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Jessica Meighan Herrin
UTHealth School of Public Health

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AREA-LEVEL LANDFILL DENSITY AND ASTHMA PREVALENCE IN URBAN TEXAS AREAS

by

JESSICA MEIGHAN HERRIN, BS

APPROVED:

Harold W. Kohl, III

HAROLD W. (BILL) KOHL, III, BA, MSPH, PHD

MARY ANN SMITH, PHD

Anna Wilkinson

ANNA VICTORIA WILKINSON, BSC, PHD

DEDICATION

To Terry & Elsie Herrin

AREA-LEVEL LANDFILL DENSITY AND ASTHMA PREVALENCE IN URBAN TEXAS AREAS

by

JESSICA MEIGHAN HERRIN
BS, TEXAS A&M UNIVERSITY, 2016

Presented to the Faculty of The University of Texas

School of Public Health

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

THE UNIVERSITY OF TEXAS
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AREA-LEVEL LANDFILL DENSITY AND ASTHMA PREVALENCE IN URBAN TEXAS AREAS

Jessica Meighan Herrin, BS, MS
The University of Texas
School of Public Health, 2020

Thesis Chair: Mary Ann Smith, PhD

Abstract:

Environmental exposures, especially air pollutants, pose a threat for an increase in asthma prevalence. In particular, hydrogen sulfide (H_2S) gas can cause severe health effects closely resembling asthmatic symptoms. Ambient concentrations of H_2S gas correlates with the amount of solid waste found in landfills. The potential for adverse health risks associated with H_2S emitted from landfills is of concern for those populations living in close proximity to landfills. Asthma is one of the adverse health effects that can occur due to H_2S exposure. However, there is a lack of detailed studies characterizing possible associations between the density of landfills and asthma prevalence in Texas. Understanding the potential exposure to landfills for Texas residents has public health implications. This proposed study examined the census tract-level association between landfill density and asthma prevalence in several urban areas in Texas. We hypothesized that census-tracts with the highest density of landfills had the highest prevalence of asthma. Population data was obtained from existing datasets from the 500 Cities Project, the Texas Commission on Environmental Quality (TCEQ), and the Municipal Solid Waste Sites and Landfills. This study used count regression models for data analyses, and found no definitive relationship between Texas landfills and asthma prevalence census-tracts. Findings from this study provides more information pertaining to landfills and asthma prevalence. These results may contribute to the already established Texas public health data and policies regarding landfill locations and potential health risks among neighboring populations; however, future research is needed to investigate further associations and exposure.

Key Words: air pollution, asthma prevalence, landfills, landfill health effects, hydrogen sulfide gas, hydrogen sulfide gas health effects

AREA-LEVEL LANDFILL DENSITY AND ASTHMA PREVALENCE IN URBAN TEXAS AREAS

Final Thesis
for the
Master of Science in Epidemiology

By

Jessica Meighan Herrin, B.S.

The University of Texas Health Science Center at Houston (UTHealth)

August 3rd, 2020

Committee members:

Mary Ann Smith, Ph.D.
Research Supervisor
Environmental Minor
Department of Epidemiology, Human Genetics and Environmental Sciences
UTHealth Science Center at Houston, School of Public Health in Houston

Harold W. (Bill) Kohl, III, B.A., M.S.P.H., Ph.D.
Academic Advisor, & Committee Member
Epidemiology Major
Department of Epidemiology, Human Genetics and Environmental Sciences
UTHealth Science Center at Houston, School of Public Health in Austin

Anna Victoria Wilkinson, B.Sc., Ph.D.
Committee Member
Global Health Certificate
Department of Epidemiology, Human Genetics and Environmental Sciences
UTHealth Science Center at Houston, School of Public Health in Austin

ABSTRACT

Environmental exposures, especially air pollutants, pose a threat for an increase in asthma prevalence. In particular, hydrogen sulfide (H_2S) gas can cause severe health effects closely resembling asthmatic symptoms. Ambient concentrations of H_2S gas correlates with the amount of solid waste found in landfills. The potential for adverse health risks associated with H_2S emitted from landfills is of concern for those populations living in close proximity to landfills. Asthma is one of the adverse health effects that can occur due to H_2S exposure. However, there is a lack of detailed studies characterizing possible associations between the density of landfills and asthma prevalence in Texas. Understanding the potential exposure to landfills for Texas residents has public health implications. This study examined the census tract-level association between landfill density and asthma prevalence in several urban areas in Texas. We tested the hypothesis that census-tracts with the highest density of landfills had the highest prevalence of asthma. Population data was obtained from existing datasets from the 500 Cities Project, the Texas Commission on Environmental Quality (TCEQ), and the Municipal Solid Waste Sites and Landfills. This study used count regression models for data analyses. In summary, findings from this study failed to reject the null hypothesis, indicating that there was no association between landfill density and asthma prevalence census-tracts in the selected urban Texas Areas. These results, however, provide more information pertaining to potential associations between landfills and asthma prevalence. These results will can contribute to the already established Texas public health policies regarding landfill locations and potential health risks among neighboring populations; however, future research is needed to investigate further associations and exposure.

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BACKGROUND

In the United States (U.S.), asthma is a public health concern for both children and adults (1). This is especially true for individuals from diverse backgrounds and ethnicities (1). As compared with non-Hispanic whites, non-Hispanic blacks have a higher asthma death rate, by about 15.5 deaths per million persons more, leading one to question the potential for disproportioned exposure to environmental factors (1). With respect to possible disproportionate environmental exposure, annual economic costs, particularly medical costs for asthma treatment continues to grow every year, averaging around $983 per child (1). For those with limited or no medical insurance, these costs present an issue that can deter families from seeking appropriate medical attention for either themselves or their children, and ultimately lead to adverse health consequences if left untreated. Medical costs are not the only economic burden for families. Loss of work and/or school time are another detrimental result, due to asthma related events, averaging a total of $56 billion a year (1). With loss of work or school time, economic costs for overall loss of health and wellness may follow, leading to further health complications, and/or a decline in everyday life functionality, education and social interaction (1). In the 2015-2016 U.S. Centers for Disease Control and Prevention (CDC) National Health Interview Survey (NHIS), a total of 24.6 million individuals were currently living with asthma in the U.S. (2). In Texas, the adult current asthma prevalence for 2016 was estimated at 7.6% (3). In the same year, asthma prevalence in each of the four most populous cities in Texas, Houston, Dallas, San Antonio, and Austin, were 8.8%, 9.4%, 8.4%, 8.3%, respectively (3-5).Comparison of these prevalence estimates is important because it shows that all four cities have a higher asthma prevalence than the states' overall asthma prevalence. Thus, this may lead one to question why this may be the case for each of these cities, and what, if any, potential environmental exposures may contribute to their asthma prevalence.

Environmental exposures to air pollutants have been implicated as causative factors for severe respiratory illnesses including asthma (6-8). This includes air pollutants released by landfills, like hydrogen sulfide (H_2S) (9), a toxic gas released by the decomposition of landfill waste (10). Higher amounts of fresh landfill waste lead to higher ambient concentrations of H_2S gas (9, 11); and consequently, a greater potential for adverse health risks among populations living in close proximity to landfills (9-13). This raises an environmental concern for Texas's growing populations, particularly those living in urban areas that are more heavily populated and have a greater number of landfills.

Asthma

Asthma is a chronic lung disease that causes severe tightening and inflammation of the bronchial airways (14, 15). Asthma symptoms may worsen for individuals who are regularly exposed to various types of indoor and outdoor air pollution (16-18). Both types of air pollution present a major concern for minority populations living in Texas, especially those without insurance, who tend to live in lower-income areas found closer to landfills (19, 20). In Texas, those uninsured are four times more likely to lack any source of medical insurance (19). In 2018, it was estimated that 1 in 6 individuals residing in Texas live at or below the poverty level with no type of health coverage, and in 2017 11% of all children residing in Texas were uninsured (19). Thus, this increases the chances for those uninsured to be less likely to receive medical care, and inevitably develop life threatening health issues, such as found with asthma (19).

Common asthma symptoms include shortness of breath, chest tightness or pain, coughing, and wheezing (14, 15). Asthma may be triggered by allergic and/or non-allergic exposures (14-16). Allergic triggers may involve exposure to pet dandruff, dust, pollen, mold, and other allergens (14, 20). However, non-allergic triggers include: changes in climate (like hot and cold air), smoke emissions not produced by industrial production (e.g. cigarette smoke), and finally smoke emissions that are produced by industrial air pollution (16-18, 20, 21). Both in the U.S. and worldwide, outdoor air pollutants pose a threat for an increase in asthma symptoms (6-8, 14, 15). While short-term exposures to outdoor air pollution can result in exacerbations of symptoms among asthmatics, long-term exposures, can increase risk for asthma in both children and adults (16).

In an epidemiological study investigating air pollution and asthma severity in adults, ambient ozone (O_3) concentrations were significantly associated with asthma in adults (18). However, air pollutants can also be released by the breakdown of landfill waste, such as seen with hydrogen sulfide (H_2S) gas (9, 10). This was found in three studies, all of which reported on H_2S emissions from decomposition of waste areas and landfills (9-11). Therefore, the density of landfills may contribute to Texas's air quality, as well as the health of its residents, thus potentially impacting the state's overall asthma prevalence.

Exposure to Hydrogen Sulfide Gas (H_2S)

H_2S is a toxic gas that is corrosive, highly flammable and explosive, and has been detected around sources, such as landfills, which have been reported to emit H_2S (10, 13, 22). H_2S ambient concentrations may range between absolute measurements of 0.00011– 0.00033 parts per million (ppm) (10, 13). H_2S average or mean ambient concentrations have also been documented, showing a range between 0.00071- 0.066 ppm (22). However, human olfactory senses detection can occur at low concentrations from 0.0005 to 0.01 ppm, ultimately resulting with initial odor complaints (10, 12). H_2S is naturally produced by industrial activities, such as natural gas drilling, wastewater treatment, geothermal power-plants, and paper mills (10, 13, 18, 23). However, it is most commonly formed with the breakdown of human and animal wastes, as found in either sewage or landfills (10, 13, 18). A 2017 literature review indicated that H_2S was capable of causing initial health effects and nasal irritation beginning at ambient concentrations between the ranges of 0.01-5 ppm; with potential death resulting at 100 ppm (10). These range effects can be seen below in Figure 1, which details "Categories of Lethal and Sub-Lethal H_2S Poisonings" (10). Looking at Figure 1, Rubright maps her review findings for 72 differing studies, conducted on various H_2S gas sources (10). Furthermore, from these 72 studies, Rubright determined that urban areas had higher ambient concentrations of H_2S (as high as 1 ppb or 0.001 ppm), when compared to rural area counterparts (10). Therefore, since urban areas were found to have higher H_2S concentrations than the norm environmental concentrations, ranging between 0.00011-0.00033 ppm, this may provide justification to assume that living near sources of H_2S (natural and/or man-made) could adversely impact asthma. Finally, the analysis determined that living closer to sources producing H_2S gas, and higher ambient H_2S concentrations within the environment, could lead to health complications (10). Exposure sources that were reviewed in this paper, includes but are not limited to, animal feeding operations (AFOs), industrial power plants like paper mills, natural gas drilling, sewer systems, and landfills (10).

