessitates sacrifices. Pedestrians and residents must give up public space, as well as private space, to make room for cars. Automobility replaces pedestrian-oriented landscape in favor of roads with automobile-oriented values: functionality, speed, and readability (Sheller and Urry 2000). In addition to creating a physical barrier to pedestrian mobility, prioritizing mobilization of cars stretches out and separates different aspects of life; the distances required to travel between home, work, business and retail districts, friends' and relatives' homes, non-car and public spaces, and leisure sites are only bridgeable through the use of a car (Sheller and Urry 2000). Prioritizing cars' mobility is exemplified in the decision to increase road space through arterial construction rather than decrease car numbers (through solutions like public transit) in response to congestion in Poughkeepsie.

The intersections of transportation and environmental injustice have been analyzed through different lenses. Schweitzer and Valenzuela (2004) analyze equality of access to general transportation facilities and assess if those who experience the highest amounts of pollution also enjoy the greatest benefits from the transportation structures. Verbeek (2019) found that median household income was the best indicator for automobile air pollution exposure. To some extent, discussions of environmental injustice associated with transportation have had effects on governmental ordinances. The Transportation Equity Act for the 21st century (TEA-21) required evaluation of environmental justice needs for all new plans and projects (Chakraborty 2006). Current guidelines from the Federal Highway Administration enumerate actions that should be taken in a new transportation project to account for environmental justice. This includes mitigating disproportionate human health, social, and economic effects, and to ensure that nearby minority and low-income populations receive the benefits from the project (Chakraborty 2006). However, these laws do not address remediating existing transportation systems that do not meet standards of environmental justice.

### ***Pedestrian Mobility and Connections to Health***

Prioritizing car mobility over human mobility has long-term health effects for neighborhood residents (Speck 2012). Reshaping communities to facilitate pedestrian mobility means giving people the right to move through their own neighborhood. The infrastructure within a community can impact regularity and distance of active pedestrian transportation (Kay 1997). Hindered pedestrian mobility, in addition to being inconvenient, can contribute to decreased physical activity and an increase in risk of diseases related to obesity (Frank et al. 2006). Furthermore, a walkable environment is an important aspect of overall quality of life and safety for pedestrians. Frank et al. (2006) highlight the health risks associated with forgoing walkability in favor of automobility in their comparison of resident health in neighborhoods that were built in more traditional walkable designs with those built in spread-out, car-dependent suburban plans. When infrastructure enabled pedestrian mobility, obesity rates declined.

Pedestrian safety is also linked to mobility within a built environment. Arterial roads, where there is more traffic that moves at faster speeds, can be less safe for pedestrians. The Federal Highway Administration’s Pedestrian Road Safety Assessment (RSA) guidelines lists arterial roads as an environment that would benefit in particular from pedestrian safety auditing (FHA, 2006). They note that arterial streets are often centers of pedestrian issues, and how the prioritization of mode of transport (cars) over another (pedestrian) often leads to safety issues (FHA, 2006). The Governors Highway Safety Association outlined safety concerns of prioritizing automobility in their 2018 Pedestrian Fatality report (GHSA 2018). In 2018, the United States had the highest pedestrian deaths since 1990, with a 51% increase since 2009. Additionally, while pedestrian deaths have increased by 4% since 2017, overall automobile crash deaths have decreased by 1% in the same time (GHSA 2018). Driving is getting safer for drivers and passengers, but deadlier for pedestrians who are hit by them.

Walkability also has effects within on the social fabric of a community. A pedestrian-oriented environment encourages people to spend time outside, increasing interactions between people (Speck 2012). Additionally, creating an environment where only cars can move easily severely disadvantaged people who cannot drive or do not have a car. Building communities with walkable areas in mind will mean more mobility for more people (Speck 2012).

### ***Pollution Indicators in Roadside Soil***

Vehicle traffic is widely known to be a major source of heavy metal pollution in urban soils (Dao et al. 2010). Within urban areas, heavy metals are more likely to be found in roadside soils than in other soils, excepting industrial sites (Solgi et al. 2016, Pariente et al. 2019). After they are emitted from cars, heavy metals settle out of the air quickly due to their weight. If they land on pavement, they will likely be remobilized by air or water, but once they reach soil they bond with other particles and are likely to stay in place. Few heavy metals undergo microbial or chemical degradation, meaning if they land in soil they are likely to remain and persist for long periods of time (Wuana & Okieimen 2011). Soils and sediments naturally store many kinds of pollution, making testing soil is a good medium for assessing heavy metal exposure in an environment (Hoffman et al. 2009). I chose to analyze soil for heavy metal pollution in Poughkeepsie because automobile pollution is a major source of heavy metals in an environment.

Heavy metals are loosely defined as a group of inorganic chemical hazards that are often found at sites of pollution (Wuana & Okieimen 2011). They all can occur naturally but are often concentrated at sites of pollution from anthropogenic sources. Heavy metals can enter the environment through automobile emissions or through degradation of automobile parts. The heavy metals I sampled in this study, Chromium, Nickel, Manganese, Zinc, Lead, Arsenic, Copper, and Cadmium, are often introduced into an environment through automobile pollution. Manganese, Arsenic, Copper, and Zinc are commonly found in brake lining abrasion (Wawer et al. 2015). Zinc can also be found in tire degradation and used engine oil (Davis et al. 2001). Some environmental Lead remains from when leaded gasoline was in use, while other sources include brake lining abrasion and corrosion of engine parts (Westerlund 2001). Cadmium can be found in brake lining, tire rubber, and petrol additives (Wawer et al. 2015). Chromium can be found in brake lining, catalytic converters, and some chrome paints (Saha et al. 2011). Nickel can be sourced from combustion in cars and trucks (Fishbein 1981).

High concentrations of heavy metals can impair human health. This is especially true for vulnerable populations, like seniors, children, and those with preexisting conditions. Additionally, those who live near a concentrated source of heavy metal pollution would experience chronic exposure, which can lead to health complications. Long-term daily exposure to high heavy metal concentrations can cause serious and lifelong health effects.

Soil is not stationary; humans, air, and water can act as vectors that spread soil pollutants. The top centimeters of soil are in constant interaction with the atmosphere, meaning pollutants in the soil can be transported into the air and inhaled. Humans can be further exposed by dirt and dust that is transported into the house on clothes and shoes, or during yard work and outdoor play (Boivin et al. 2008). Air movement, from wind and automobile slipstreams, can scatter pollutant-carrying soil particles and disrupt settled sediments. Similarly, cars splashing through puddles on the side of the road can spread pollutants (Werkenthin et al. 2014). From the soil, organisms can transport heavy metals through many different vectors. Plants can absorb them, and animals can ingest them directly or indirectly. Humans can inhale them, and children can accidentally ingest them (Boivin et al. 2008). Understanding the means through which pollution in soil can come into contact with humans is important to realizing the effects it can have on those who live near polluted soil.

Werkenthin et al. (2014) found pollutants could travel up to 50 meters from the road before settling, with most of them concentrating within 10 meters. Piron-Frenet et al. (1994) found that levels of lead in soil increased as far as 500 meters away when traffic increased, but also found that the largest magnitude of was much closer to the road. Once metal pollutants settle in soil, they tend to bond with soil particles, and are resistant to downward movement, with the clear majority of metals remaining in the top 10 centimeters of soil (Boivin et al. 2008). The shallow deposition makes heavy metals remain in interaction with the environment, rather than becoming dormant after settling. Although I only sampled along the road verge, research shows pollution in this soil will move and are capable of reaching peoples' homes and yards (Boivin et al. 2008). Because of its ability to retain dangerous heavy metals and be transported into people's homes, soil is important to measure in any circumstance of potential pollution.

### *Air pollutants associated with automobiles*

Automobile emissions negatively affect air quality by emitting nitrous oxide, ozone, volatile organic compounds (VOCs), and particulate matter pollution (PM). Studies have found that the highest levels of air pollution occur within 150 meters of a heavily trafficked road and note that pollution does not reach background levels until 600 meters away (EPA 2015, Venn et al. 2001). This means that even houses that are not directly adjacent to the arterials may be affected, but that those that are adjacent will likely experience the worst effects from air pollution.

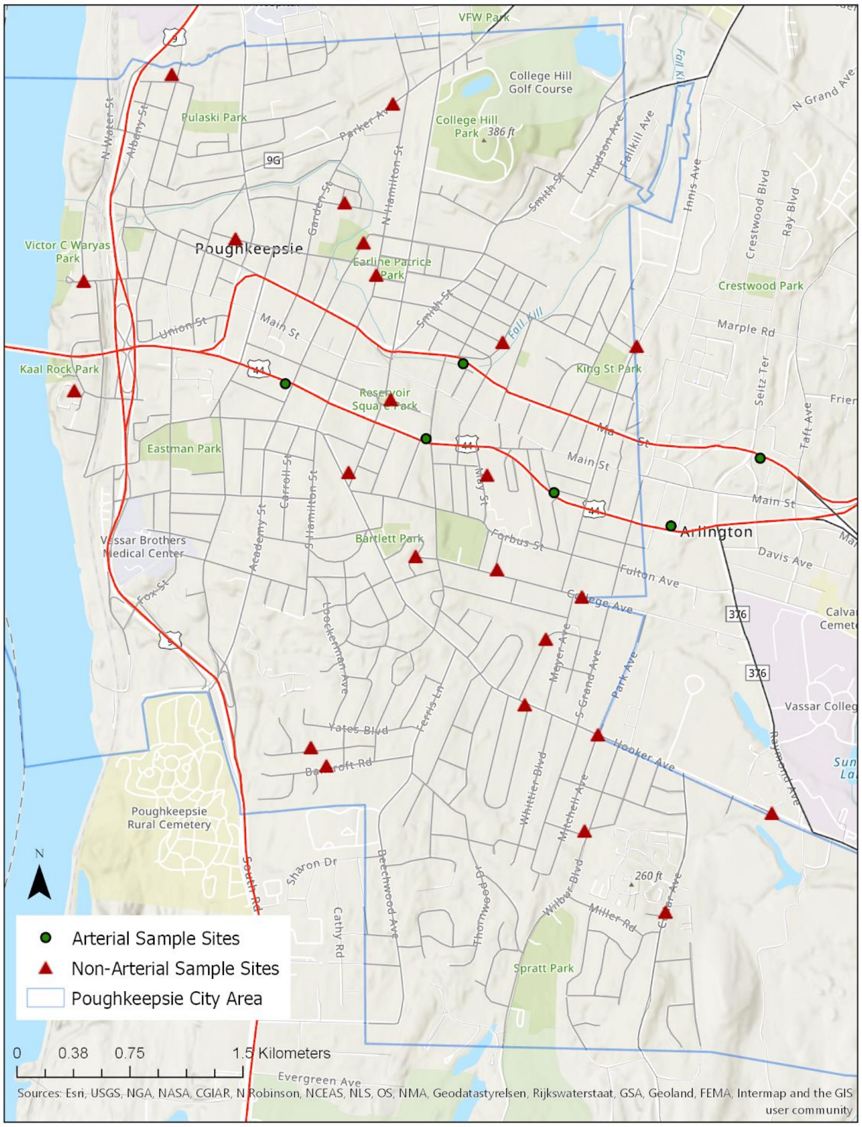
Poor air quality negatively affects the health of a community. Vehicles produce nitrous oxide, ozone, and volatile organic compounds (VOCs) and particulate matter (PM) which can have chronic health effects (Frank et al. 2006). Proximity to high traffic areas has been associated with asthma, reduced lung development and function, cardiovascular disease, and other ailments (Schweitzer and Valenzuela 2004). Children and people with lung conditions are at higher risk of negative health effects due to automobile fumes. Air quality is particularly important to measure when examining an area affected by high automobile traffic.