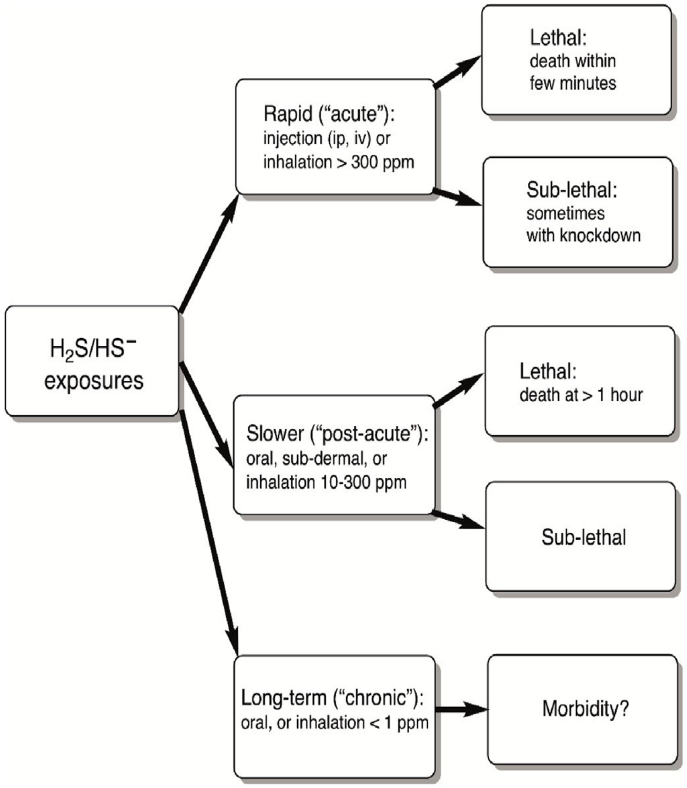


Figure 1. Malone Rubright, S., Pearce, L., & Peterson, J. (2017)
"Categories of Lethal and Sub-lethal H_2S Poisonings."

Inhalation is the main and most common route of exposure to H_2S gas (10, 13). Once inhaled, the hazardous gas is absorbed into the lungs (10). When absorbed, H_2S gas can cause a wide range of health outcomes, both acute and long-term, depending on the level of concentration and the duration of exposure for residents living near industries or areas emitting hydrogen sulfide (10, 13, 24). Acute health outcomes occurring at low H_2S ambient concentrations that have been released by landfills range between 0.01 ppm to 5 ppm include: eye irritation, nausea, headaches, airway issues or bronchial constriction, and nasal irritation resulting from odor pollution (9, 10, 13, 24). As this gas concentration increases to moderate-high levels, e.g. from 20 ppm up to 50 ppm, symptoms become more severe, showing development of gas eye, coughing, dizziness, respiratory tract irritation, unconsciousness, and death after 48 hours (10, 24). In addition, those exposed to H_2S at moderate (20 ppm) landfill ambient concentrations, may begin to experience olfactory fatigue, the loss of sense of smell that can become permanent after prolonged exposure (10, 24). Prolonged exposure may vary both for workers and people living near landfills. The Occupational Safety and Health Administration (OSHA) permissible exposure limit for H_2S at 20 ppm though is set at a total 15-minute cap for a total 8-hour workday for workers in either petroleum or mining industries (20, 21). Higher H_2S gas concentrations, at levels from 50 ppm to 100 ppm are considered by the OSHA to be Immediately Dangerous to Life and Health (IDLH) for workers, and can lead to sudden death (10, 12, 21, 22). Exposure to these higher H_2S levels are again normally observed, and/or encountered by occupationally-exposed persons in petroleum or other mining industries (12, 21, 22, 25, 27). These occupational H_2S limits, however, may be relevant for individuals living near urban sources of H_2S, like landfills, and sewer or sewer-runoff environments. Landfills and sewer environments also have the potential to emit ambient concentrations of H_2S, which could lead to health issues found in combination with longer duration of exposure periods for current residents (13, 23, 27). What causes some uncertainty regarding H_2S impact for these residents, are the environmental factors which might play a key role in H_2S's development and exposure, differing from that of the occupational-exposed personnel. Climate change is a key component when discussing effects of many environmental exposures. Record high temperatures for example, or high humidity, altitude level, along with prevailing winds and/or change in wind direction, all in combination with proximity and living duration to the exposure source, can influence the intensity and severity of one's exposure to the exposure source. This may also be true for H_2S, and for those living close to landfills and other sources of H_2S. Thus, those who may be regularly exposed to higher levels of H_2S, for longer periods of time, could be at risk for adverse health effects (13, 23, 27).

Health Effects Associated with Living Near Landfills

Some studies have reported that individuals living near municipal waste landfills experienced differing health outcomes, including but not limited to, headaches, an increase in respiratory illnesses, and possible trigger of asthmatic symptoms, or an increase in asthma exacerbations (28-32). For instance, self-reported health surveys, recorded by individuals living near landfills, consistently described a number of health outcomes, notably headaches, allergies, respiratory diseases, and irritation of the eyes, nose, and skin (28,29). Vrijheid et al, could not firmly conclude the prevalence or incidence of these health conditions solely on toxic waste site emissions (28), due to possible reporting bias, including the observed exposed population's opposition or expressed fear and stress towards nearby waste sites (28). Kret's review suggested that though their findings needed additional investigation that would address health concerns expressed by exposed households, the respiratory system should be considered one of the most vulnerable parts of the human body when exposed to environmental pollutants (29). In a systematic review by L. Fazzo, evidence was found for hazardous waste effects by H_2S exposure on acute otolaryngologic (ear, nose, and throat), and respiratory symptoms (Asthma) (30). Fazzo's research though considered limited, was based on a rating system (5-4) that indicated the number of studies reviewed which had positive findings for strong/high values for relative risk and precise associations between waste site air pollutants and asthma (30). His findings however, provided reason to assume that there was a limited causal association between waste sites emitting air pollutants, like H_2S, and asthma for persons living near exposure sources (30). Lastly, two cohorts, one conducted by Eero Pukkala and Antti Pönkä (31), and the other by Francesca Mataloni (32), both found associations between waste site exposure and asthma. In Pukkala and Pönkä's research, ambient and indoor air samples were collected and showed that asthma incidence increased significantly with exposure to waste sites, having a standardized incidence ratio (SIR) of 1.63, and a 95% confidence interval (CI) between 1.27-2.07 (31). Though environmental exposures are not known to be risk factors for asthma, except in individuals already living with asthma where their symptoms may worsen by environmental pollution, Pukkala and Pönkä could not rule out the possibility that the risk of asthma may be associated with landfill toxic emissions (31). In the cohort by Mataloni, associations were found specifically between landfill H_2S and mortality and morbidity for asthma in adults and children (32). These associations were reflected using effect estimates given in quartile distributions for H_2S (25–50, 50-75 and>75 percentile of the distribution vs<25 percentile) and for a linear increase of H_2S equal to 1 ng/m3 (32). For cause-specific mortality in all persons, associations between H_2S exposure and respiratory diseases, including asthma measurements, resulted in a Hazard Ratio (HR) of 1.30, with a 95% Confidence Interval (CI) of 0.99-1.70 (32). These findings were later confirmed when H_2S exposure was seen as a linear trend, which then provided a HR of 1.09, and a 95% CI of 1.00–1.19 for respiratory diseases (32). For morbidity, Mataloni found associations between the highest quartiles for exposure to H_2S and hospitalizations for respiratory diseases (including asthma measurements), having a HR of 1.05, and 95% CI 0.99–1.11 (32). These associations were also confirmed when considering H_2S exposure as linear, showing a HR of 1.02, and 95% CI 1.00–1.03 (32). Lastly, a link was determined between H_2S exposure and respiratory diseases (including asthma) (for the highest quartile, HR 1.11, 95% CI 1.01–1.22), as well as for acute respiratory (including asthma) hospital admissions for children (for the highest quartile, HR 1.20, 95% CI 1.04–1.38) (32). Mataloni concluded that her findings determined that exposure to H_2S could be a link between landfills and asthma, particularly pediatric hospital admissions for asthma (32).

Other health outcomes that occurred with living near waste sites include the development of certain cancers, such as laryngeal cancer and lung cancer, as well a number of birth defects, and neurological conditions like unconsciousness with the exposure of H_2S) (32-38). These papers, however, also suggested that further research was needed, including individual-level studies that would investigate landfill exposure and direct asthma development (9, 10, 13, 24, 26, 32-38). Specific steps towards improvement on H_2S monitoring systems and equipment were also proposed, along with better state and city documentation reporting on current and new exposures, resulting health effects, and expansion on treatment methods for waste sites (9, 10, 13, 24, 26, 32-38). With that being said, increasing the density of landfill sites could potentially increase ambient concentrations of H_2S gas, suggesting that living in close proximity to landfills might be a risk factor for higher asthma prevalence in Texas, via a H_2S gas mechanism in both adults and adolescents (9, 10, 13, 24, 26).

Hydrogen Sulfide Gas (H_2S) Mechanism of Action in Asthma

Some studies also regard H_2S gas, including H_2S gas emitted from landfills, as a chemical respiratory irritant (10, 22, 39). H_2S gas is considered both moderately hydrophilic and has lipophilic properties (10, 40, 41). These characteristics increase H_2S chances of being absorbed into the human body, thus disrupting normal human biological activity (10, 40, 41). In mammals, including humans, studies have shown that endogenous H_2S is regulated by the central nervous system (CNS) and enzymes, cystathionine β-synthase (CBS) and cystathionine γ-lyase (CSE) (13, 41-45). However, because of its capability of transmitting chemical signals and inducing physiological bodily changes once inhaled, researchers' have termed H_2S as a 'gasotransmitter' (13, 41). Gasotransmitters are capable of passing through cell membranes (41, 44). They can either be internally produced or synthesized (endogenously) in the organism, as mentioned earlier, or are inhaled from ambient/atmospheric gas concentrations (exogenously), which can then transmit chemical signals promoting or inducing various physiological changes inside a mammalian body (41, 44, 45). Their effect inside the body, however, depends on their concentration (41, 44, 45). Thus, if exogenous H_2S were to be inhaled, disrupting an individual's normal endogenous H_2S bodily concentration, normal cell and enzymatic regulatory functions in the CNS would be affected (13, 41, 44). This could ultimately have an adverse impact on human health.

In addition, altering H_2S gas levels regulated within the CNS will change the level of gas concentrations found throughout the body (45). In fact, research detected levels of both enzymes, CBS and CSE in the respiratory system which can be affected by the level of exogenous H_2S exposure (45-47). In an experimental study, participants reported having an increase in upper respiratory symptoms including nasal congestion, choking, throat irritation, and/or nose irritation with exposure to H_2S (48, 49). Lower respiratory symptoms such as shortness of breath, wheezing, chest tightening, chest pain, and/or coughing were also reported with an increase in exogenous H_2S exposure (48, 49). H_2S's role in the respiratory system includes regulations of airway tone, and controlling for pulmonary or lung fibrosis, oxidative stress, and lung function and inflammation (45, 46, 50, 51). In human studies, higher exposure to H_2S concentrations disrupted these same physiological functions, which are associated with the development of asthma and worsening of symptoms in asthmatic patients (52-55). In a review conducted by Bazhanov, H_2S role in lung function was measured and found that even low concentrations of endogenous H_2S correlated with abnormal lung pulmonary function and asthma severity tests (52, 56-58). Likewise, two studies, showed that changes in the pathophysiology, or signs, symptoms, and triggers for asthma were due to changes to the synthesis of endogenous H_2S (53,54). Therefore, it may be reasonable to assume that this change to asthma pathophysiology could be caused by the disruption of inhaled or ingested exogenous H_2S, inevitably leading to changes to internal endogenous H_2S gas concentrations within the respiratory tract, and thus triggering asthmatic development (55, 59-63). My study investigated estimates of a possible association between landfills (exposure) and census-tract level asthma prevalence (outcome) via a potential H_2S mechanism for Texas's growing populations.

Global Health Implications

The impact of our worlds' growing population has inevitably caused the amount of municipal solid waste to rise (64-68). Globally, waste-site management practices in developing or lower and middle-income countries have been faced with many obstacles regarding proper waste management systems; especially in regards to legislation and financial funds that would help implement proper waste systems and enforce environmental and human health protection policies (69-71). In a review by Ziraba et al, Sub-Saharan African urban areas, once deemed as places for opportunity, education, and overall better quality of life and health, are now areas in decline that are struggling to meet basic human demands for food, water, and shelter, whilst generating an abundance in waste (69). With the continuous demands of society, these challenges have ultimately led countries to either lack current disposal practices or fall behind in enforcing regulations for proper sanitation and disposal methods (67, 69-71).

Having inadequate waste-site management disposal systems that cannot meet the demands of a countries population can lead to severe environmental concerns, which can later impact a populations overall health (66-73). Infectious diseases resulting from standing waste, as well as toxic emissions released by the breakdown of waste can have a great impact on environmental resources, as well as the health of those living in these urban areas (66-73). For instance, the growing populations in China, India, and Japan have ultimately resulted with rapid growth in urban waste, particularly industrial construction and demolition (C&D) waste (68); which if not managed properly has been recorded to emit toxic H_2S gases (9, 25, 42) resulting in respiratory health complications, including asthma (30-32, 52-55). As compared to the United States, lower-income countries tend to have fewer regulations and filtration systems concerning landfill management, causing these toxic emissions to accumulate resulting in even stronger environmental and human health effects (67, 69, 74, 75). Moreover, these toxic health effects are commonly found amongst the poorer populations within the country who have limited resources to food, water and medical care; as is seen among those living in the slums of Dhaka, Bangladesh (76, 77). As such, proper waste management practices today are more important than ever to reduce the risk of potential harmful health implications found with the continuous rise of global waste.

Public Health Significance

Texas’ current, and only, practice for municipal waste disposal is landfill dumping (78). This includes solid waste produced by all municipal, community, commercial, institutional and recreational activities (78). The presented literature in this thesis indicating potential for adverse health effects to occur with living in close proximity to landfills raises a concern for Texas’s growing population. Thus, further investigation is needed to identify a possible association between Texas landfills and asthma prevalence (79-88). Controlled U.S. census-tract level data on population demographics, such as age, gender, race/ethnicity, insurance coverage, as well as social-economic and health status factors in my analysis, better identified possible susceptible populations. Controlled covariates, however, did not reveal that minority neighborhoods are disproportionately exposed to landfills in Texas’ four most populated cities: Austin, Dallas, Houston, and San Antonio (89). Lastly, this information could lead to more research that may assess individual-level exposures and asthma prevalence, and further contribute to the current information both on landfill waste management policies, and on other minority communities who may be facing environmental injustice in Texas. From a global standpoint, results from this study can serve to raise awareness and provide insight into the rising global waste epidemic occurring in developing countries, where populations face severe health implications resulting from the lack thereof, or improper management of disposal waste-sites.

Specific Aims

The current and publicly available information provided by Centers for Disease Control and Prevention (CDC), states that in 2016 the asthma prevalence in Texas was 7.6% (3). Asthma is an incurable, chronic condition that causes tightening of the lungs' airways (14). Environmental exposures such as industrial air pollutants and chemical irritants are risk factors that can increase the prevalence of asthma (16, 17). This entails pollutants like H_2S, including landfill H_2S (9, 10). Research has shown possible associations between H_2S gas function in the development of respiratory illnesses (10, 11, 60). However, the gap in research examining landfill exposure hinders our ability to understand the role that landfill sites may play on asthma prevalence in Texas.

The aim of this project was to examine the association between census tract-level density of landfill sites and census-tract level prevalence of asthma in select urban areas in Texas from 2015-2016. My study's long-term goal is to provide more information on factors that contribute to asthma prevalence, along with providing direction how to mitigate those factors for those affected. The overall objective of my thesis, in attaining my long-term goal, is to add to the already available information pertaining to the impact of environmental exposures, like density of landfills, on asthma prevalence in Texas urban areas. Therefore, my central hypothesis states that there is a positive association between higher area-level density of landfill sites and higher census-tract level asthma prevalence in urban areas in Texas. In contrary, the null hypothesis for my study states that there was no association between higher area-level density of landfill sites and higher census-tract level asthma prevalence in urban areas in Texas.

METHODS

Study Design

This study used an ecologic study design to analyze data obtained from existing data sources: the 500 Cities Project (79) (see details below), the Texas Natural Resources Information System (TNRIS) Municipal Solid Waste Sites and Landfills dataset, and the Texas Commission on Environmental Quality (TCEQ) datasets for inventory on Texas landfills (80-82). The analysis for this study was conducted on a subset of the 2018 released 500 Cities Project data; which examines the 2015-2016 census-tract level asthma prevalence data in Texas's four largest urban areas: Austin, Dallas, Houston, and San Antonio (79, 83-88). These data were linked with exposure data on locations of landfills in the same cities drawn from the TNRIS, TCEQ, and the TCEQ Municipal Solid Waste Permit Department (80-82, 90). Detailed descriptions of these datasets and methods and the analytical approach follow.

Study Area

Density of landfill sites were compared to asthma prevalence estimates assessed approximately at 200 to 600 different census-tracts center points, for varying urban areas within each of the four most populated cities in Texas: Austin, Dallas, Houston, and San Antonio (79-88). Maps of these cities and their city boundaries can be found at the end of this proposal in Appendix A, labeled "Additional Maps – City Boundaries." Geographic information system (GIS) shapefiles were used for my analysis to store the geometric location and attribute information of geographic features for landfill and asthma prevalence location coordinate information.

Data Collection

Outcome Data. Census tract-level asthma prevalence estimates for Texas's four most populated cities were abstracted from the 500 Cities Project (79, 86). The 2015-2016 500 Cities Project was developed and launched in 2018 by The Robert Wood Johnson Foundation, the CDC Foundation and Centers for Disease Control and Prevention (CDC) (79, 84). The parent project used small-area estimation (SAE) of population health outcomes for the largest 500 cities (by population size) in the U.S. (83-88). The researchers conducted a case-study using prevalence surveillance data for 27 chronic diseases gathered from the CDC Behavioral Risk Factor Surveillance System (BRFSS), U.S. 2010 Census, and the American Community Survey estimates (83-88, 91-95). This included estimates for the health outcome asthma; where the 500 City study provided census-tract prevalence data for adults aged 18 years or older, living within the population of the selected urban cities during the 2015-2016 time period (83-88).

Study eligibility for the 500 Cities project for asthma included answering 'Yes' to both BRFSS self-reported surveys questions: (a), 'Have you ever been told by a doctor, nurse, or other health professional that you have asthma?', and (b) 'Do you still have asthma?'(85-88). For the 500 cities project, data were taken from the BRFSS surveys and then combined with county and state level population estimates to approximate the prevalence of asthma (85-88). This was done using a multi-level regression analysis to create probabilities for urban city populations, and to approximate census-tract level data estimates for asthma prevalence (85-88). Furthermore, the researchers used a post–stratification (MRP) approach with the multi-level regression to help link the geo-coded BRFSS health surveys to the spatial population demographic and socioeconomic (SES) data (85-88). The census-tract and city-level data from the 500 Cities study was validated by other CDC internal and external research (91-95), and publicly released in 2018 via an interactive “500 Cities” website (85-88).

Exposure Data. My analysis included landfills up to a ½ mile outside of each 500 City asthma prevalence census-tract. Within the study area, number of landfill locations were obtained from the TNRIS Municipal Solid Waste (MSW) facility shapefile raw data, the TCEQ Excel spreadsheet on registered active landfills, and the TCEQ Excel spreadsheet on registered closed landfills for a complete dataset of Texas landfills in the selected four cities (80-82). Landfill active dates for possible exposure represented the years from 1970 to 2016, and were also identified using a separate TCEQ MSW Excel spreadsheet provided by the TCEQ MSW permit department (90). This information was added to the full count dataset created for Texas landfills in the selected four cities, as mentioned above. The exposure variable in my analysis was defined as the number of landfills up to a ½ mile outside each asthma prevalence census-tract center. Landfill density was calculated first by defining and setting a ½ mile buffer around each asthma prevalence census-tract center. The number of landfills surrounding each asthma census-tract center, including landfills within the ½ mile buffer, was calculated using ArcGIS Mapping software. Resulting ArcGIS maps and tables for landfills surrounding each asthma census-tract center were exported and are shown in the results section.

***Landfill Identification*.** Landfills were identified by specific waste disposal type, consisting of but not limited to types 1, 1AE, 2, 3, 4, and 4AE; which were important to include in this research because it aids in further identifying landfills that may regularly release H_2S gas; such as those used for construction and demolition waste labeled 1, 1AE, 4, and 4AE (96-100). Disposal facilities labeled Type 1 accept all types of municipal solid waste which cannot be salvaged (96-100). Types 2 and 3 facilities are labeled historical waste sites, and are required to be updated to Type 1 disposal waste facility standards for continued active use and control of hazardous emissions (96-100). A Type 4 facility only accepts brush, and industrial construction and demolition waste (96-100). Waste sites labeled "AE" are considered "Arid Exempt" based on certain qualifications such as: total waste acceptance rate is less than 40 tons per day, there is no existing groundwater contamination evidence, no waste management alternative for the community, and/or the facility area receives no more than 25 inches of annual precipitation (96, 97, 99, 100). Thus, Type 1AE may accept the same waste as Type 1, following the "AE" qualifications (96, 97, 99, 100). This same rule applies to facility Type 4AE (96, 97, 99, 100).

Data Analysis

For initial, GIS analysis, excel census-tract asthma prevalence information for each Texas city, (Austin, Dallas, Houston, and San Antonio), was first imported to ArcGIS Mapping software using the "Add XY Coordinate Data" tool and a geographic WGS_1984 coordinate system. Initially, ArcMap was unable to read the geographic asthma prevalence data latitude and longitude coordinates; therefore, the data frame projection system was converted to WGS_1984 Web Mercator Auxiliary Sphere (EPSG 3857) to provide a more accurate geolocation planar representation. Keeping this same data frame projection system, the asthma data was then exported as a feature class to create a workable mapping layer. This entire process was then repeated once again for the imported landfill XY coordinate data. Next, using ArcMap's, Analyst Toolbox - Buffer Tool, a 0.5-mile buffer was created around each of the asthma prevalence census-tract center points, setting the groundwork to begin the spatial analysis for landfill count calculations, for the number of landfills found up to a ½ mile outside each asthma prevalence census-tract center.

Finally, to conduct the GIS analysis, the ArcMap's, Spatial Join Function with a one-to-one join option, was used to count the number of landfill points contained within each of the 0.5-mile buffers. The resulting attribute table for the spatial join data was then exported into a Word Excel document, where it was then prepared for the Poisson regression analysis. In preparation for running the Poisson regression, socioeconomic data were taken from the 2015 American Community Survey (ACS) U.S Census Data to provide descriptive information for variables; gender, age group, race, ethnicity, education, annual household income, and insurance coverage. From these explanatory variables, regression variables of interest (landfills (total count), % asthma prevalence, % population uninsured, % population non-white, % population with Latino ethnicity, % household income less than $35,000, and finally % population age 18 to 44 years) were then created for the study. Once these regression variables were created, they were then joined to the ArcGIS landfill-asthma prevalence data by merging both data formats into one document. After the distributions were found, the merged regression variables and ArcGIS landfill-asthma prevalence data were used to run the Poisson analysis in the analytical software, STATA 16.

A Poisson model regression was the set analysis to examine the possible association between density of landfills and census-tract level asthma prevalence (79-88). The unit of analysis for this particular regression model is the census-tract. A generalized linear model (GLMMs) with asthma count as Poisson response and population data from 2015 American Community Survey (ACS) U.S Census Data as offset, was implemented to evaluate the association between census-tract level landfill density and asthma prevalence (101-109). This model enabled any interaction between areal-level landfill density and asthma prevalence to be observed, while adjusting for potential confounders as covariates (107-109).