Coarse particulate matter exposure can cause lung inflammation and exacerbate breathing difficulties in sensitive populations (Hargrove et al. 2018).

Exposure to fine particulate matter, which I measure in this thesis, can cause serious health effects (Hook et al. 2002, Chen et al. 2017). Particulate matter, or PM, consists of a mixture of solid and liquid particles of less than 10 nanometers in diameter that are suspended in the air. These particles vary in chemical composition and physical properties (Amann et al. 2006). Their size is used to define them because it is so integral to how they travel through the air and their capacity to be inhaled into the respiratory system. Sulfate, nitrate, ammonium, carbon, and heavy metals can make up PM (Amann et al. 2006). PM 2.5 can be particularly harmful to human health because it is small enough to deeply penetrate the human respiratory system, providing a pathway for toxins to enter the bloodstream (Lipman et al. 2000). Assessing air quality is integral to improving public health, and my thesis provides an overview of current PM levels in Poughkeepsie.

# Chapter 3: Methods

In order to compare the environment along the arterials to the environment along roads in the rest of Poughkeepsie, I split my soil sampling into two main groups: arterial and non-arterial. For the arterials, I sampled once roughly every 0.3 km. To assess roads in Poughkeepsie excluding the arterials, I used ArcMap to randomly generate sample sites along all non-arterial streets throughout the city. I first generated a layer of points over a layer of roads in Poughkeepsie, meaning there were thousands of points on each road. To get the sample size to a manageable amount, I had ArcMap select a random 10% of the dots multiple times, until there were about thirty points left. A map of these sample sites can be seen in Figure 4. These values were generated randomly in order to prevent survey bias, and to provide an overview Poughkeepsie. Although arterial samples included sites in the town and city, since the arterials span both, I limited non-arterial sampling to the city of Poughkeepsie. I decided to limit the sampling area in this way because of collection constraints. I collected most samples on my bike, so distance and time were limited. Soil samples were collected at sample sites, while air quality data was collected continuously during sampling. Mobility measurements were taken using Google Maps.



Sources: Esri, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community

*Figure 4: Sample sites taken for this study, including arterial (green circle) and non-arterial (red triangles). Arterial roads are in red, and non-arterial roads are in green.*

### ***Mobility Methods***

To approximate effects on pedestrian mobility, I defined a number of measurable pedestrian stressors, and compared those measurements between arterial and non-arterial roads. Width per lane, road edge to sidewalk edge (RE → SE), road edge to furthest sidewalk edge (RE → FSE), sidewalk width, and daily traffic were measured at each of 23 non-arterial roads and at six sites along the arterials. Distance measurements were taken using the measure tool in Google Maps. Two major factors that affect pedestrian comfort are distance from road and speed of cars near the road. To assess distance from road, I measured the distance from road edge to sidewalk at each sample site and measured sidewalk width. When these are added together, it measures the total distance a pedestrian has from the road. I was also interested in approximating the distance between the pedestrian and the place in the road where the car is driving. When lanes are wider to allow for side-street parking or passing, cars still tend to drive close to the center of the road. This means that wider lanes allow for more space between where cars are driving and where pedestrians are walking. To measure width per lane, I divided road width by the number of lanes. I also counted ADA intersection ramps along the streets I was sampling using the satellite view in Google Maps. ADA ramps make crossing the street easier and safer, especially for mobility or visually impaired pedestrians. Daily traffic counts similarly affect walkability, as higher traffic roads are more stressful for pedestrians (Zegeer 2002). Traffic counts were retrieved from Esri's "World Traffic" map (Esri 2018). By compiling information on pedestrian stressors, I can assess relative mobility along different roads.

### *Soil Methods*

The upper surface layer is most often sampled to determine heavy metal pollution (Wawer et al. 2015, Boivin et al. 2008). The top ten centimeters of soil provide a good indication of heavy metal accumulation (Boivin et al. 2008). I used a trowel to collect a soil sample from the top ten centimeters at each site, although depth within that range varied slightly depending on the circumstances at the site. Depth of sample and distance from road varied depending on conditions at the sample site. When there was a strip of grass between the road and the sidewalk (called a road verge), I collected samples in the grass strip. In some cases, I had to adjust the placement of my sample site because there was no road verge, or because snow covered the soil. In all places, the sample site was within 2 meters of the road and was as close to the road as possible in each circumstance. Piron-Frenet et al. (1994) found the highest concentrations of lead from automobiles within 1.5 meters, and wherever possible my samples were taken within 1.5 meters of the road. I also tried to avoid collecting vegetation in my samples.

To measure metal ion concentrations, soils were dried in an oven at 60°C, ground, and sieved to make the soil sample uniform. Inductively coupled plasma mass spectronomy (ICP-MS) performs precise measurements on a dilute liquid matrix. To create a mixture the machine is able to analyze, the samples had to be digested, a process that entails adding acids and water to the dried soil sample. This digestion process is slightly modified from the EPA procedure for determining heavy metals in soil. The digestion process included adding $H_2O_2$, or hydrogen peroxide, to remove organic matter from the sample, and $HNO_3$, which helps prepare the metals into ions and compounds that the ICP MS can easily recognize. The full procedure for this process, which is derived from an EPA procedure, can be found in Appendix 1. The samples were then diluted by a factor of ten to accommodate for the sensitivity of the machine.

Four samples were randomly chosen to be tested as triplicates. The results of each triplicate sample, and their percent relative standard deviation (%RSD), could then be compared to assess the quality of the procedure as well as the consistency of the values of the machine.

I tested for eight heavy metals in total. I included Chromium (Cr), Manganese (Mn), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As), Cadmium (Cd), and three isotopes of lead (Pb), 206, 207, and 208. This suite of heavy metals is often tested for in soil pollution assessments. T-test calculations were done using R.

### ***Air Quality Methods***

Air quality was assessed using the Air Quality Egg, also called the Egg (Wicked Devices 2019), which measures particulate pollution in air (figure 5). The sensor runs continuously and saves data (averaged by minute) to an SD card, which can later be downloaded. The sensor can distinguish between and record particle pollutants that are 1.0µm, 2.5µm, and 10µm. Because it samples continuously, I used averages for general areas to indicate air quality. I collected 52 samples from along the arterials, and 250 samples along non-arterial roads. The difference in these numbers reflects that the non-arterial roads cover a much larger space than the arterials. I clipped the Egg to the outside of my backpack, and it was connected to a power source in my backpack. I kept the Egg sampling continuously while I rode my bike between sample sites. This created a suite of data that I separated by whether the sampling was done along the arterials or along any other road. If I had to travel along the arterials to get to another sample site, I would disconnect the Egg from its power source to prevent it from sampling. My sample sites were too distant to all sample in one day by bike, so sampling was done over the course of three days. When possible, I rode my bike in the shoulder, otherwise I rode on the sidewalk, but was regardless as close as I could safely be to the road. T-test calculations were done using R.

*Figure 5: Wicked Device’s Air Quality Egg (pen for scale)*

# Chapter 4: Results

### *Mobility Restrictions*

Mobility measurements found that pedestrians along the arterials have significantly less distance from the road, and that traffic along the arterials is significantly greater. These two stressors affect the pedestrian environment. Overall, the non-arterials had wider lanes than the arterials. Sidewalks along non-arterial road were on average narrower than arterial sidewalks, but when the distance between the road and sidewalk was added, non-arterial pedestrian areas were further from the road. Width per lane, road edge to sidewalk edge, road edge to furthest sidewalk edge were all found to be narrower along the arterials, with the arterials being a statistically significant explaining factor. The arterials also had statistically significant greater amounts of traffic. Arterials were found to have statistically significant wider sidewalks. All intersections along the arterials were equipped with ADA ramps, while only 3 out of 23 non-arterial roads had ADA ramps. The daily traffic along the arterials was about 6 times that along non-arterial roads (Esri 2018). Figures 6-10 show graphed representations of mobility results. A map of daily traffic counts in Poughkeepsie can be seen in Figure 11. Overall, these results show that pedestrians along the arterials experience increased levels of common stressors than pedestrians along non-arterials.

Table 1: Including results for width per lane, road edge to sidewalk edge (RE→ SE), Sidewalk width, road edge to furthest sidewalk edge (RE→ FSE), and most recently measured daily traffic value (Esri 2018).

| | Arterial mean (min, max) | Non-arterial mean (min, max) | Estimated Difference | Standard Error | t-value | Pr(>\|t\|) (p-value) |
|---|---|---|---|---|---|---|
| Width per lane | 4.03 (3.85, 4.13) | 4.75 (3.17,7.30) | -0.72 | 0.378 | -9.188 | 0.0001 |
| RE→ SE | 0.64 (0, 0.83) | 1.649 (0, 3.06) | -1.01 | 0.218 | -4.628 | 0.0001 |
| Sidewalk width | 1.58 (1.22, 2.64) | 1.13 (0, 2.64) | 0.45 | 0.23 | 1.956 | 0.048 |
| RE→ FSE | 2.22 (1.12, 2.64) | 2.78 (0, 4.26) | -0.557 | 0.213 | -2.618 | 0.0141 |
| Daily Traffic | 35170.20 (30000, 40105) | 5963.62 (882, 12910) | -29207 | 1881 | -15.53 | 1.27E-12 |
| ADA ramps | 6 out of 6 sample sites had ADA ramps | 3 out of 23 sample sites had ADA ramps | - | - | - | - |