Furthermore, a simple count weighting algorithm was utilized as a primary exposure metric to count the total number of landfill sites. This primary exposure metric is denoted in the following equation:

$$\text{Landfill Exposure} = \text{Number of Landfills within } \tfrac{1}{2}\text{-Mile of Centroid}$$

In addition, landfill sites that became active after the year 2016 were identified again using the TCEQ Municipal Solid Waste facility (MSW) Excel spreadsheet provided by the TCEQ MSW permit department (90), and were excluded from my study. Finally, the Poisson model analysis was performed using analytical software, Stata (Version 16) (110), with a set statistical significance declared at $p<0.05$ with 95% confidence intervals.

Covariates. For each asthma prevalence census-tract, I determined and compared landfill density estimated to variables: % population non-white, % low annual household income status (below $35,000), % younger communities (below the age of 44), % of high school education or higher, and % of uninsured populations, for landfill-asthma prevalence census-tract center correlation (101-109). These percentages are shown in Tables 6-10, and were initially obtained using 2015 American Community Survey (ACS) U.S Census Data on population descriptive statistics for variables; gender, age groups, race/ethnicities, annual household income, number of landfills, insurance coverage, asthma health status (101-105). Furthermore, to explore select social and demographic urban area differences in the association between landfill density and asthma prevalence, the fully-adjusted model was fixed by city (Austin, Dallas, Houston, San Antonio). The given TractFIPS geocodes for landfills and asthma prevalence in this model method provided accuracy for determining a possible association between area-level landfill density and asthma prevalence at the aggregated data level in the selected urban Texas areas (106-109).

Descriptive Statistics. Maps for population proximity to landfills illustrated the observed differences in asthma prevalence exposure, set by ½ mile buffers around each asthma prevalence census-tract center (59-63, 98, 106, 111). These figures, along with any other descriptive maps were produced using ArcGIS software, ArcMAP, and depicted city-landfill proximity for potential association to asthma prevalence (111). Lastly, for each of the four cities (Austin, Dallas, Houston, San Antonio), 2015 American Community Survey (ACS) U.S Census Data was included for population descriptive statistics, and displayed in Tables 1-5 as both mean percentages and whole number counts for census-tracts for the following variables: gender, age groups, race/ethnicity, education, annual household income, and insurance coverage (101-105).

Finally, my research serves as a preliminary study that evaluated a possible association between density of landfill sites (exposure) and census-tract level prevalence of asthma (health outcome/disease) in selected urban areas in Texas from 2015-2016. Lastly, findings from my study can be used to provide reason for future research, environmental or individual-level analyses, to build a stronger case for more public health policies that better monitor population health for asthma prevalence.

Human Subjects

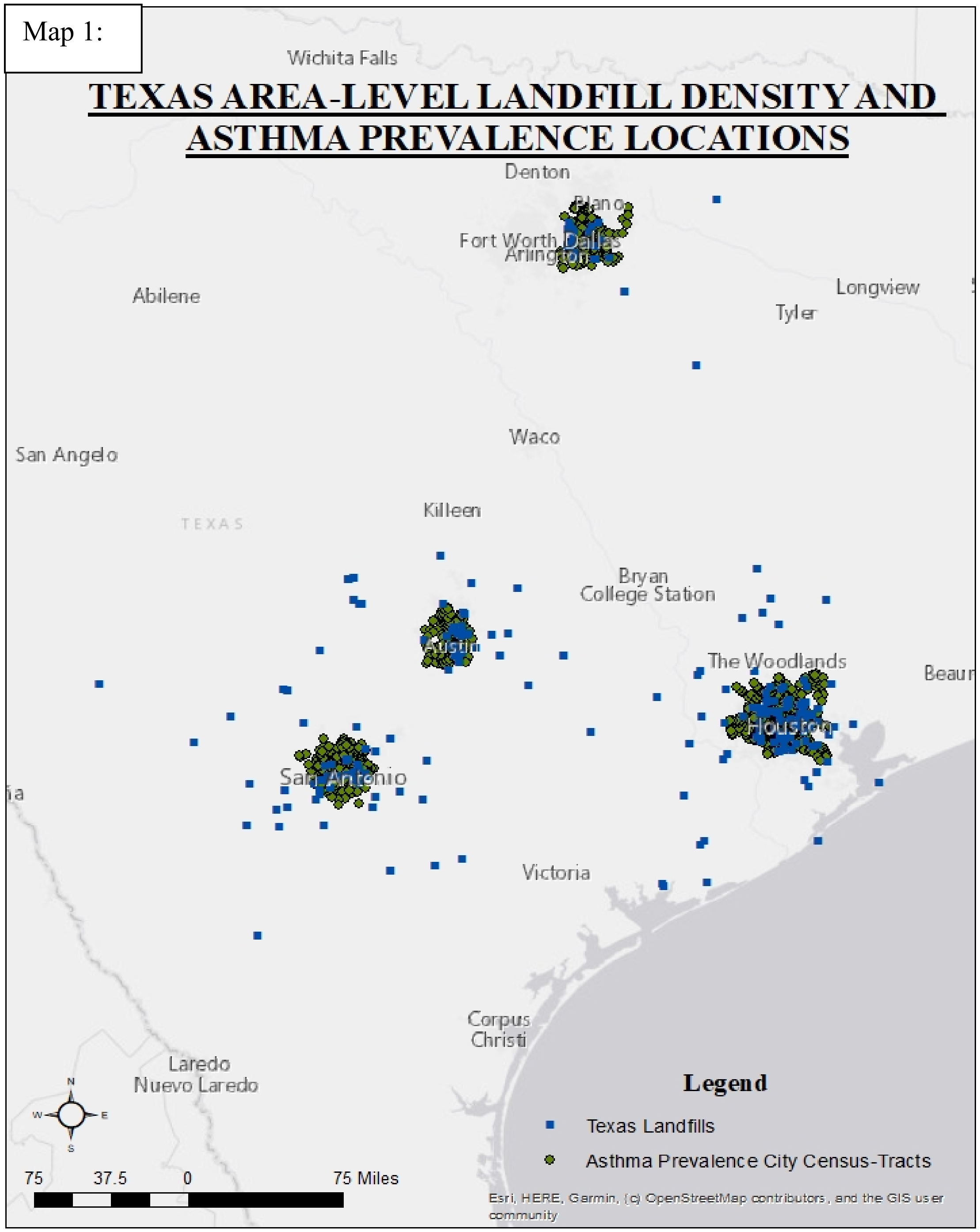
The 500 City Project dataset, the Municipal Solid Waste Sites and Landfills dataset for Texas, and the Texas Commission on Environmental Quality (TCEQ) datasets on inventory for Texas landfills were made publicly available, containing no personally human subject information. Before analyzing the data and completing the final thesis, my proposed research protocol was submitted to, and received approval from the Committee for the Protection of Human Subjects (CPHS) (www.uth.edu/CPHS), the Institutional Review Board (IRB) of The University of Texas Health Science Center at Houston (UTHealth).

RESULTS

ArcGIS Analysis

Within this study, ArcGIS software was used to provide a descriptive overview of the state of Texas, its surrounding active and inactive landfills in select cities Austin, Dallas, Houston, and San Antonio, as well as plot the 500 cities asthma prevalence census-tract coordinate locations for each of these four cities. As can be seen in the first descriptive map labeled, Map 1: “Texas Area-Level Landfill Density and Asthma Prevalence Locations,” Texas landfills, active and closed, are depicted as blue squares, and asthma prevalence city census-tract points are shown as green circles. This map depicts the overall state view for Texas landfill and asthma prevalence census-tract coordinate locations. When using the “zoomed-out” ArcGIS tool, landfills initially seemed to reside within the inner most part of each cities, as is depicted in Map 1 seen below.

Map 1:



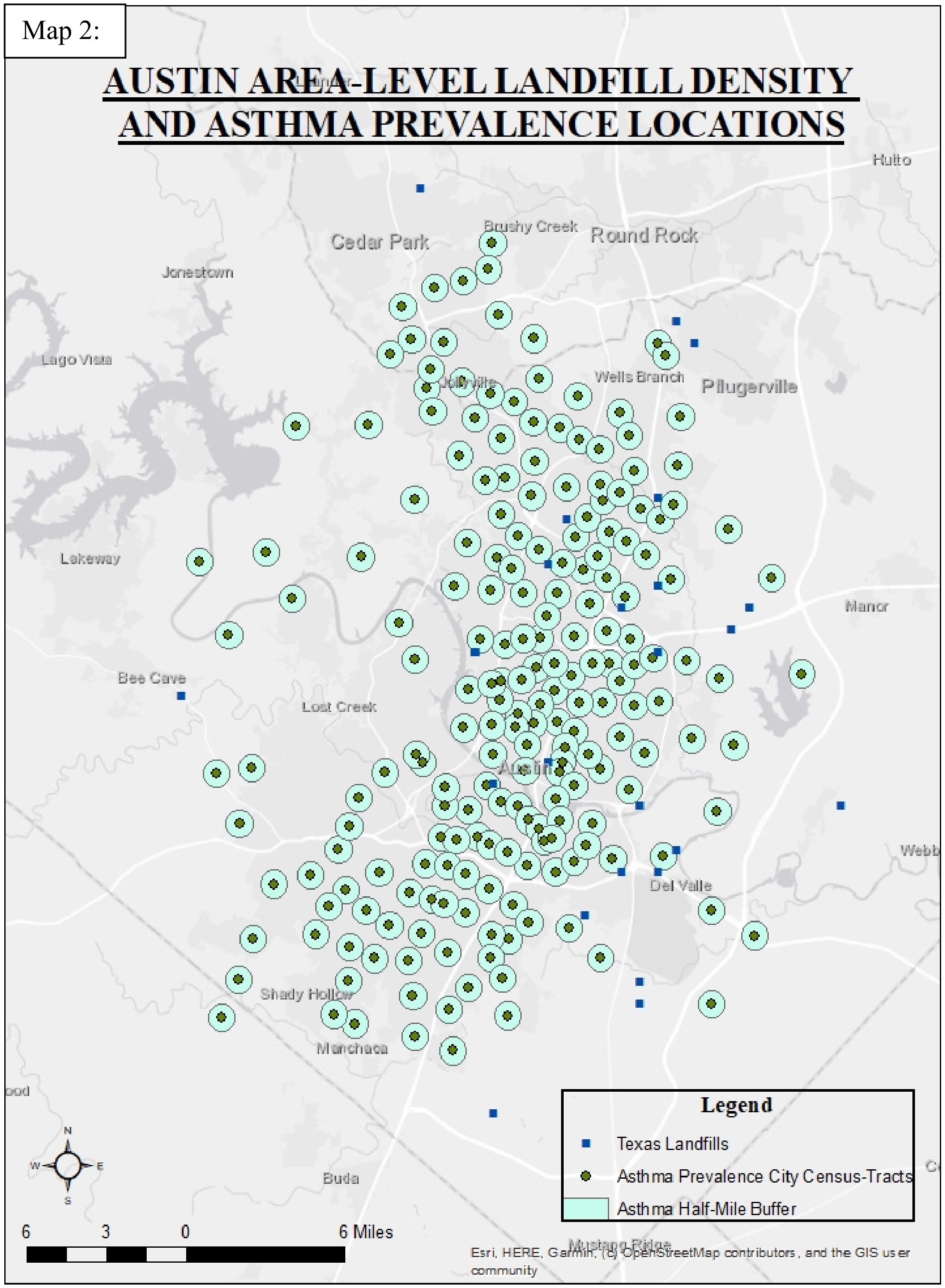
TEXAS AREA-LEVEL LANDFILL DENSITY AND ASTHMA PREVALENCE LOCATIONS

Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

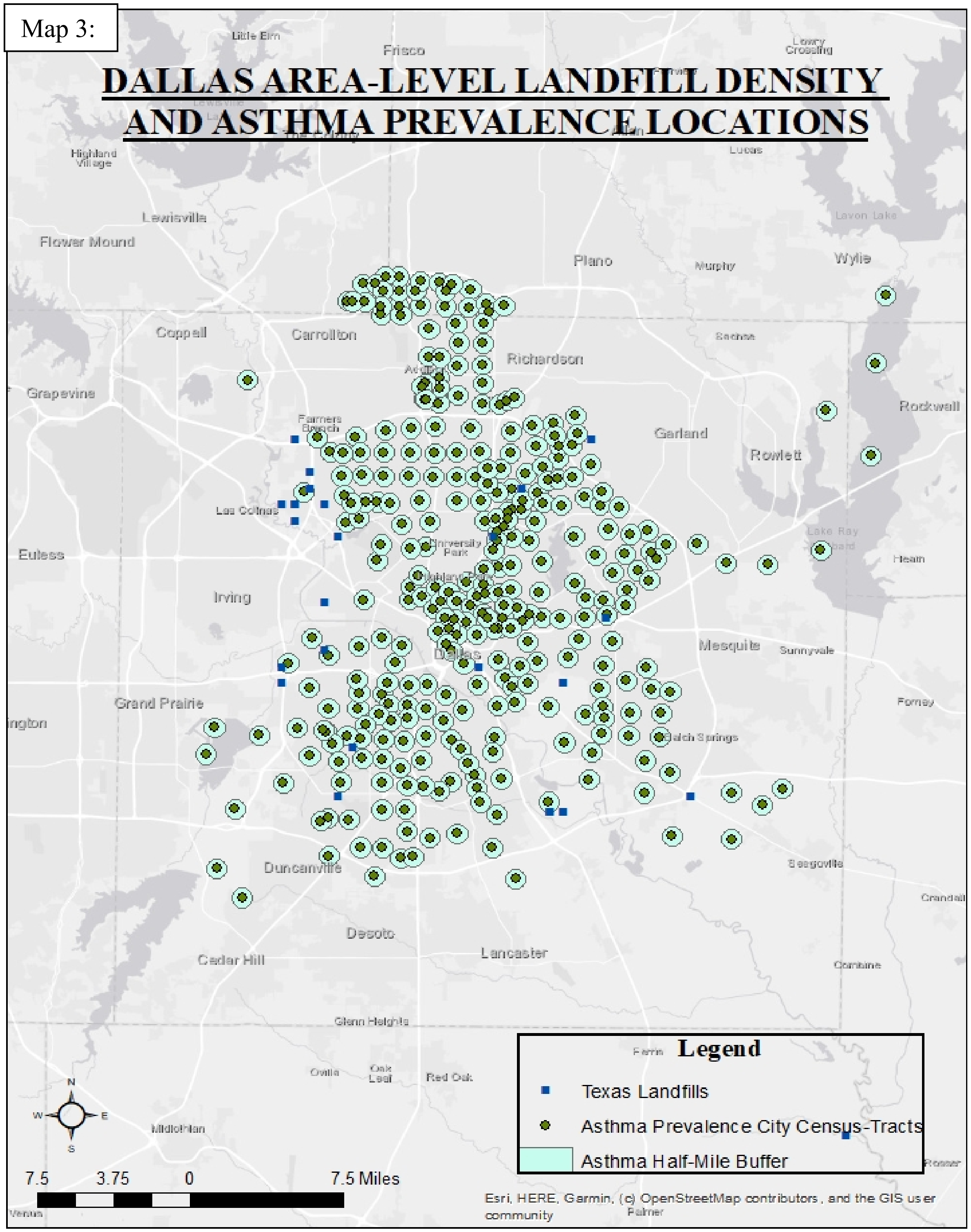
Following this descriptive overview map however, individual maps (Maps: 2-5) created for Austin, Dallas, Houston, and San Antonio Texas, showed a close-up view indicating that majority of landfills were found outside the inner most part of the cities. Furthermore, after a 0.5-mile buffer were set and applied around each asthma prevalence census-tract centroid, depicted here in the maps as a light blue color, landfills again were shown mostly located outside each city limits. This finding could be due to the physical geographic region, as well as its feature variation within the area of interest, and in-turn may lead to differences in census-tract development. Another possible reason could be these urban areas are less populated, which unfortunately suggests the question of possible geographical disparity. Since both types of descriptive Texas maps seem to allude to the conclusion that landfills may not be in close proximity to asthma prevalence census-tract points; thereby not acting as possible contributing factors to asthma prevalence within these census-tracts, then perhaps other industrial powerplants could be the reason for asthmas' prominence found in these urban areas. Maps 2-5 are shown below.

Map 2:

AUSTIN AREA-LEVEL LANDFILL DENSITY AND ASTHMA PREVALENCE LOCATIONS

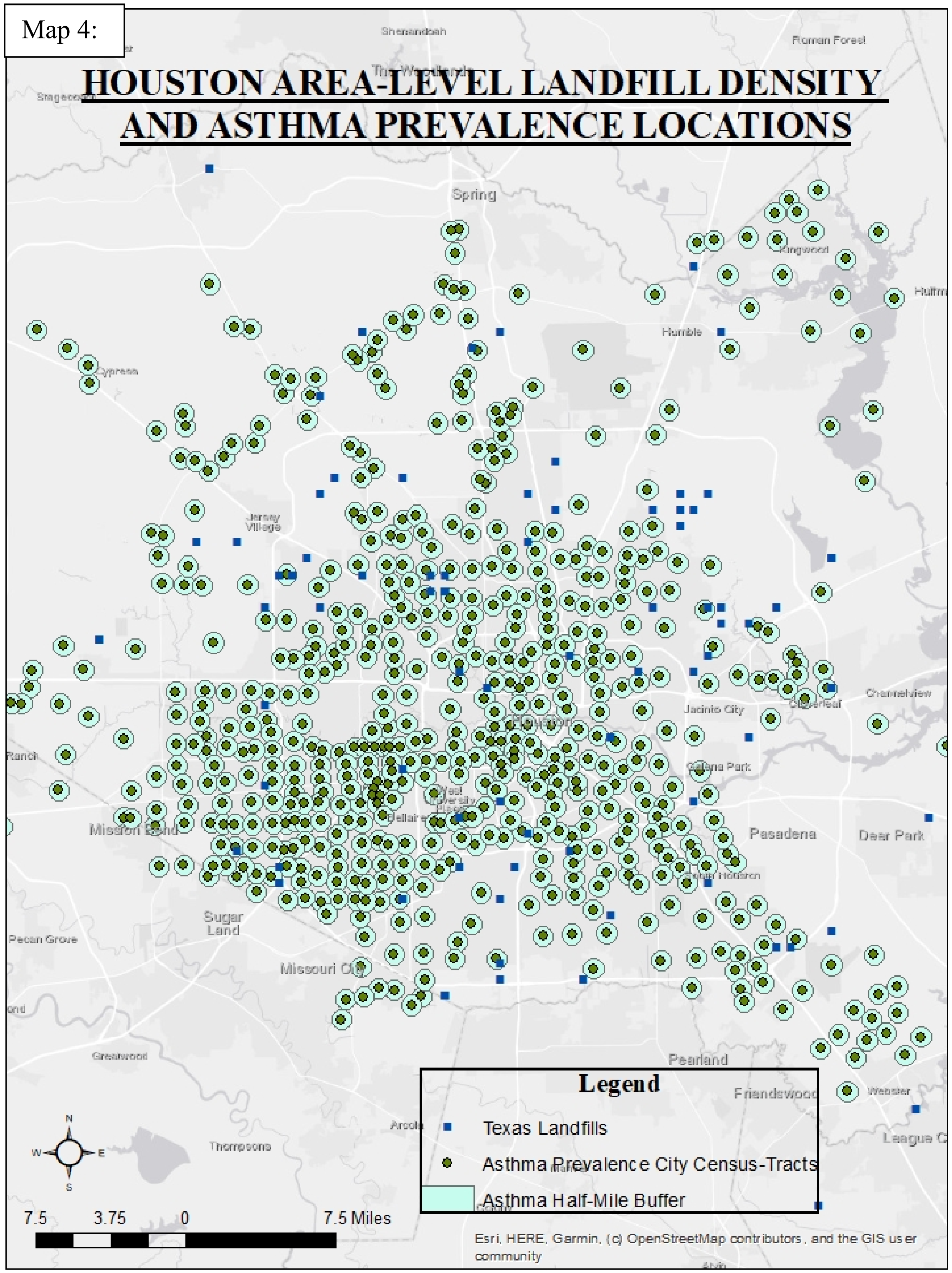


Map 3:



DALLAS AREA-LEVEL LANDFILL DENSITY AND ASTHMA PREVALENCE LOCATIONS

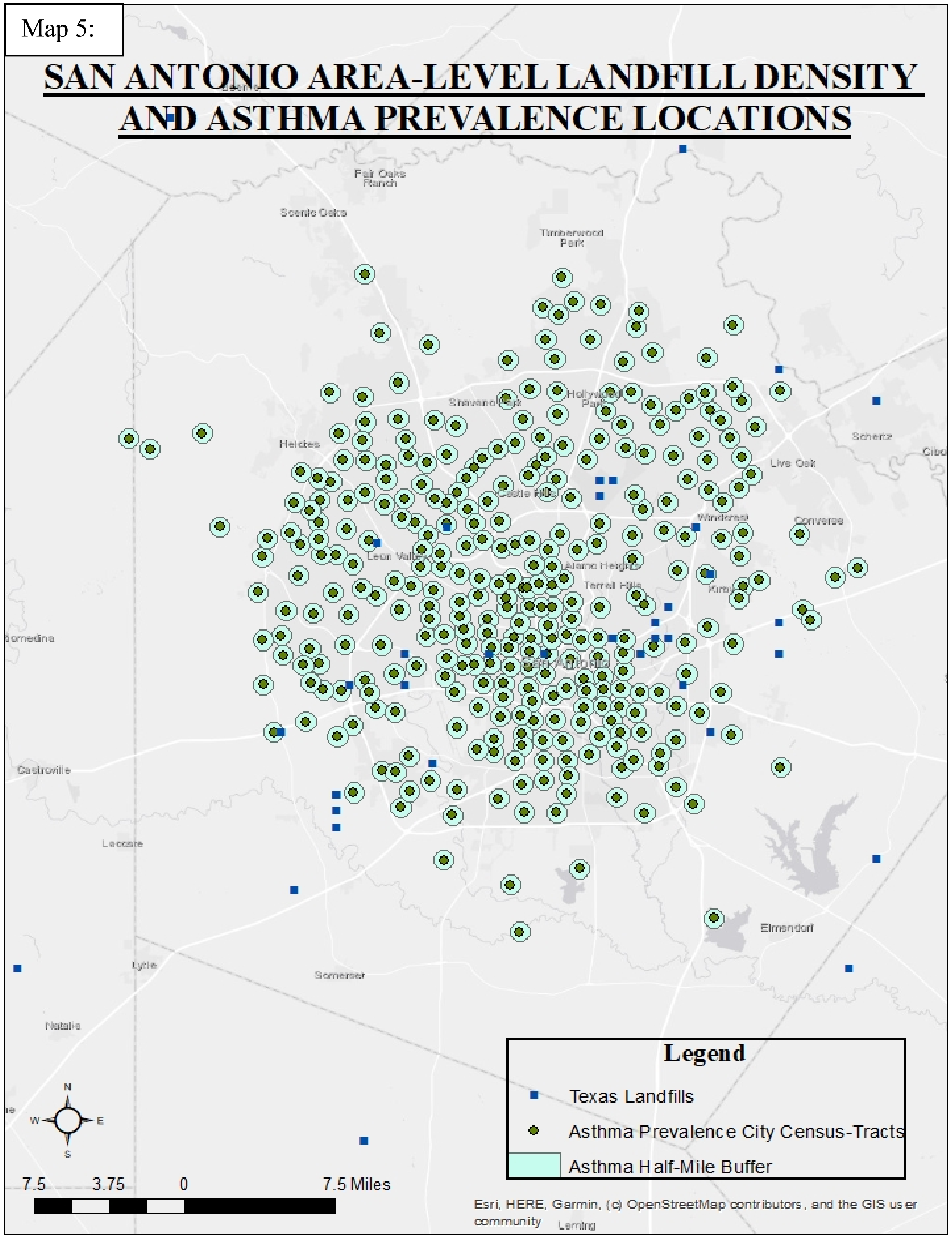
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