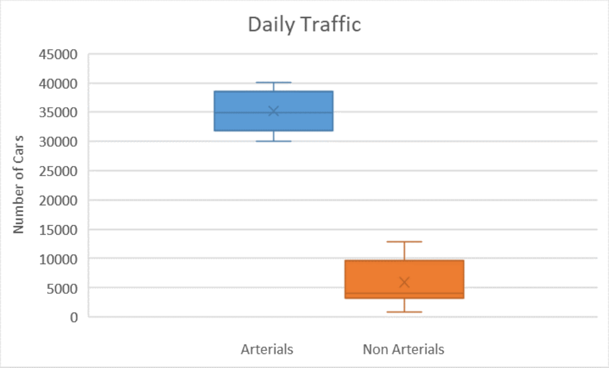


*Figure 6: Daily Traffic medians, quartiles, and outliers*

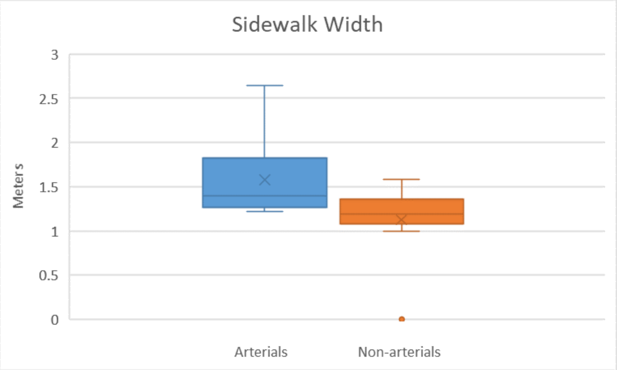


*Figure 7: Sidewalk Width median, quartiles, and outliers*

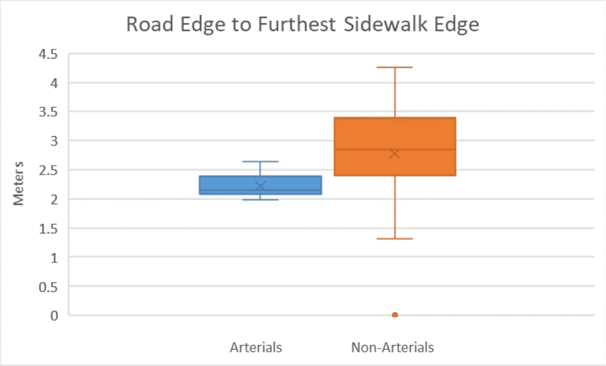


*Figure 8: Road Edge to Farthest Sidewalk Edge*

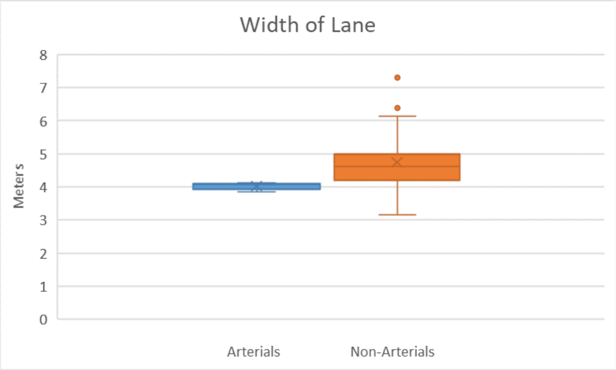


*Figure 9: Width of Lane median, quartiles, and outliers*

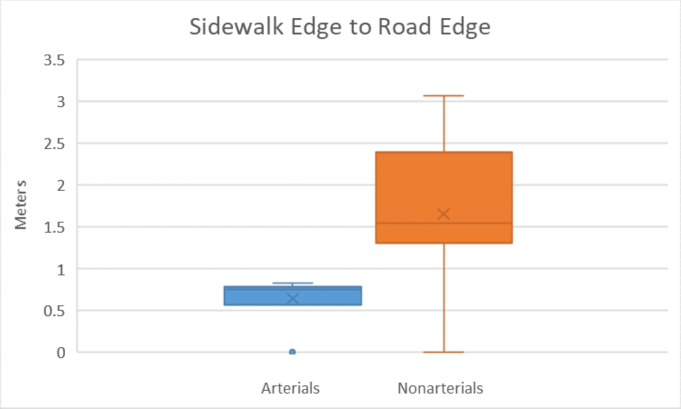


*Figure 10: Sidewalk Edge to Road Edge medians, quartiles, and outliers*

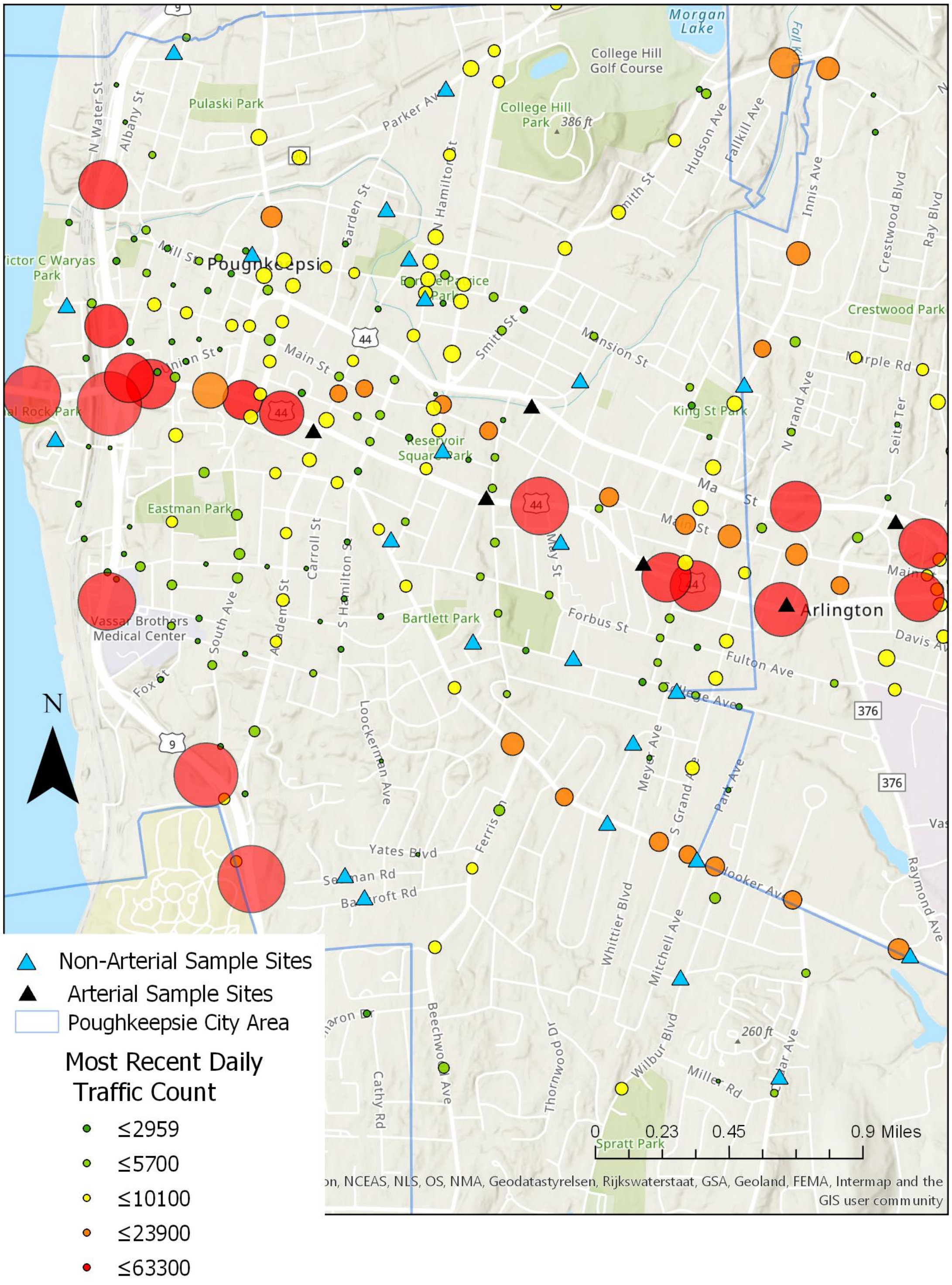


*Figure 11: Soil sample sites (blue triangle, non-arterial; black triangle, arterial) and most recent daily traffic count (Esri 2018).*

### ***Soil Quality***

Zinc, chromium, and cadmium all had statistically significant higher levels of contamination along arterial roads than along non-arterial roads (Table 2). The location of concentrations of zinc, chromium, and cadmium can be seen in Appendix 2. Arsenic, lead, nickel, and manganese were not significantly different between arterial and non-arterial samples (Table 2). Soil data reflects samples from 6 arterial and 23 non-arterial sample sites. Overall, 98.03% of the samples had a relative standard deviation (%RSD) value, a measurement done by the ICP-MS to assess accuracy, of less than 10%, which is considered to be the cutoff for accuracy. Values that were less accurate could have been impacted by the 'matrix effect', when material is too concentrated in a sample for the machine's usual calibrations.

Within the four triplicate samples, which were taken to assess the consistency of the procedure, 97% of results for each heavy metal had a less than 10% relative standard deviation between samples. Lead had some extreme variance between samples, possibly as a result of the matrix effect.

|  | Arterial mean (min, max) | Non-arterial mean (min, max) | Estimated Difference | Standard Error | t-value | Pr(>\|t\|) (p-value) |
|---|---|---|---|---|---|---|
| Zinc | 466.73 (171.30, 324.21) | 180.66 (70.12, 357.69) | -286.07 | 91.33 | -3.13 | 0.004 |
| Chromium | 42.44 (25.77, 57.96) | 19.14 (10.80, 47.20) | -23.25 | 4.07 | -5.71 | 4.02E-06 |
| Lead | 135.91 (47.51, 520.75) | 97.89 (23.95, 302.62) | -38.02 | 45.86 | -0.83 | 0.414 |
| Nickel | 23.20 (20.61, 25.97) | 20.93 (13.50, 31.80) | -2.27 | 1.52 | -1.50 | 0.145 |
| Manganese | 648.66 (505.35, 762.99) | 660.29 (484.00, 989.36) | 11.63 | 57.29 | 0.20 | 0.841 |
| Copper | 46399.92 (41216.70, 51941.57) | 41857.41 (27001.02, 63598.02) | -4542.00 | 3033.00 | -1.50 | 0.145 |
| Arsenic | 6.57 (5.65, 8.84) | 7.91 (5.36, 16.44) | 1.34 | 0.99 | 1.36 | 0.184 |
| Cadmium | 0.43 (0.26, 0.63) | 0.31(0.13, 0.56) | -0.12 | 0.05 | -2.34 | 0.026 |

Table 2: Metal concentrations in arterial and non-arterial soil samples

Figures 12-19: The following figures show median, quartiles and outliers for heavy metals. All arterial values are in blue on the left, and all non-arterial values are in orange on the right.

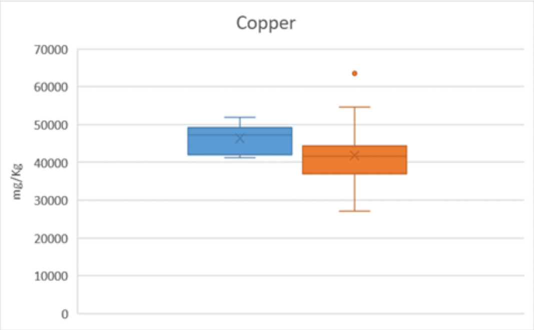


*Figure 12:Copper median, quartiles, and outliers*

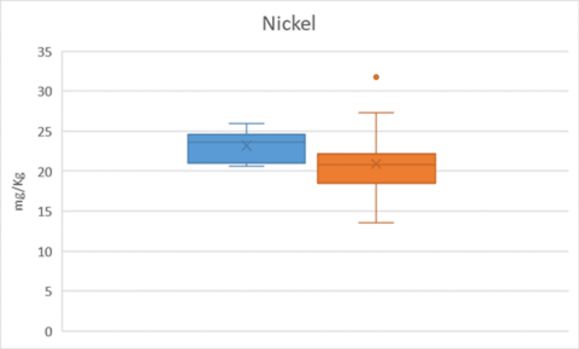


*Figure 13: Nickel median, quartiles, and outliers*

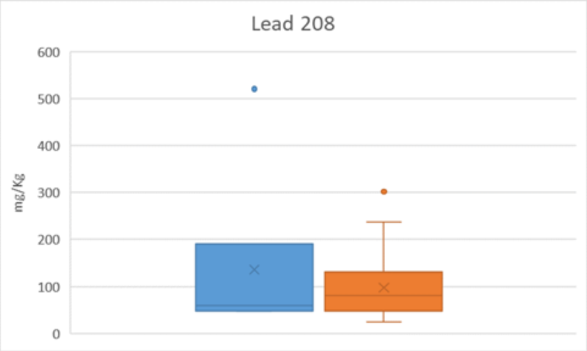


*Figure 14: Lead (208) median, quartiles, and outliers*

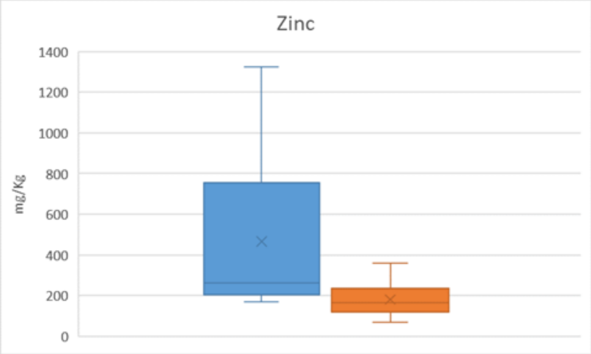


*Figure 15: Zinc median, quartiles, and outliers*

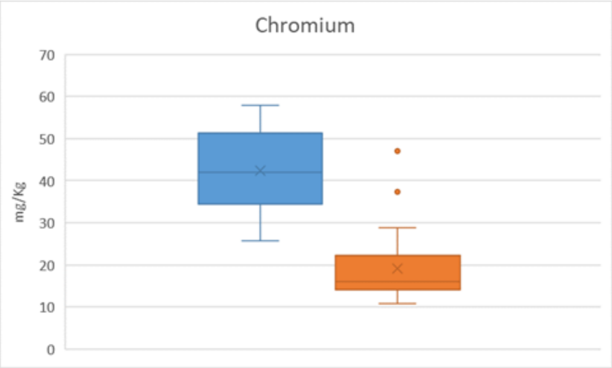


*Figure 16: Chromium median, quartiles, and outliers*

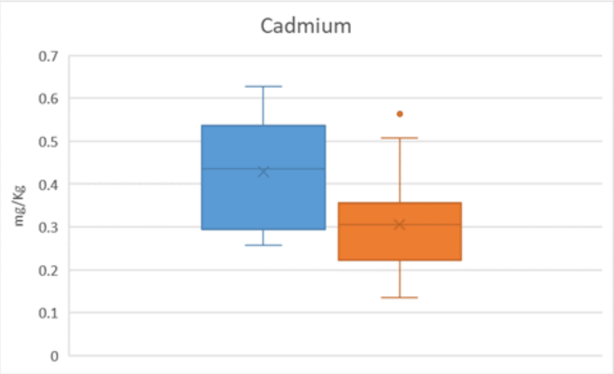


*Figure 17: Cadmium median, quartiles, and outliers*

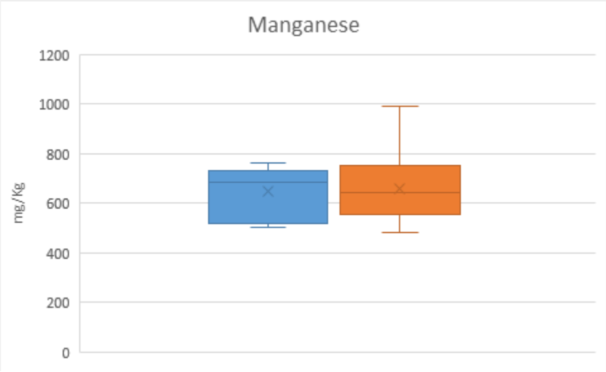


*Figure 18: Manganese median, quartiles, and outliers*

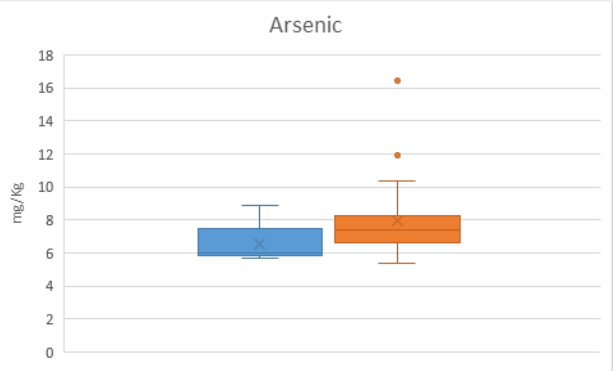


*Figure 19: Arsenic median, quartiles, and outliers*

### *Air Quality*

Particulate matter of all sizes was higher along arterials than non-arterial roads (table 3). The difference was greatest for heaviest particulate matter (PM 10) and least for the finest particulates (PM 1.0: figure 20), but it was significant for all types (table 3). Smaller sized particles (PM 2.5 and PM 1.0) have acute and significant effects on human health, and their significant higher concentration along the arterials is particularly concerning (Lipman et al. 2000). Particulate matter was measured in nanograms (µg) per meter cubed, or parts per million.

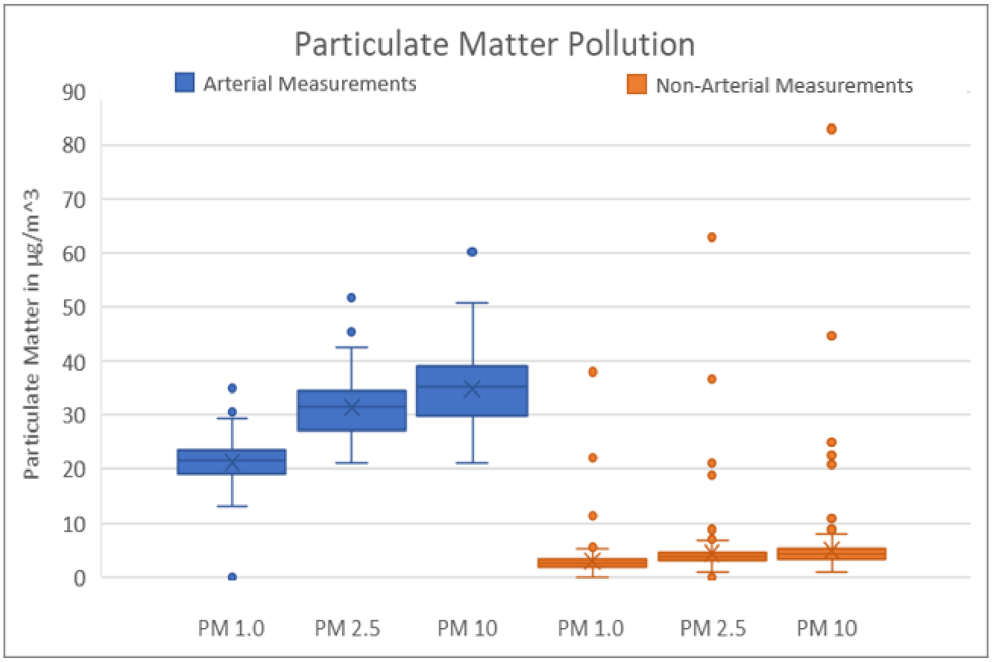


*Figure 20: Particulate matter medians, quartiles, and outliers*

T-tests indicated that difference in particulate matter pollution between the arterial and non-arterial roads was statistically strongly significant for all three sizes of particles (Table 3). The model estimated that mean concentrations non-arterial roads would have between 18.595 ppm (for PM1) and 29.9 ppm (PM10) less particulate matter pollution than arterial roads.

| PM | Mean (arterials) | Mean (non-arterials) | Estimate Difference | Standard Error | t-Value | Pr(>\|t\|)<br>(p-value) |
|---|---|---|---|---|---|---|
| 1 µm | 21.57 ppm | 2.99 ppm | -18.60 | 0.48 | -38.62 | <2e-16 |
| 2.5 µm | 31.43 ppm | 4.41 ppm | -27.02 | 0.78 | -34.83 | <2e-16 |
| 10 µm | 34.86 ppm | 4.96 ppm | -29.90 | 0.98 | -30.53 | <2e-16 |

Table 3: Particulate matter concentrations (PM 1.0, 2.5, or 10 µm diameter) along arterial (N = 52) and non-arterial (N = 250) roads.

# Chapter 5: Discussion

Mobility, soil pollution, and air pollution all contribute to the outcome of human health. Although this study cannot assess the exact extent of effects the arterials have had on human health, it does show how they have changed these three factors. Issues of localized environmental degradation that affect some populations more than others are a central tenet to theories of environmental injustice. Sacrifice zones are often associated with major extractive and industrial landscapes. However, this thesis supports how less extreme industries can also create a micro-environment of pollution and limited mobility.

While sampling, I was struck by the starkly different experiences between sampling along the arterials and sampling anywhere else in Poughkeepsie. Although I sampled along other busy roads (see figure 11), none had the same volume of cars, the lack of shoulder, or the same car speed. Most streets had side parking, or at least the equivalent of 2.5 lanes, which increases the space between a pedestrian on the sidewalk. Although this difference is not very noticeable in a car, the lack of space between sidewalk and traffic was intensely noticeable as a pedestrian. Sampling in the road verge felt very dangerous along the arterials. Frequently, speeding cars would be less than two feet away. It felt so unsafe that I would wait until a lull in traffic to collect my sample, a precaution I did not feel the need to take anywhere else.

### *Mobility Impacts*

When considering conditions of livability, it is important to remember that some impacts from are more difficult to measure than others. Although I have the ability to quantify soil and air quality through measurements which can then be related to health impacts, constraints on walkability require a pedestrian's perspective to be recounted. My sampling experience along the arterials was significantly more stressful than any other road I sampled along because of the speed, volume, and proximity of the cars. Other factors affecting pedestrian mobility are also difficult to quantify. One of the most important factors for pedestrian safety, the distance between driving cars and walking pedestrians, is ambiguous and difficult to calculate without proper instruments. It is difficult to measure exactly how far driving cars are on average from the sidewalk edge. Along the arterials, cars drive along the white line, leaving an average of a 0.6-meter gap between pedestrians and automobiles. However, many roads in Poughkeepsie do not have white lines delineating where the driving lanes ends. When there is side street parking, cars drive closer to the middle of the road to leave room for the parked cars, providing a cushion of ten or twenty feet from the driving lane and the sidewalk. However, because this tendency typically not marked, it is difficult to directly quantify. Speed of car is another one of the most important factors impacting pedestrian safety. However, speed limits are not necessarily reflective of the average speed of a car. Along the arterials, the speed limit is 35 mph, but it is expected cars travel at least 40 miles per hour. However, without an accurate means of speed assessment, this reality is difficult to substantiate.