Map 4:

HOUSTON AREA-LEVEL LANDFILL DENSITY AND ASTHMA PREVALENCE LOCATIONS

Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



Map 5:

SAN ANTONIO AREA-LEVEL LANDFILL DENSITY AND ASTHMA PREVALENCE LOCATIONS

Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

After running the GIS spatial-joined analysis, this assumption was again apparent. The resulting attribute table, "Table 1: Landfill-Asthma Prevalence Census-Tract Spatial-Joined Attribute Table," as was mentioned previously showed that the highest number of landfills for an asthma prevalence census-tract point, within the 0.5-mile buffer, was found in Houston, with a total of 6 landfills. Other landfill counts for Houston asthma census-tract points included counts of 1, 2, and 4, respectfully, within the 0.5-mile buffer. The cities of Austin, and San Antonio showed no more 2 landfills at various census-tract centroids, and Dallas displayed only 1 landfill for asthma prevalence census-tract point locations. Therefore, as general description, majority of asthma prevalence census-tracts in the maps appeared outside the city limits. When compared to the asthma prevalence census-tract data in Table 1, this was again apparent when majority of asthma prevalence census-tract centers indicated having 0 number of landfills once spatial-joined, including within a set 0.5-mile buffer. This points one to continue to question if there truly is an association between the landfill density and asthma prevalence for each of the four cities. Below is the spatially joined landfill-asthma prevalence city census-tract attribute table: Table 1: Landfill-Asthma Prevalence Census-Tract Spatial-Joined Attribute Table. Note, Table 1 has been sorted, greatest to least, by the variable, Join Count. This variable represents the number of landfills found up-to or within each 0.5-mile buffer for each asthma prevalence census-tract point.

Table 1: Landfill-Asthma Prevalence Census-Tract Spatial-Joined Attribute Table

OBJECT ID	Join Count	City Name	Geographic Level	Unique ID	Data Value Type	Data Value	Population Count
1042	6	Houston	Census Tract	4835000-48201531700	Crude prevalence	7.6	2829
1017	4	Houston	Census Tract	4835000-48201521800	Crude prevalence	8	5682
152	2	Austin	Census Tract	4805000-48453002113	Crude prevalence	9.2	3571
671	2	Houston	Census Tract	4835000-48201310500	Crude prevalence	8.9	4856
832	2	Houston	Census Tract	4835000-48201420500	Crude prevalence	10.3	4041
959	2	Houston	Census Tract	4835000-48201453300	Crude prevalence	10.2	2965
1283	2	San Antonio	Census Tract	4865000-48029161902	Crude prevalence		44
1293	2	San Antonio	Census Tract	4865000-48029170800	Crude prevalence	9.8	1568
31	1	Austin	Census Tract	4805000-48453001303	Crude prevalence	7.6	2871
99	1	Austin	Census Tract	4805000-48453001813	Crude prevalence	9.6	5853
326	1	Dallas	Census Tract	4819000-48113007815	Crude prevalence	10.9	4606
340	1	Dallas	Census Tract	4819000-48113007909	Crude prevalence	7.3	2049
344	1	Dallas	Census Tract	4819000-48113007913	Crude prevalence	8.3	1860
386	1	Dallas	Census Tract	4819000-48113009900	Crude prevalence	7.8	1803
390	1	Dallas	Census Tract	4819000-48113010500	Crude prevalence	10.8	2798
392	1	Dallas	Census Tract	4819000-48113010602	Crude prevalence	10.7	3010
427	1	Dallas	Census Tract	4819000-48113012211	Crude prevalence	10.8	3961
564	1	Houston	Census Tract	4835000-48201211900	Crude prevalence	9.1	5225
604	1	Houston	Census Tract	4835000-48201231100	Crude prevalence	10.6	4729
615	1	Houston	Census Tract	4835000-48201232401	Crude prevalence	8.8	1933
626	1	Houston	Census Tract	4835000-48201233102	Crude prevalence		18
638	1	Houston	Census Tract	4835000-48201240702	Crude prevalence	9.4	602

705	1	Houston	Census Tract	4835000-48201313900	Crude prevalence	8.1	4495
736	1	Houston	Census Tract	4835000-48201330900	Crude prevalence	9.7	7886
748	1	Houston	Census Tract	4835000-48201332100	Crude prevalence	11.3	3037
824	1	Houston	Census Tract	4835000-48201413100	Crude prevalence	6.9	3087
825	1	Houston	Census Tract	4835000-48201413201	Crude prevalence	7	2626
828	1	Houston	Census Tract	4835000-48201420100	Crude prevalence	8.9	3062
917	1	Houston	Census Tract	4835000-48201433600	Crude prevalence	10.5	5281
947	1	Houston	Census Tract	4835000-48201452202	Crude prevalence	8	2963
965	1	Houston	Census Tract	4835000-48201453601	Crude prevalence	9.8	2108
988	1	Houston	Census Tract	4835000-48201510600	Crude prevalence	6.5	4763
991	1	Houston	Census Tract	4835000-48201510900	Crude prevalence	6.9	6070
993	1	Houston	Census Tract	4835000-48201511002	Crude prevalence	7	4261
1041	1	Houston	Census Tract	4835000-48201531600	Crude prevalence	8	2823
1043	1	Houston	Census Tract	4835000-48201531800	Crude prevalence	11.6	2352
1044	1	Houston	Census Tract	4835000-48201531900	Crude prevalence	11.5	4708
1099	1	Houston	Census Tract	4835000-48201551400	Crude prevalence	7.7	749
1138	1	San Antonio	Census Tract	4865000-48029110600	Crude prevalence	9.1	7553
1172	1	San Antonio	Census Tract	4865000-48029121404	Crude prevalence	10.4	4945
1199	1	San Antonio	Census Tract	4865000-48029130800	Crude prevalence	11.7	4848
1353	1	San Antonio	Census Tract	4865000-48029181402	Crude prevalence	8	1995
1363	1	San Antonio	Census Tract	4865000-48029181704	Crude prevalence	8.3	4481
1	0	Austin	City	4805000	Age-adjusted prevalence	8.2	790390
2	0	Austin	City	4805000	Crude prevalence	8.3	790390
3	0	Austin	Census Tract	4805000-48209010901	Crude prevalence		2

4	0	Austin	Census Tract	4805000-48453000101	Crude prevalence	7.3	3611
5	0	Austin	Census Tract	4805000-48453000102	Crude prevalence	7.4	2552
6	0	Austin	Census Tract	4805000-48453000203	Crude prevalence	8.8	1546

Poisson Regression

As shown in Tables 2-5, each city revealed having an equally average percent of the population of asthma prevalence per census-tract; Austin with 8.30, Dallas with 9.31, Houston with 8.87, and San Antonio with 8.43. Moreover, Houston displayed having the greatest number of landfills per census-tract at a count of 37; followed by San Antonio at 9.0, Dallas at 7.0, and Austin at 4.0. This socioeconomic descriptive data along with the landfill count for each of the four cities, Austin, Dallas, Houston, and San Antonio can be viewed below in Tables 2-5. Note: Tables 2-5 provides the mean percentage of the population, as well as the coincide mean count per asthma prevalence census-tract for each descriptive variable.

Table 2. Census-Tract Descriptive Statistics of Austin, Texas, 2015-2016

Total Population: 1,040,175

Variable		Average % of Population	Average Count per Census-Tract (N)
Gender	Male	50.81	528605
	Female	49.18	518730
Age Group	18-34	32.37	329732
	35-44	15.55	164700
	45-64	22.52	233244
	≥ 65	8.49	81542
Race	Asian	7.11	81745
	Black	8.94	93076
	White	79.21	822224
	Other	7.98	84805
Ethnicity	Latino	32.36	352154
Education	< Highschool	12.25	97015
	Highschool or GED	17.35	140111
	> Highschool	70.38	572092
Annual Household Income	< $34, 999	29.68	
	$35,000-$49,999	13.84	
	$50,000-$74,999	17.57	
	> $75,000	38.91	
Number of Landfills			4
Insurance Coverage	Insured	82.43	857636
	Uninsured	17.56	182539
Asthma Crude Prevalence	% With Asthma	8.30	

Table 3. Census-Tract Descriptive Statistics of Dallas, Texas, 2015-2016

Total Population: 1,406,581

Variable		Average % of Population	Average Count per Census-Tract (N)
Gender	Male	49.52	705227
	Female	50.47	715396
Age Group	18-34	28.29	398485
	35-44	13.88	200973
	45-64	23.25	318716
	≥ 65	10.25	133492
Race	Asian	4.07	53623
	Black	24.15	351083
	White	63.80	892504
	Other	10.64	161738
Ethnicity	Latino	37.00	576121
Education	< Highschool	23.12	251983
	Highschool or GED	22.46	245795
	> Highschool	54.41	553888
Annual Household Income	< $34, 999	39.95	
	$35,000-$49,999	14.48	
	$50,000-$74,999	16.41	
	> $75,000	29.14	
Number of Landfills			7
Insurance Coverage	Insured	75.00	1030877
	Uninsured	24.99	375704
Asthma Crude Prevalence	% With Asthma	9.31	

Table 4. Census-Tract Descriptive Statistics of Houston, Texas, 2015-2016

Total Population: 3,241,803

Variable		Average % of Population	Average Count per Census-Tract (N)
Gender	Male	50.02	1618335
	Female	49.97	1638845
Age Group	18-34	27.31	878192
	35-44	14.06	467212
	45-64	23.49	750654
	≥ 65	98.06	295574
Race	Asian	7.53	272834
	Black	23.27	737244
	White	60.90	1971611
	Other	10.43	350996
Ethnicity	Latino	41.11	1346820
Education	< Highschool	22.22	503589
	Highschool or GED	23.93	563042
	> Highschool	53.83	1325001
Annual Household Income	< $34, 999	37.79	
	$35,000-$49,999	13.84	
	$50,000-$74,999	16.55	
	> $75,000	31.81	
Number of Landfills			37
Insurance Coverage	Insured	75.27	2444747
	Uninsured	24.72	797056
Asthma Crude Prevalence	% With Asthma	8.87	

Table 5. Census-Tract Descriptive Statistics of San Antonio, Texas, 2015-2016

Total Population: 1,633,172

Variable		Average % of Population	Average Count per Census-Tract (N)
Gender	Male	49.47	818988
	Female	50.52	844448
Age Group	18-34	26.75	444885
	35-44	13.06	220178
	45-64	23.21	380155
	≥ 65	11.20	180358
Race	Asian	3.21	56935
	Black	8.05	139311
	White	80.55	1338378
	Other	11.28	182040
Ethnicity	Latino	62.03	1010724
Education	< Highschool	18.59	208109
	Highschool or GED	26.63	323273
	> Highschool	54.76	694194
Annual Household Income	< $34, 999	37.70	
	$35,000-$49,999	14.26	
	$50,000-$74,999	18.48	
	> $75,000	29.54	
Number of Landfills			9.0
Insurance Coverage	Insured	80.99	1331684
	Uninsured	19.00	301488
Asthma Crude Prevalence	% With Asthma	8.42	

Regression variables were then created for the study, and distributions were recorded for any changes in landfill count, percent of asthma prevalence per census-tract, and in the remaining census-tract regression variables. As was indicated in Tables 6-9, all 4 cities had on average 1.95, 2.19, 6.15, and 2.76 landfills, respectfully, per census-tract. The city of Houston again had the most positive count of landfills at 6.15 per census-tract. Austin, Dallas, and San Antonio had equally the same low average of landfills per census-tract. For regression variable percent asthma prevalence, all four cities had approximately the same average per census-tract. This was also true for the other census-tract regression variables, when compared across each percentile. Overall, no significant descriptive or distribution changes were observed between only tables 2-5 and tables 6-9; however, one interesting finding seen in tables 6-9 was that all four cities had a high percentage of population with a high school degree or higher. Tables 6-9 distributions for merged data can be seen below.