Some obstacles to mobility, like transient obstacles, are also difficult to gather information on. While I was sampling along the arterials, I encountered two obstacles that were not directly related to street structure or traffic. In one case, snow had been plowed into a pile in front of an ADA ramp at an intersection, forcing me to carry my bike about four feet to get onto the sidewalk. Also along the arterials, a work truck was parked on the sidewalk, completely blocking any pedestrian traffic. I had to double back to the nearest stoplight and cross the street to get around. When shoulders and street parking are neglected, what is intended to be exclusively pedestrian space becomes optional automobile territory. These instances of obstacles to mobility would be very difficult to record and compare because they are not permanent.

The variables that affect pedestrian stress that I could measure show a clear difference between the mobility environment along the arterials compared to other roads. Possibly the most defining characteristic of the arterials is the daily volume of cars that use them. The North-South arterial, or Route 9, is the only other road in Poughkeepsie that has similar car volumes. When the range of daily traffic is compared between the arterials and the non-arterials, the difference is very clear. The lowest value along the arterials is still more than twice that of the largest number of cars along the non-arterials (table 1).

Other measurable qualities that augment pedestrian stress were shown to be worse along the arterials as well. The arterials have very narrow lane width compared to other streets, which means there is not much extra space in the road and forcing cars to drive close to the road edge. Narrow lane width creates an environment where cars drive closer to where pedestrians walk (table 1). Measuring the distance from road edge to furthest sidewalk edge also provides an assessment of pedestrian proximity to cars. The data shows that pedestrians have less distance from the road along the arterials than along other roads (table 1).

Although the data cannot quantify the extent to which pedestrian mobility is inhibited by the arterials, it clearly shows that several important stressors to mobility are more stressful along the arterials. It is also important to note how these factors interact. Not only is the volume of cars much higher along the arterials, pedestrians are also closer to those cars. These results have implications for mobility, quality of life, and resident health. Landscapes that discourage pedestrian mobility can increase lack of exercise related health effects like obesity (Frank et al. 2006), and increased stress from car proximity and volume can increase stress related diseases

(Speck 2012). The stressful pedestrian environment along the arterials contributes to the automobility sacrifice zone along the arterials.

### ***Soil Quality***

Three of the heavy metal pollutants tested, zinc, chromium, and cadmium all had statistically significant higher levels of pollution along the arterials than along non-arterial roads. Two others, nickel and copper have low p values (both were 0.145), which may become statistically significant in a study with a larger number of sample sites. Lead, manganese, and arsenic had very little statistical difference between arterial and non-arterial sites. The higher p value of lead (0.414) may reflect that lead has become a less significant pollutant from automobiles since lead in fuel has been banned (Pariente et al. 2019, Wawer et al. 2015).

Determining which aspect of vehicle operation causes higher concentrations is not evident from the data. The heavy metals that were statistically significant did not have an obvious source. Zinc, cadmium and chromium can all be found in brake lining (Saha et al. 2011, Wawer et al. 2015), but many of the other heavy metals tested can also be found in brake lining. Cadmium and zinc are released through tire degradation as well, while chromium is the only tested pollutant that comes from catalytic converters and some kinds of paint. Although this study does not conclude what specific kind of automobile emission is causing pollution, it does show that certain heavy metals associated with automobile pollution are found in greater concentration along the arterials than along other roads in Poughkeepsie.

Although the arterials have statistically higher values of some pollutants, these higher values still do not reach the threshold for the EPA to consider them necessary to clean up (Grubinger and Ross n.d.). However, the potential for serious health effects from these concentrations should not be overlooked. Cadmium is persistent and toxic and has been found to be an endocrine disruptor and can affect bone growth (Pan et al. 2009). Long term exposure to chromium can cause damage to liver, kidney circulatory and nerve tissues, as well as skin irritation (Martin and Griswold 2009). Zinc has a lower risk of harming humans once it is in the soil because such high quantities would need to be consumed to affect a human, but it could cause skin irritation (US Department of Health and Human Services 2005). As long as traffic levels remains the same on the arterials, heavy metal levels should continue to be monitored. Because the data shows that the arterials likely create concentrations of certain kinds of pollutants, it is possible that over time these concentrations will increase. Although lead values were not statistically significant, one sample site along the arterial had more than 100 ppm more lead than the EPA soil level requiring cleanup (EPA 2015). Again, because the arterials cross through residential areas, chronic exposure can lead to increased danger of heavy metals accumulating in a body (Hassaan et al. 2016). The fact that the current amount of traffic can impact the concentration of heavy metals along the arterials impresses the importance of continued monitoring. Although the levels of soil pollutants found do not require immediate remediation, their concentration shows that the arterials affect soil health.

### ***Air Quality***

The air quality data shows a clear and significant differences between air quality along the arterials and along other roads (see figure 20 and table 3). Particulate matter (PM) pollution along the arterials was shown to be multiple times greater than the non-arterials. In particulate matter pollution, the EPA considers PM 2.5 to be the most harmful. This is because the particles are small enough to easily be inhaled and transferred into the bloodstream, meaning it can have the greatest effect on human health. As of 2011, the EPA set the limit of acceptable annual exposure to PM 2.5 to 12 micrograms/cubic meter. Along the arterials, PM 2.5 averaged at 32 micrograms/cubic meter, nearly three times the recommended exposure limit by the EPA (EPA 2013).

Health effects from particulate matter exposure can range from non-permanent damage to respiratory processes to severe and life-threatening complications. Chronic exposure to PM 2.5 pollution has been found to shorten life expectancy and increase likelihood of respiratory diseases like asthma (Amann et al. 2006). Additionally, susceptibility varies greatly on a person by person basis, and negative health effects can occur at even very low levels of exposure, especially in vulnerable groups like children and those with preexisting conditions (Amann et al. 2006, Grigg 2009).

This data reveals a need for further air quality sampling of additional pollutants beyond particulate matter. Because particulate matter pollution is so high near the arterials, it is likely that other pollutants from automobile emissions, like NOx and VOCs, are also in higher concentrations along the arterials and should be quantified. Additionally, it shows that immediate action needs to be taken in order to increase air quality to acceptable EPA standards. Although altering the arterials through changing the volume traffic would be most effective towards improving air quality, it would also take significant time. In the interim, vegetation could be planted to ameliorate some effects of automobile emissions (Baldauf 2017).

The difference in particulate matter pollution along the arterials clearly shows how creating automobility also creates sacrifice zones. Concentrations in 2.5PM are roughly three times EPA recommended chronic exposure levels and are on average seven times that of non-arterial levels. Chronic exposure to these levels can cause serious respiratory health effects, in particular to already vulnerable groups. The decreased air quality along the arterials contributes to the micro-environment of pollution and has severe implications for resident health.

### ***Vulnerable Groups***

In issues of environmental injustice, it is important to acknowledge the patterns along racial lines where instances of environmental pollution often occur. Figure 21 shows populations of people of color (POC) divided by whites using data aggregated by 2010 census block groups, where darker blue areas indicate higher concentrations of people of color. POC/Whites is an equation take from the Federal Highway Administration guidelines created to determine if adverse effects are disproportionate within a buffer zone of a transportation system change (Chakraborty 2019). Most recent census data was not available on a fine enough scale to assess race and income by household to determine effects within a 150-meter buffer, but the block groups along the arterials in figure 21 have proportionately higher people of color than other areas. Although there is not evidence that the arterials have created the uneven spatial distribution of racial groups, this map does show that groups often affected by environmental injustice is also affected by the increased pollution found along the arterials.

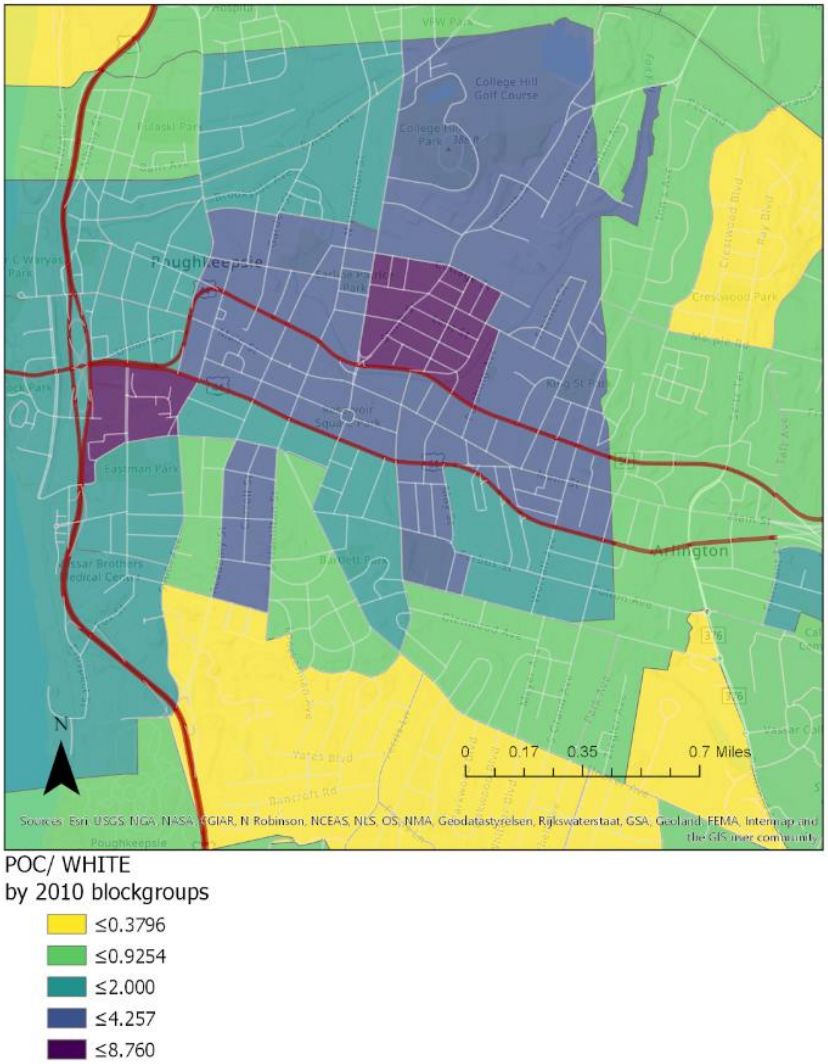
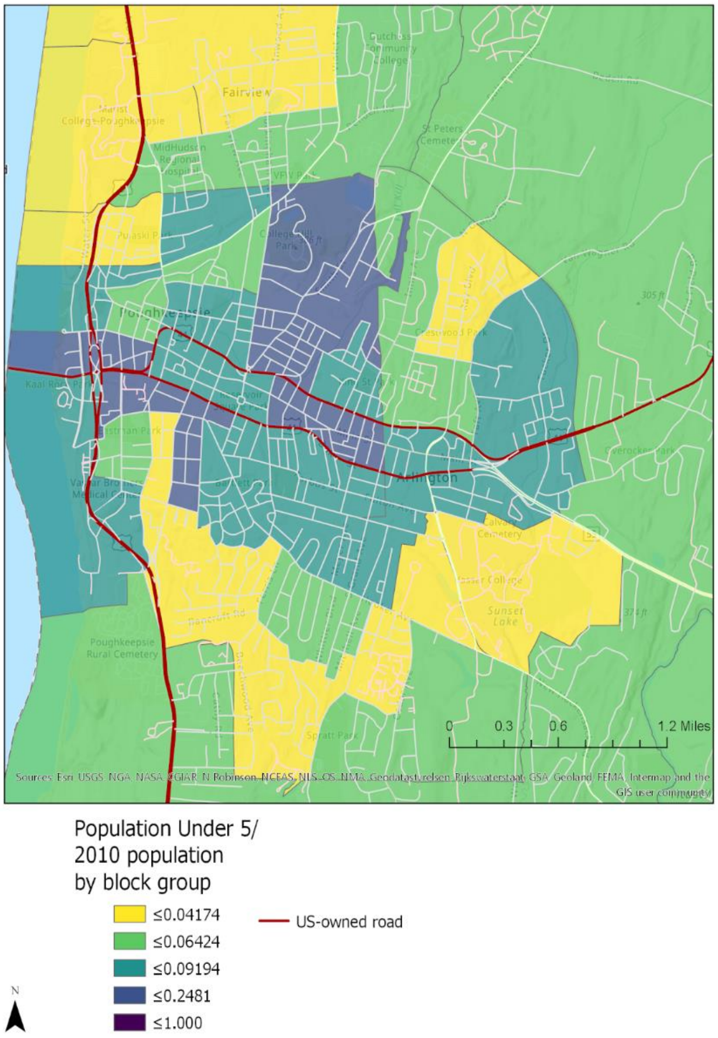