Table 6: Distributions of Landfills, Asthma Prevalence, and Census-tract Level Factors in Austin, Texas Census-tracts, 2015

	Mean	25th Percentile	50th Percentile	75th Percentile
Landfills	1.95	0.00	0.00	0.00
% Asthma Prevalence	8.30	7.60	8.00	8.90
% Population Uninsured	17.56	9.10	15.90	23.50
% Population Non-White	24.03	14.20	21.00	33.60
% Population w/Latino Ethnicity	32.36	13.70	26.20	49.20
% Household Income <$35,000	29.68	17.30	26.20	40.50
% Population w/Highschool Degree or Higher	87.74	80.33	93.24	97.27
% Population age 18-44 years	47.92	40.29	45.88	55.01

Table 7: Distributions of Landfills, Asthma Prevalence, and Census-tract Level Factors in Dallas, Texas Census-tracts, 2015

	Mean	25th Percentile	50th Percentile	75th Percentile
Landfills	2.19	0.00	0.00	0.00
% Asthma Prevalence	9.31	7.90	9.10	10.40
% Population Uninsured	24.99	13.40	26.85	35.30
% Population Non-White	38.88	19.50	35.75	55.60
% Population w/Latino Ethnicity	37.00	14.40	30.05	57.20
% Household Income <$35,000	39.95	23.60	39.40	53.70
% Population w/Highschool Degree or Higher	76.87	62.81	77.63	93.65
% Population age 18-44 years	42.17	34.80	40.05	48.05

Table 8: Distributions of Landfills, Asthma Prevalence, and Census-tract Level Factors in Houston, Texas Census-tracts, 2015

	Mean	25th Percentile	50th Percentile	75th Percentile
Landfills	6.15	0.00	0.00	0.00
% Asthma Prevalence	8.87	7.80	8.80	9.70
% Population Uninsured	24.72	14.40	24.90	34.00
% Population Non-White	41.24	22.80	38.30	56.40
% Population w/Latino Ethnicity	41.11	19.30	36.10	60.30
% Household Income <$35,000	37.79	22.30	36.60	52.30
% Population w/Highschool Degree or Higher	77.77	66.13	79.73	92.00
% Population age 18-44 years	41.37	36.14	40.27	45.01

Table 9: Distributions of Landfills, Asthma Prevalence, and Census-tract Level Factors in San Antonio, Texas Census-tracts, 2015

	Mean	25th Percentile	50th Percentile	75th Percentile
Landfills	2.76	0.00	0.00	0.00
% Asthma Prevalence	8.42	7.80	8.30	8.90
% Population Uninsured	19.00	11.90	19.50	26.10
% Population Non-White	22.55	14.70	19.90	26.90
% Population w/Latino Ethnicity	62.03	43.30	60.35	83.60
% Household Income <$35,000	37.70	20.60	38.90	52.50
% Population w/Highschool Degree or Higher	81.40	70.69	85.35	94.02
% Population age 18-44 years	39.81	34.74	38.04	42.34

Poisson regression was then performed. As depicted in Table 10, the relationship between asthma prevalence census-tract points, and the census-tract covariates differed. For the covariate predictor variable, landfill, a p-value of 0.999 was provided, along with a 0.0000307 coefficient. Having a p-value greater than the set 0.05 standard p-value significance level, and or a coefficient that is approximately 0.00, indicates that there is no statistical significance between the two variables in comparison. Therefore, having both measures, p-value of 0.999, and coefficient of 0.0000307, for this study, suggests that there is no significant relationship or association between landfills and asthma prevalence via census-tracts. Therefore, we fail to reject the null hypothesis, the null hypothesis being that there no association between higher area-level density of landfill sites and higher census-tract level asthma prevalence in urban areas in Texas. For other covariates such as % population non-white, % household income < $35,000, and % population with high school degree or higher, all showed an overall p-value less than the set 0.05 significance p-value level, at 0.000, 0.000, 0.023, respectfully; indicating significant corresponding coefficients of 0.002793, .0035904, and -0.3680682. Since Poisson analysis uses a log-linear model, the coefficients 0.002793, 0.0035904, and -0.3680682 of covariates, % population non-white, % household income < $35,000, and % population with high school degree or higher, can be used to describe the likelihood of these variables' relationship to asthma prevalence. For instance, a one-unit increase (X/Y = 1/1) in the % of the non-white population in a census-tract, with the expected number of % of asthma prevalence, will increase by 1.002797 times (Exp^ (0.002793) = 1.002797). The same method can be applied for the variable % household income < $35,000 in a census-tract, indicating that a one-unit increase (X/Y = 1/1) for percent household income less than $35,000, with the expected number of % of asthma prevalence, will increase by 1.0036 times (Exp^ (0.0035904) = 1.0036). Since the coefficient for % population with high school degree or higher is negative the likelihood changes. Thus, for a one-unit increase (X/Y = 1/1) in % population with high school degree or higher, with the expected number of % of asthma prevalence, will decrease by 0.6921 times (Exp^ (-0.3680682) = 0.6921). Therefore, because the Poisson analysis was modeled to examine the relationship between variables, the results found are correlational, not causational. All other covariates listed had a p-value more than the set 0.05 standard p-value significance level. Lastly, the Poisson regression model was fixed by city, with Austin, Texas used as the reference city automatically applied by STATA. The resulting p-values for each city, once the fixed effect had been applied, were then compared. All cities provided p-values greater than the 0.05 standard p-value significance level, and was therefore also considered statistically not significant. Table 10 can be found below, displaying the resulting Poisson analysis data which indicates no association between area-level landfill density and asthma prevalence in urban Texas areas.

Table 10: Results of Poisson Model Evaluating the Association Between Areal-Level Landfill Density and Asthma Prevalence for 2015-2016

NUMBER OF OBS = 1,360
LR CHI2(10) = 223.28
PROB > CHI2 = 0.0000
LOG LIKELIHOOD = -2757.8581 PSEUDO R2 = 0.0389

Asthma Prevalence	Coefficient	Standard Error	Z	P-Value (P>|Z|)	(95% Confidence Interval)	
Covariates:						
Landfills	.0000307	.033944	0.00	0.999	-.0664984	.0665598
% Population Uninsured	-.0004784	.0016569	-0.29	0.773	-.0037258	.002769
% Population Non-White	.002793	.0005907	4.73	0.000	.0016353	.0039507
% Population w/Latino Ethnicity	-.0009122	.0008994	-1.01	0.310	-.0026749	.0008506
% Household Income <$35,000	.0035904	.0008397	4.28	0.000	.0019446	.0052362
% Population w/Highschool Degree or Higher	-.3680682	.1619298	-2.27	0.023	-.6854448	-.0506916
% Population age 18-44 years	-.1860601	.100628	-1.85	0.064	-.3832874	.0111673
Asthma Prevalence Fixed by City: (Note: Austin, Texas used as Reference City in STATA)						
Dallas	-.0131009	.0337458	-0.39	0.698	-.0792415	.0530398
Houston	-.0546757	.0313281	-1.75	0.081	-.1160776	.0067263
San Antonio	-.0210806	.0393517	-0.54	0.592	-.0982085	.0560473
Interception	2.38319	.1689034	14.11	0.000	2.052145	2.714234

DISCUSSION

The findings from my research differed from those examined in the literature review, which suggested an association between landfills, respiratory illnesses including asthma, and the role of Hydrogen Sulfide Gas (H2S) to play a role as a potential biologic mechanism for asthma. This was definitively mentioned in Rubrights' study, suggesting a strong correlation between landfills and their ability to release hydrogen sulfide (H_2S) gas, leading to a number of severe health outcomes including asthma. My resulting Poisson data, however, did not support this claim, nor my hypothesis, which alone stated there was a positive association between landfills and asthma prevalence in these Texas urban areas. Moreover, because my study used publicly available population data based on census-tract coordinate points, not individual data, I am unable to provide any inferences or reasonable evidence suggesting that H_2S can act as biological mechanism, which may lead to asthma or trigger asthmatic symptoms.

Furthermore, as was stated in Vrijheid and Krets studies, future research is needed to provide a closer look at environmental exposures, specifically landfill air pollutants, which still may pose a great threat for an increase in asthma prevalence. Additional studies are needed further evaluating potential landfill-asthma prevalence correlations, to better understand and provide a more conclusive idea as to what, if any, geographic disparities are found particularly within each of the Texas cities, Austin, Dallas, Houston, and San Antonio, with regards to landfill locations.

Study Strengths and Limitations

An ecologic study design has both strengths and weaknesses. Conducting an ecologic study can be useful when individual data are either not available or possible, when there are limited funds or a limited time frame, or the focus remains on only ecologic variables, such as environmental exposures (106-109, 112, 113). Geographical, ecologic studies are typically an examination of group-level associations of diseases and/or adverse health outcomes, while making geographical comparisons (106-109, 112, 113). Performing an ecologic study, however, does come with challenges. Ecologic fallacy, ecologic bias, or aggregation bias as it is sometimes known, is found specifically with ecologic study designs (106-109, 112, 113). This occurs when we assume that results observed at the group-level are also true at the individual-level; thus, not accounting for the varying individual demographic and socio-economic information and potential individual-level confounders (106-109, 112, 113). Geographical confounding can also occur in ecologic studies (114). This type of confounding happens when making comparisons between various locations where city and census-tract level data are missing for select areas, or database location coordinates or dates are inaccurate (114). My research attempted to control for possible geographical confounding by including census-tract level covariates taken from the U.S. Census (101-105). Moreover, individual data estimates used in the 500 City researcher’s multi-level analysis were not made publicly available, thus potentially impacting the results of my study using only census-tract data, as well as influencing my findings regarding possible geographically disparities and asthma prevalence.