*Figure 21:This map shows populations of POC divided by white populations by 2010 census block groups. Red lines indicate arterial roads, while white lines are non-arterials.*

This pattern can be seen in Figure 2, which shows median household income in Poughkeepsie and in the broader Dutchess county area. Higher concentrations of lower income groups are seen in Poughkeepsie, and especially along the arterials. Again, although the arterials are not the only factor affecting distribution of income groups, the arterials were built through an area of lower income, and those residents bear the majority of its effects.

When measuring any pollution, younger people are more susceptible to negative health effects. The EPA often implements lower thresholds when children are likely to be exposed. Particulate matter pollution that is less than 10 nanometers, like that measured along the arterials, can negatively affect growth of lung function and increase the likelihood of respiratory issues in children (Grigg 2009). Figure 22 shows percentages of 5-year-olds normalized by total population within block groups from the 2010 census. The darker blue areas have more children 5 and under, showing higher concentrations of young children along the arterials.



Sources: Esri, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community

*Figure 22: shows concentrations of populations under 5 by 2010 block census groups. Red lines show arterial roads and white lines show non-arterial roads.*

A central component of environmental justice is examining intersections of pollution and low income and minority groups. Although laws were passed in the 1990's that acknowledge and attempt to disrupt the patterns of the harms of transportation systems (Chakraborty 2006), my analysis indicates that the arterials distribute negative effects disproportionately to vulnerable groups. Additionally, the presence of young children living along the arterials causes additional concern, as children are more susceptible to developing negative health effects due to pollution exposure, such as PM 2.5. The arterials embody ideas of environmental injustice and sacrifice zones, both in their environment of concentrated pollution and decreased mobility and in their disproportionate effects on low income groups and people of color.

# Conclusion

My study of the effects of the arterials has shown that concentrating cars in residential areas negatively affects the environment in ways that have the potential to impact human health. Our prioritization of and dependence on cars has created a narrative where sacrificed zones have become necessary to enable their mobility. Cars are so necessary that as a society we tend to not notice or question the infrastructure or the problems they cause, even when they starkly disrupt a residential area. From the vantage point of a car, the arterials the speed and ease of driving on the arterials make them unremarkable. Only a fraction of people who use the arterials will ever interact with them without a car. These experiences make it easy for the general public to ignore the potential negative health impacts of the arterials.

Although arterial air quality is significantly worse than in non-arterial areas, it is not exceptionally worse than many urban areas (Amann et al. 2006). This level of exposure to pollutants that entails serious health effects has become normalized in order to prioritize car mobility. Concentrating car traffic in residential areas will create a sacrifice zone, chronically exposing the people that live there to higher pollution levels and increasing mobility stress, two components that affect health. A world of streamlined automobility is a world where car speed is prioritized over human health.

Proximity and duration are integral to the severity of exposure from pollution. Because the arterials run through residential areas, often very close to homes, the current landscape disregards exacerbations of pollution impacts. If roads with similar volume as the arterials were made in a less dense area, where homes could be further from the road, the environmental pollution would be similar, but less people would be adversely affected. Obviously, there are many obstacles to completely redoing any major road. In the interim, decreasing the arterials to two wider lanes would increase the space between homes and cars. Increasing vegetation between the road and homes would also improve air quality (Venn et al. 2001).

The current lack of information about the arterials' impact on their surroundings allows them to seem unimportant or even non-existent. The status quo can masquerade as a neutral path, and doing anything to change it, such as changing the arterials, challenges what we consider normal. This can make it seem like ignoring the effects of the arterials causes no harm, when in actuality the arterials have cumulative and consistent effects on environmental and human health. This quantitative assessment of the consequences of the arterials gives future projects the ability to cite the specific impacts caused by the arterials compared to the environment for most city denizens.

The arterials embody issues associated with environmental justice. First, there is a delineated area were residents experience an environment of increased pollution. Second, many of those residents are likely to be a part of already exploited racial and socioeconomic groups. Third, the benefit of the arterials is unevenly distributed to those who travel through Poughkeepsie, and not for those who live in Poughkeepsie. The unequal distribution of benefits and harm along lines of class and race make the arterials important to discussions of environmental justice.

The effects of the arterials are not isolated or unique. My study in Poughkeepsie can show the myriad of effects of these projects that were not considered in the initial reckoning of cost. Poughkeepsie's arterials represent challenges and silences in the greater national narrative against urban highways. By advocating for a full understanding of the cumulative effects of structures like the arterials on the livability and health of residents, I challenge the narrative that the built environment and the presence of cars are neutral occurrences. The arterials' impacts on health, the built environment, mobility, and environmental effects all interact to create reduced livability, and continue to reproduce the forces that initially shaped these impacts through the construction of the arterials.

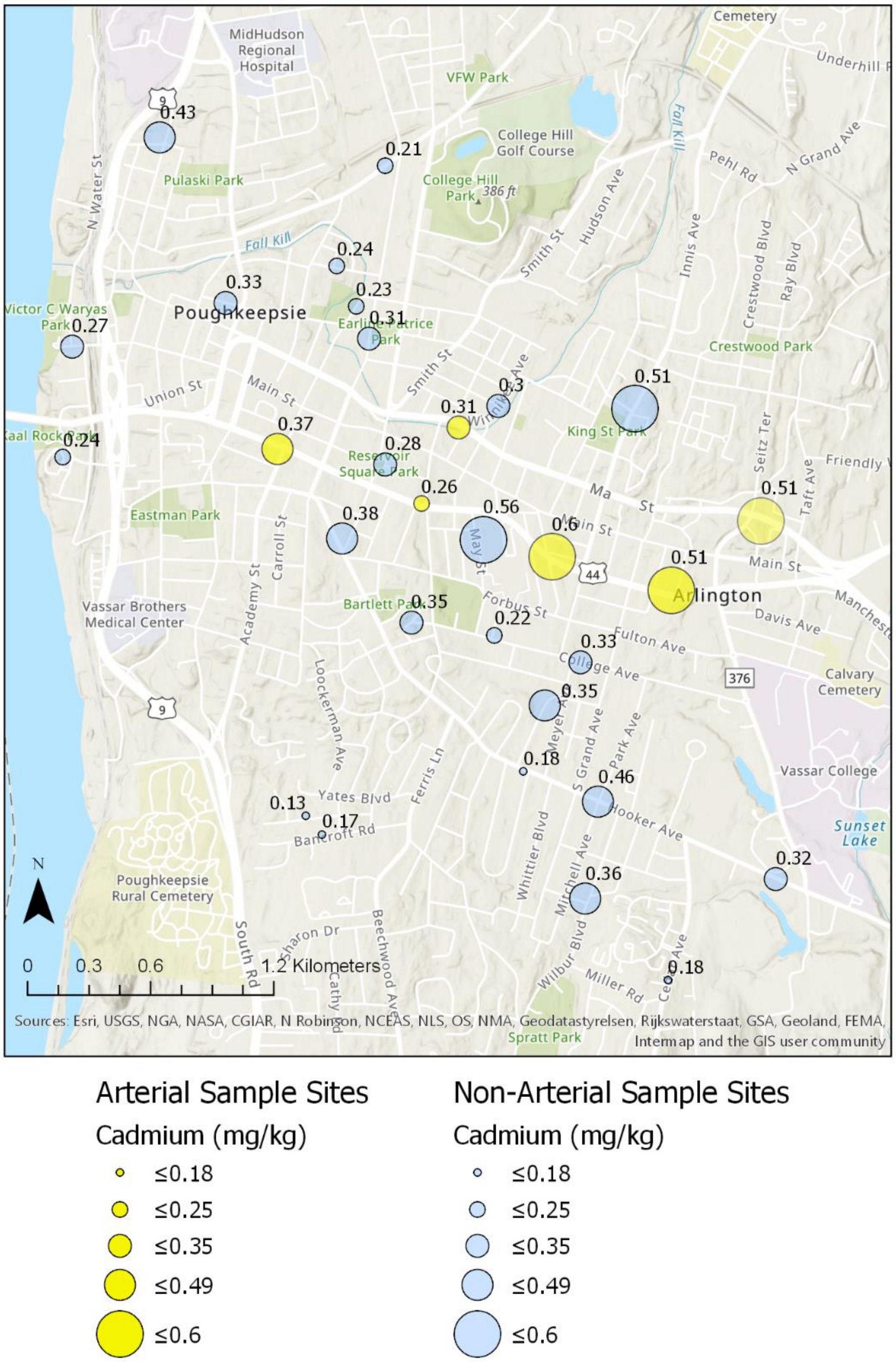
# Appendix 1: Soil Analysis Procedure

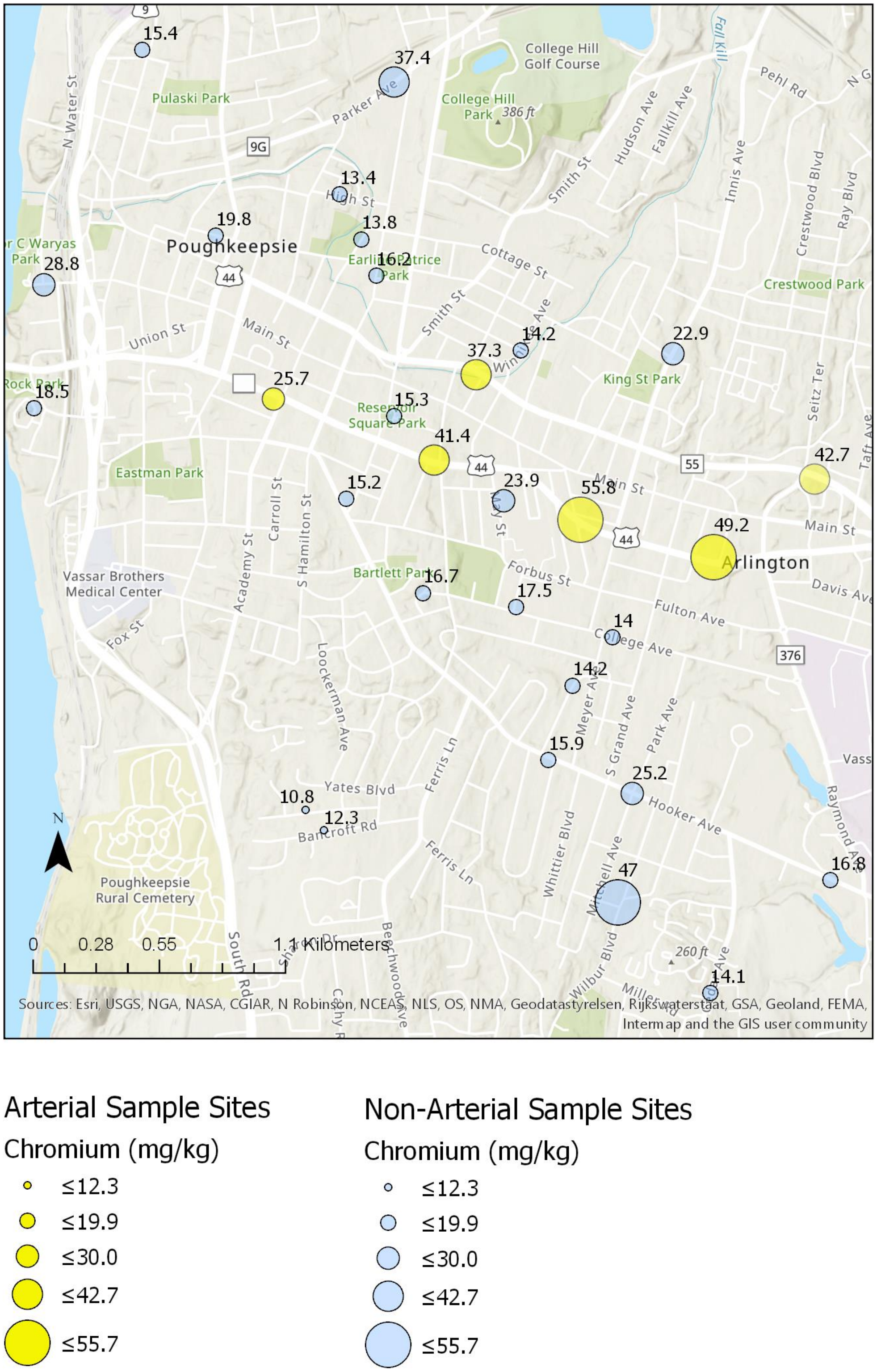
**Procedure:** To test for heavy metal pollution in soil samples, soils were dried, digested, and analyzed using inductively coupled plasma mass spectronomy (ICPMS). The digestion procedure below is modified from EPA standard procedure. Soil samples were collected and dried at 60˚C. They were then ground and sieved so grain size was uniform, and detritus was removed.

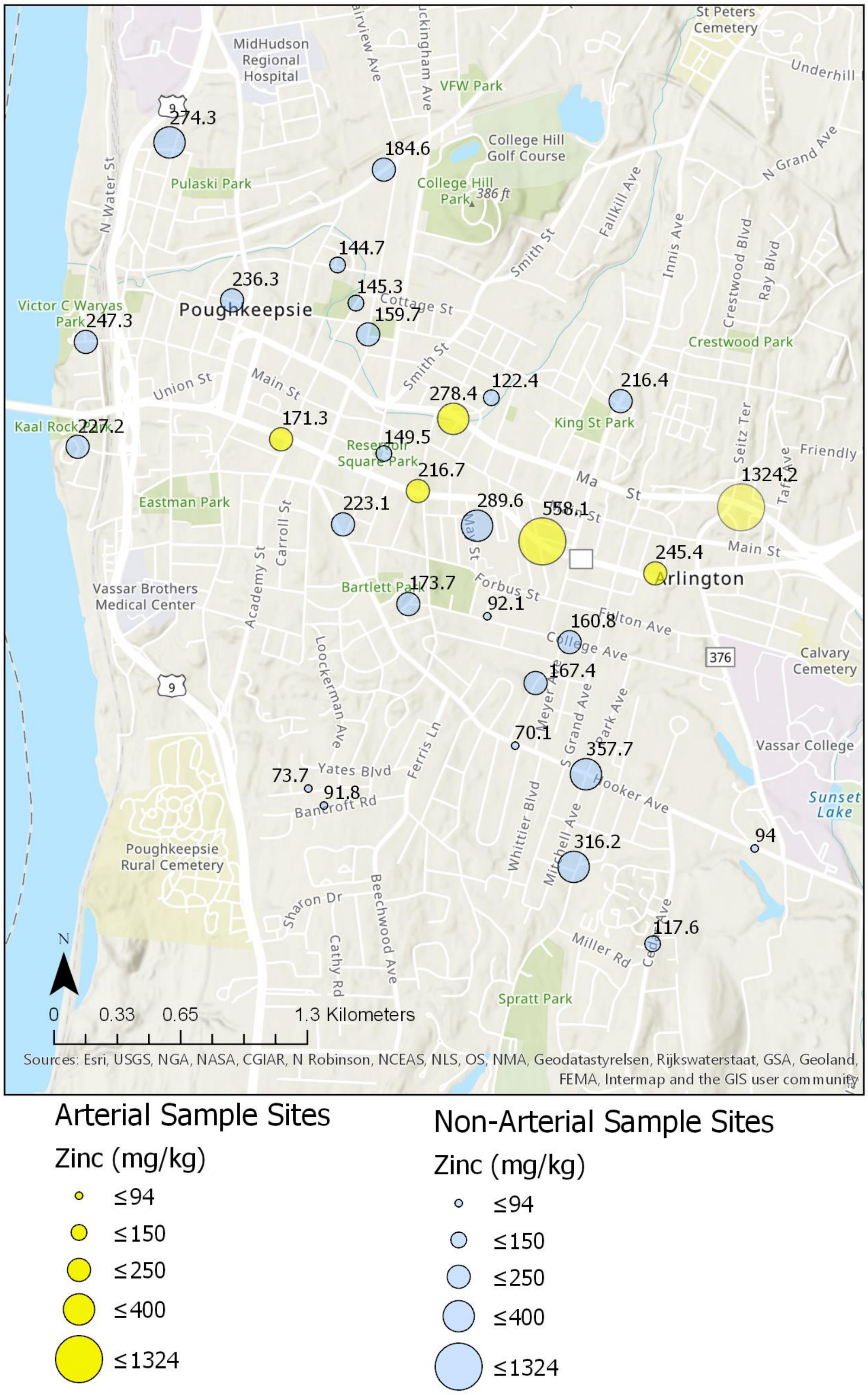
**Digest for ICP MS**

1. Weigh out approximately 0.5 grams to the nearest 0.1 mg of each sample into a DigiPrep digestion tube. Choose one sample to do 2 replicates (3 samples total) and one of the higher NIST reference soils to digest as well.
2. Also include two empty digiprep tubes to use as digest blanks.
3. Add 5 mL 50% trace metal grade $HNO_3$, cover with a watch glass, and heat on the digiprep at 95°C for 15 minutes without boiling.
4. Allow the sample to cool and add 2.5 mL concentrated $HNO_3$. Take care to not lose digest from the watch glasses or mix up or contaminate watch glasses.
5. Replace the cover and heat for 30 min, or until no powder remains visible.
6. Add 1.0 mL water and 1.5 mL 30% $H_2O_2$.
7. Repeat the addition of water and peroxide until no further bubbling is observed, up to 5 aliquots added in total.
8. Heat for another 30 minutes at 95° C with watch glasses on top. Do not allow the samples to go dry-- add further water as needed.
9. Bring samples to 50 mL with dd H2O in the digiprep tubes.
10. Cool, then filter with fluted filter paper and save the digest in a clean 50 mL centrifuge tube.

# Appendix 2: Distribution of Significant Heavy Metals in Poughkeepsie




15.4
37.4
College Hill Golf Course
Pulaski Park
Parker Ave
College Hill Park
386 ft
N Water St
9G
13.4
High St
19.8
13.8
Poughkeepsie
C Waryas Park
28.8
Earlier Beatrice Park
16.2
Cottage St
Smith St
Hudson Ave
Fallkill Ave
Innis Ave
Crestwood Blvd
Ray Blvd
Pehl Rd
Fall Kill
Crestwood Park
Union St
Main St
14.2
22.9
37.3
King St Park
Rock Park
18.5
25.7
Reservoir Square Park
15.3
41.4
Seitz Ter
Taft Ave
55
42.7
Eastman Park
15.2
23.9
55.8
Main St
Carroll St
S Hamilton St
Academy St
49.2
Arlington
Vassar Brothers Medical Center
Bartlett Park
16.7
Forbus St
17.5
Davis Ave
Fulton Ave
Fox St
14
College Ave
376
Loockerman Ave
14.2
Meyer Ave
S Grand Ave
Park Ave
Ferris Ln
15.9
Vass
25.2
Yates Blvd
Hooker Ave
10.8
12.3
Bancroft Rd
Raymond Ave
N
16.8
Whittier Blvd
Mitchell Ave
47
Poughkeepsie Rural Cemetery
0
0.28
0.55
1.1 Kilometers
South Rd
Beechwood Ave
Wilbur Blvd
260 ft
14.1
Sources: Esri, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community
Arterial Sample Sites
Chromium (mg/kg)
≤12.3
≤19.9
≤30.0
≤42.7
≤55.7
Non-Arterial Sample Sites
Chromium (mg/kg)
≤12.3
≤19.9
≤30.0
≤42.7
≤55.7



Sources: Esri, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community

# References

Ajmone-Marsan, F., Biasioli, M., Kralj, T., Grčman, H., Davidson, C. M., Hursthouse, A. S., . . . Rodrigues, S. (2008). *Metals in particle-size fractions of the soils of five european cities* doi://doi.org/10.1016/j.envpol.2007.05.020

Amann, Markus, Richard Derwent, Bertil Forsberg, Fintan Hurley, Michal Krzyzanowski, Birgit Kuna-Dibbert, Steinar Larssen, Frank de Leeuw, Sally Jane Liu, Jürgen Schneider, Per E. Schwarze, David Simpson, John Stedman, Peter Straehl, Leonor Tarrasón and Leendert van Bree. (2006). *Health risks of particulate matter from long-range transboundary air pollution.* World Health Organization.