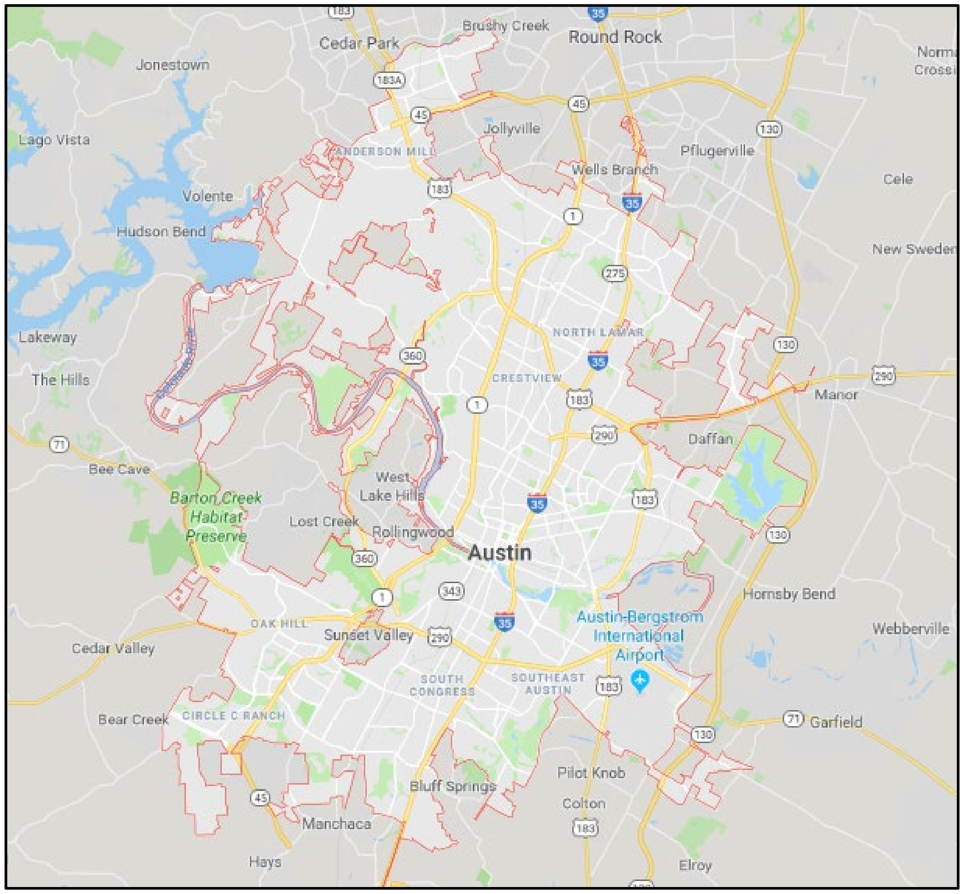
CONCLUSION

Asthma is serious public health concern, worthy of further investigation, regardless of the method or way of exposure. Though this ecological study did not provide statistically significant evidence of an association between area-level landfill density and asthma prevalence in the selected urban Texas areas, it can provide information for future groundwork to be performed in other studies, environmental or otherwise. Future research, however, should focus their efforts on expanding spatial GIS observations to entire Texas census-tracts, rather than simple buffers around specific asthma prevalence centroids. This may provide a better count of Texas landfill exposure for multiple asthma prevalence census-tract coordinates that may overlap. Additional studies could expand their reach, and examine other ways of Texas landfill exposure and its effects on asthma prevalence, via notions of climate change, wind direction, or soil or groundwater contamination. This study touched briefly on these concepts in the literature review, but did not provide in-depth observation.

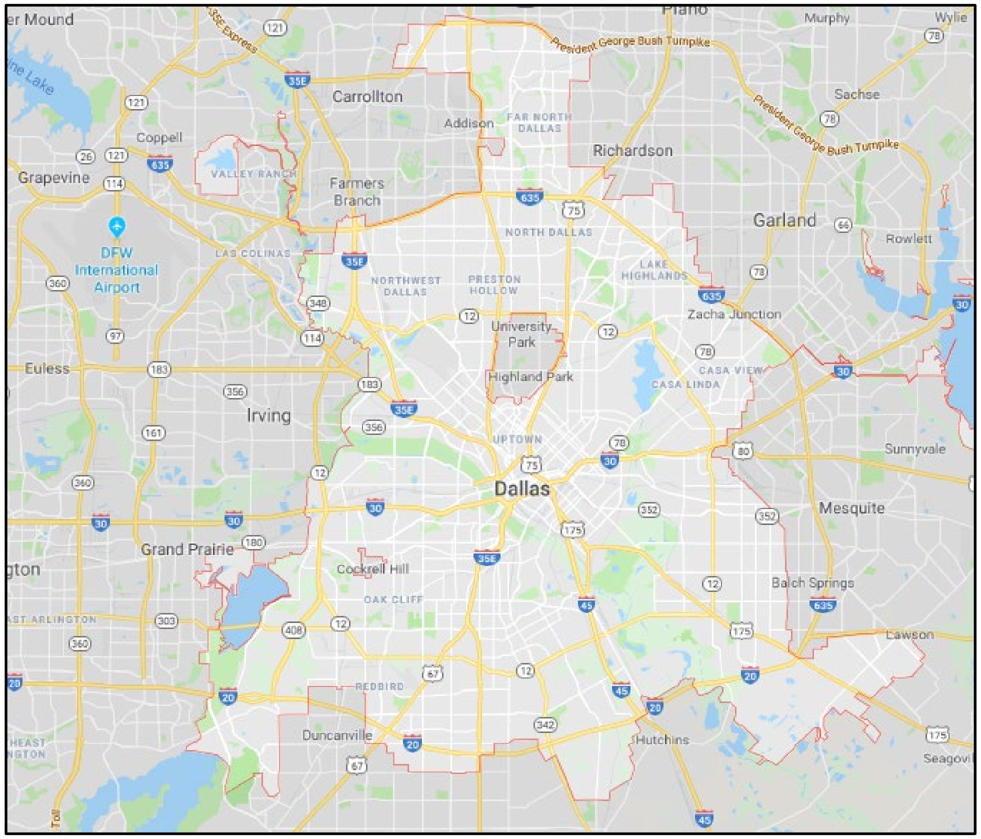
APPENDICES

Appendix A: Additional Maps – City Boundaries

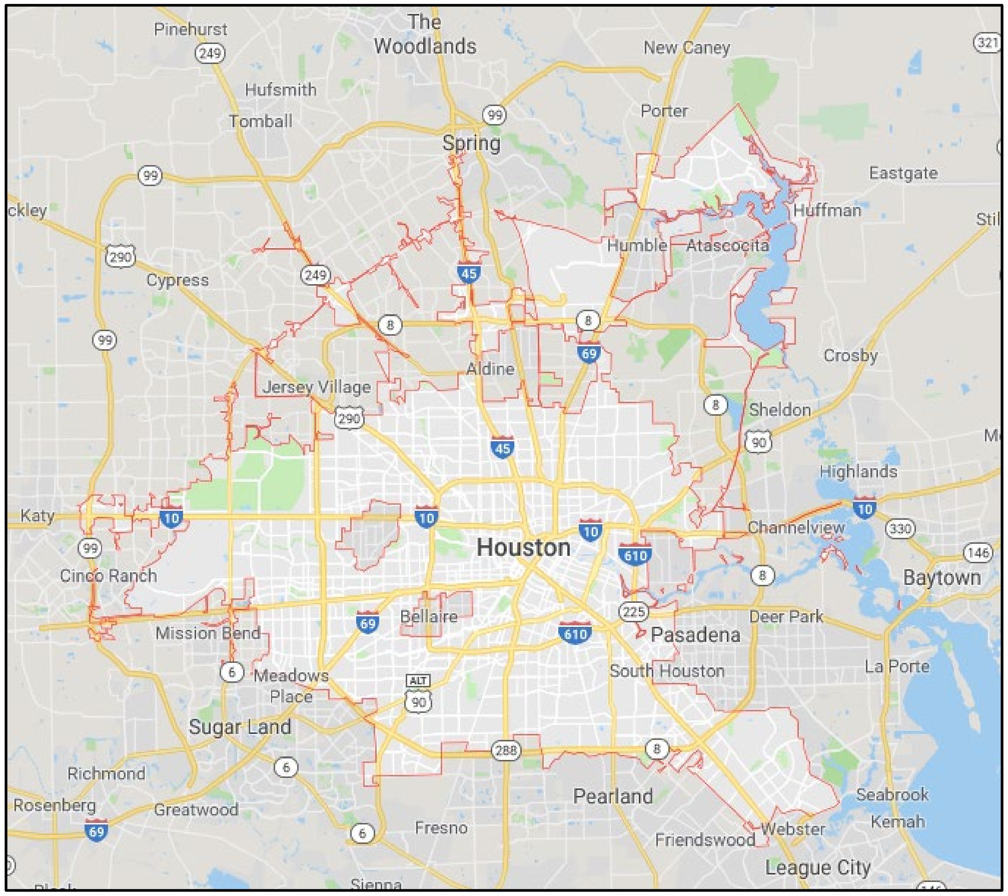
MAP 6: AUSTIN, TX CITY BOUNDARIES



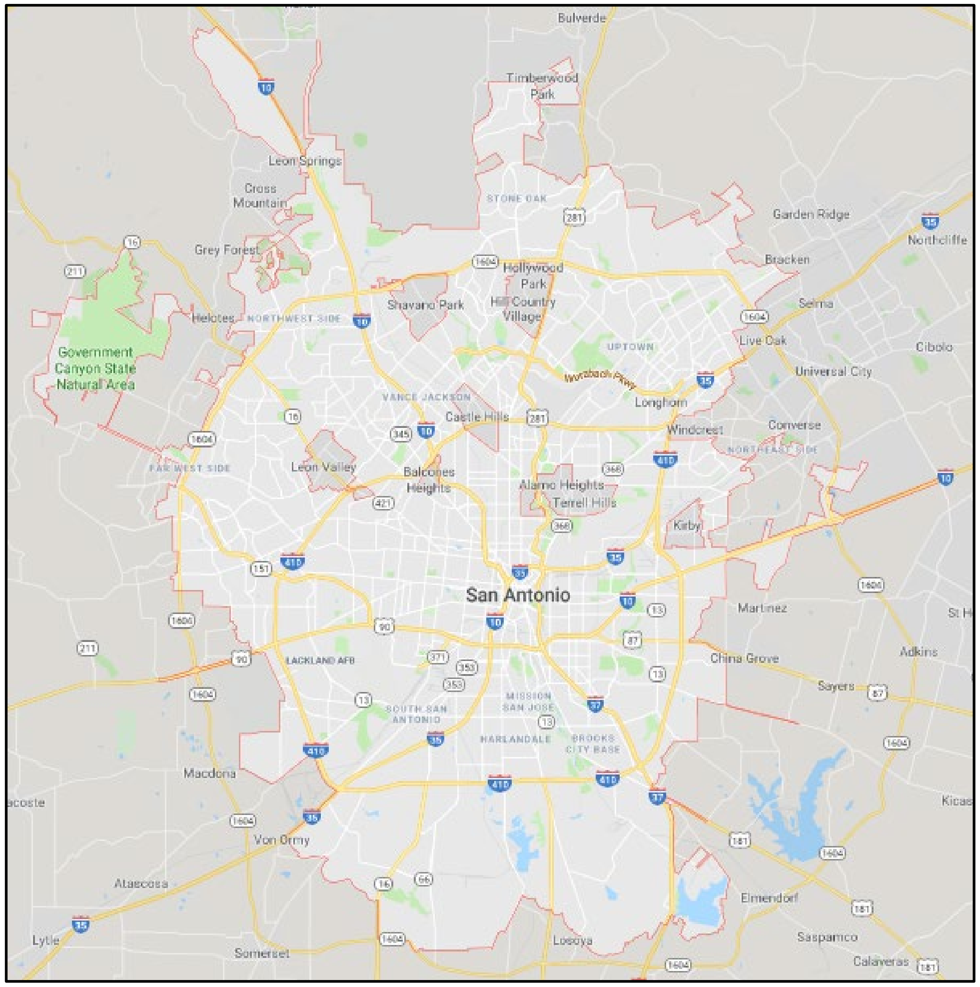
MAP 7: DALLAS, TX CITY BOUNDARIES



MAP 8: HOUSTON, TX CITY BOUNDARIES



MAP 9: SAN ANTONIO, TX CITY BOUNDARIES



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