Avila, E., & Rose, M. H. (2009). Race, culture, politics, and urban renewal: An introduction. *Journal of Urban History, 35*(3), 335-347. doi:10.1177/0096144208330393

Baldauf, R. (2017). *Roadside vegetation design characteristics that can improve local, near-road air quality*doi://doi.org/10.1016/j.trd.2017.03.013

Bullard, R. D. (2015). Environmental justice in the united states. *International encyclopedia of the social & behavioral sciences: Second edition*(pp. 756-762) doi:10.1016/B978-0-08-097086-8.91013-4 Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85014825071&doi=10.1016%2fB978-0-08-097086-8.91013-4&partnerID=40&md5=4bd1eb58b3c00b5766226040656edd33

Chakraborty, J. (2006). *Evaluating the environmental justice impacts of transportation improvement projects in the US*doi://doi.org/10.1016/j.trd.2006.06.003

Chen, H., Kwong, J. C., Copes, R., Tu, K., Villeneuve, P. J., van Donkelaar, A., . . . Burnett, R. T. (2017). Living near major roads and the incidence of dementia, parkinson's disease, and multiple sclerosis: A population-based cohort study. *The Lancet, 389*(10070), 718-726. doi:10.1016/S0140-6736(16)32399-6

Crenson, M. A. (1971). *The un-politics of air pollution: A study of non-decisionmaking in the cities*. Baltimore: Johns Hopkins Press.

Dao, L., Morrison, L., & Zhang, C. (2010). *Spatial variation of urban soil geochemistry in a roadside sports ground in Galway, Ireland* doi://doi.org/10.1016/j.scitotenv.2009.11.022

Davidson, H. (2009). Methods of soil analysis - A summary of some of the many methods of soil analysis. Retrieved from https://www.mdpi.com/1660-4601/10/3/762/htm

Davis, A. P., Shokouhian, M., & Ni, S. (2001). *Loading estimates of lead, copper, cadmium, and zinc in urban runoff from specific sources*doi://doi.org/10.1016/S0045-6535(00)00561-0

Design for Health. 2007. Health Impact Assessment Preliminary Checklist Background and Instructions. Version 2.0. www.designforhealth.net

Dilawar, A. (). New york city transplants and a river town’s natives fight for its soul. *March 1, 2019*

Environmental Protection Agency. 2015. Best Practices for Reducing Near-Road Pollution Exposure at Schools. https://www.epa.gov/sites/production/files/2015-10/documents/ochp_2015_near_road_pollution_booklet_v16_508.pdf.

Esri. "World Traffic" [Map]. Scale Not Given. "World Traffic Map". October 18, 2018. https://vassar.maps.arcgis.com/home/item.html?id=bbdcd78953e5439985004023c8eda03d (April 18, 2019).

Fishbein, L. (1981). Sources, transport and alterations of metal compounds: An overview. I. arsenic, beryllium, cadmium, chromium, and nickel.*Environmental Health Perspectives, 40*, 43-64. doi:10.1289/ehp.814043

Flad, H. K., & Griffen, C. (2009). *Main street to mainframes: Landscape and social change in poughkeepsie*. Albany: Excelsior Editions.

Fox, J. (1999). Mountaintop removal in west virginia: An environmental sacrifice zone. *Organization & Environment, 12*(2), 163-183. doi:10.1177/1086026699122002

Frank, L. D., Sallis, J. F., Conway, T. L., Chapman, J. E., Saelens, B. E., & Bachman, W. (2006). Many pathways from land use to health: Associations between neighborhood walkability and active transportation, body mass index, and air quality. *Journal of the American Planning Association, 72*(1), 75-87. doi:10.1080/01944360608976725

Grad, F. P., Rosenthal, A. J., Rockett, L. R., Fay, J. A., Heywood, J., Kain, J. F., . . . Tietenberg, T. (1975). No title. *Automobile and the Regulation of its Impact on the Environment,*

Grigg, J. (2009). Particulate matter exposure in children: Relevance to chronic obstructive pulmonary disease. *Proceedings of the American Thoracic Society, 6*(7), 564-569. doi:10.1513/pats.200905-026RM [doi]

Grubinger, V., & Ross, D.*Interpreting the results of soil tests for heavy metals.* ().University of Vermont. Retrieved from http://www.uvm.edu/vtvegandberry/factsheets/interpreting_heavy_metals_soil_tests.pdf

Hanson, S., & Giuliano, G. (2004). *The geography of urban transportation* (3rd ed.). New York: Guilford Press

Hargrove, M. M., McGee, J. K., Gibbs-Flournoy, E., Wood, C. E., Kim, Y. H., Gilmour, M. I., & Gavett, S. H. (2018). Source-apportioned coarse particulate matter exacerbates allergic airway responses in mice. *Inhalation Toxicology, 30*(11-12), 405-415. doi:10.1080/08958378.2018.1542047

Hassaan, M., El Nemr, A., & Madkour, F. (2016). *Environmental assessment of heavy metal pollution and human health risk*doi:10.11648/j.ajwse.20160203.11

Hoek, G., Brunekreef, B., Goldbohm, S., Fischer, P., & van den Brandt, P. A. (2002). Association between mortality and indicators of traffic-related air pollution in the netherlands: A cohort study. *Lancet (London, England), 360*(9341), 1203-1209. doi:S0140-6736(02)11280-3 [pii]

Hoffmann, V., Knab, M., & Appel, E. (1999). *Magnetic susceptibility mapping of roadside pollution* doi://doi.org/10.1016/S0375-6742(99)00014-X

Kay, J. H. (1997). *Asphalt nation: How the automobile took over america, and how we can take it back.* Berkeley: University of California Press.

Kitchens, S. (2018, Sept. 20,). Not the next Hudson Newburgh, Catskill, and Troy, once downtrodden, are hoping recent revitalization doesn’t get out of hand. *New York Magazine*

Lerner, S. (2010). *Sacrifice zones; the front lines of toxic chemical exposure in the united states* Mit Press. Retrieved from http://www.jstor.org/stable/j.ctt5hhkv7

Lippmann, M., Ito, K., Nadas, A., & Burnett, R. T. (2000). Association of particulate matter components with daily mortality and morbidity in urban populations. *Research Report (Health Effects Institute),* (95), 82.

Marshall, J. D., Michael, B., & Frank, L. D. (2009). Healthy neighborhoods: Walkability and air pollution. *Environmental Health Perspectives, 117*(11), 1752-1759. doi:10.1289/ehp.0900595

Martin, S., & Griswold, W. (2009). Human health effects of heavy metals. *Environmental Science and Technology Briefs for Citizens, 15*, 1-6.

Mohammed, A. S., Kapri, A., & Goel, R. (2011). Heavy metal pollution: Source, impact, and remedies. In M. S. Khan, A. Zaidi, R. Goel & J. Musarrat (Eds.), *Biomanagement of metal-contaminated soils* (pp. 1-28). Dordrecht: Springer Netherlands. doi:10.1007/978-94-007-1914-9_1 Retrieved from https://doi.org/10.1007/978-94-007-1914-9_1

Morton-Bermea, O., Hernández-Álvarez, E., González-Hernández, G., Romero, F., Lozano, R., & Beramendi-Orosco, L. E. (2009). Assessment of heavy metal pollution in urban topsoils from the metropolitan area of mexico city. *Journal of Geochemical Exploration, 101*(3), 218-224.

Nabulo, G., Oryem-Origa, H., & Diamond, M. (2006). *Assessment of lead, cadmium, and zinc contamination of roadside soils, surface films, and vegetables in kampala city, uganda* doi://doi.org/10.1016/j.envres.2005.12.016

Oliveira, G., & Hecht, S. (2016). Sacred groves, sacrifice zones and soy production: Globalization, intensification and neo-nature in south america. *Journal of Peasant Studies, 43*(2), 251-285. doi:10.1080/03066150.2016.1146705

Pan, J., Plant, J. A., Voulvoulis, N., Oates, C. J., & Ihlenfeld, C. (2010). Cadmium levels in europe: Implications for human health. *Environmental Geochemistry and Health, 32*(1), 1-12.

Pariente, S., Helena, Z., Eyal, S., Anatoly, F. G., & Michal, Z. (2019). *Road side effect on lead content in sandy soil*doi://doi.org/10.1016/j.catena.2018.11.014

Piron-Frenet, M., Bureau, F., & Pineau, A. (1994). *Lead accumulation in surface roadside soil: Its relationship to traffic density and meteorological parameters* doi://doi.org/10.1016/0048-9697(94)90449-9

Pucher, J., & Clorer, S. (1992). Taming the automobile in germany. *Transportation Quarterly, 46*(3)

Saha, R., Nandi, R., & Saha, B. (2011). Sources and toxicity of hexavalent chromium. *Journal of Coordination Chemistry, 64*(10), 1782-1806. doi:10.1080/00958972.2011.583646

Schweitzer, L., & Valenzuela, A. (2004). Environmental injustice and transportation: The claims and the evidence. *Journal of Planning Literature, 18*(4), 383-398. doi:10.1177/0885412204262958

Scott, R. R. (2018). Structures of environmental inequality: Property and vulnerability. *Environmental Justice, 11*(3), 137-142. doi:10.1089/env.2017.0042

Semuels, A. 2015, November 25. “Highways Destroyed America's Cities”. Retrieved December 1, 2018, from https://www.theatlantic.com/business/archive/2015/11/highways-destroyed-americas-cities/417789/

Sezgin, N., Ozcan, H. K., Demir, G., Nemlioglu, S., & Bayat, C. (2004). Determination of heavy metal concentrations in street dusts in istanbul E-5 highway. *Environment International, 29*(7), 979-985.

Shade, L. (2015). *Sustainable development or sacrifice zone? politics below the surface in post-neoliberal ecuador*doi://doi.org/10.1016/j.exis.2015.07.004

Sheller, M., & Urry, J. (2000). The city and the car. *International Journal of Urban and Regional Research, 24*(4), 737-757. doi:10.1111/1468-2427.00276

Solgi, E., Roohi, N., & Kouroshi-Gholampour, M. (2016). *A comparative study of metals in roadside soils and urban parks from hamedan metropolis, iran* doi://doi.org/10.1016/j.enmm.2016.10.006

Speck, J. (2012). *Walkable city: How downtown can save america, one step at a time* (1st ed.). New York: Farrar, Straus and Giroux

Stechmann, H., & Dannecker, W. (1990). *Characterization and source analysis of vehicle-generated aerosols* doi://doi.org/10.1016/0021-8502(90)90240-X

Venn, A. J., Lewis, S. A., Cooper, M., Hubbard, R., & Britton, J. (2001). Living near a main road and the risk of wheezing illness in children. *American Journal of Respiratory and Critical Care Medicine, 164*(12), 2177-2180.

Verbeek, T. (2019). *Unequal residential exposure to air pollution and noise: A geospatial environmental justice analysis for ghent, belgium*doi://doi.org/10.1016/j.ssmph.2018.100340

Walker, G. (2009). Beyond distribution and proximity: Exploring the multiple spatialities of environmental justice. *Antipode, 41*(4), 614-636. doi:10.1111/j.1467-8330.2009.00691.x

Wawer, M., Magiera, T., Ojha, G., Appel, E., Bućko, M. S., & Kusza, G. (2015a). *Characteristics of current roadside pollution using test-monitoring plots* doi://doi.org/10.1016/j.scitotenv.2014.10.025

Westerlund, K. G. (2001). Metal emissions from stockholm traffic-wear of brake linings. *Slb-Analys,* (2001: 3)

“Wicked Device Shop.” 2019. Wicked Device Shop, wickeddevice.com/.

Winner, L. (1986). *The whale and the reactor: A search for limits in an age of high technology*. Chicago: University of Chicago Press.

Zegeer, C. V. (2002). *Pedestrian facilities users guide: Providing safety and mobility* diane publishing.