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Estimating Vehicle Infrastructure: Downtown Albuquerque, New Mexico

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**ESTIMATING VEHICLE INFRASTRUCTURE:
DOWNTOWN ALBUQUERQUE, NEW MEXICO**

BY

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ABSTRACT

Cities have little knowledge about their parking infrastructure despite clear evidence that abundant parking has environmental, economic, and transportation consequences. The objective of this thesis is to illustrate the need to accurately estimate the area dedicated to vehicle infrastructure (parking lots and streets) within urban areas. I focused on a method that estimated the vehicle infrastructure area within the Downtown Core of Albuquerque, New Mexico, by cross-referencing geospatial cadastral data with minimum parking requirements. Three parking space types were identified: 1) parking in structures; 2) surface parking (parking lots and residential driveways); and 3) on-street parking. To illustrate the need to accurately estimate vehicle infrastructure, I also estimated the benefits and costs of replacing 10%, 25%, or 50% of surface parking with various tree species. The benefits and costs examined were for stormwater runoff, carbon sequestration, air quality, property values, energy use, maintenance costs, and planting costs.

In total, I estimated that there were 29,120 parking spaces located within the study area. The area allocated to these spaces was between 8,976,801 ft^2 and 10,000,851 ft^2. This included the estimated 8,639 spaces in parking structures and 1,899 on-street parking spaces. The total surface parking was 21,986 spaces (including the first floor in

parking structures), estimated at between 6,631,615 ft^2 (0.2379 mi^2) and 7,655,665 ft^2 (0.2746 mi^2), or 31.6% to 36.5% of the study area. The area of streets was estimated at 2,163,944 ft^2 (0.0776 mi^2), or 10.3% of the study area. Together, the area of surface parking and streets was estimated at between 8,795,559 ft^2 (0.3155 mi^2) and 9,819,609 ft^2 (0.3522 mi^2), or 42.0% to 46.9% of the study area. Replacing 10% of the parking with Northern Red Oaks would provide the most benefits: between $2,583,028 and $3,013,532 during the life of the trees. At 25%, the benefits were between $6,457,569 and $7,533,831. Converting 50% of the parking spaces would yield benefits valued between $12,915,139 and $15,067,662. Four species of tree yielded a negative net benefit: the Oriental Arborvitae, Common Pear, Japanese Maple, and Mexican Pinyon, all of which cost more to plant and maintain then the value of benefits they provided. The Oriental Arborvitae had the highest cost: 10%) -$1,827,188 to -$2,131,719; 25%) -$4,567,970 to -$5,329,298; and 50%) -$9,135,939 to -$10,658,596.

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CHAPTER 1: INTRODUCTION

Impervious surfaces within urban areas are associated with adverse environmental consequences. In urbanized areas, impervious surfaces include buildings, roofs, roads, sidewalks, and parking lots (Davis, Pijanowski, Robinson, & Kidwell, 2010, p. 68). Substantial research has documented the environmental impact of impervious surfaces. However, few cities have assessed the extent of vehicle infrastructure (parking lots and streets). Of the studies done, most have focused on parking spaces. For example, Chester et al. (2010) estimated between 105 million and 2 billion total spaces in the United States. On the regional scale, Davis, Pijanowski, Robinson, and Kidwell (2010) concluded that the four-state area of Illinois, Indiana, Michigan, and Wisconsin had 43 million parking spaces. Chester et al. (2015) estimated 18.6 million parking spaces in Los Angeles (L.A.) County, California, in 2010. Davis, Pijanowski, Robinson, and Engel (2010) found that parking lots covered 5.65 km^2 of Tippecanoe County, Indiana. Hoehne et al. (2019) estimated that there were 12.2 million parking spaces in the Phoenix, Arizona, metropolitan area. Three studies included estimations of street areas. Akbari et al. (2003) found that, on average, paved surfaces accounted for 39% of the total area in downtown Sacramento, California. In L.A. County, 41% of the urban area was covered in parking (14%) and roads (27%) (Chester et al., 2015). Hoehne et al. (2019) estimated that 36% of the Phoenix metropolitan area was covered in parking (10%) and roads (26%).

The City of Albuquerque, like many other urban areas in the United States, has grown its vehicle infrastructure during the past century. As Albuquerque's population grew in the post-war era from 35,449 in 1940 to 97,012 in 1950 (US Census Bureau, 1950), its urban form has also changed significantly over the decades. In the subsequent decades following World War II, Albuquerque has gone from a small community to a suburban landscape dominated by cars. The 1920s saw the widespread adoption of the automobile, bringing significant congestion in downtowns (Wachs, 1984). This was due to the urban form of American cities at the time, characterized by short blocks, narrow streets, organic and complex road networks, and high building densities (Muller, 2004). Initially to combat congestion, off-street parking facilities were created as a way of keeping vehicles off the road when not in use, reducing illegal parking, avoiding spillover into nearby neighborhoods, and preventing cruising for empty on-street spaces (Ferguson, 2004; Shoup & Pickrell, 1978). This later led to the implementation of minimum parking requirements (MPRs) formalizing land use patterns and was at the heart of parking supply policy. By the late 1950s and into the 1960s, Albuquerque, like many cities, was experiencing a decline of its urban core. For Albuquerque, this decline was partially brought on by the combination of traffic congestion downtown and a lack of parking, causing merchants to relocate. During this period the population more than doubled, reaching 201,503 in 1960 (LoPata, 2013, p. 21). Developers built residential subdivision on cheaper land in the Heights, far from downtown. Meanwhile, the exodus of merchants from downtown found new homes in stirp shopping centers (multi-unit buildings, often with large parking lots) that were at many major intersections in the Heights. The strip shopping centers were located close to newly built residential subdivisions, easily accessed by automobile and with plenty of parking provided. The construction of Winrock Shopping Center in 1961 followed by Coronado Mall in 1964 enticed the remaining retail giants to relocate from downtown (LoPata, 2013, p. 25). As the exodus of business from the Downtown Core continued, by 1963, 24 condemned buildings had been razed and most converted into parking lots (LoPata, 2013, p. 27).

MPRs policy is upheld by both the traffic professionals' (e.g., planners, traffic engineers) and the public's view of parking itself. Traffic professionals want to avoid criticism from the public for allowing development that subsequently creates parking spill over. This led to the perception of an oversupply of off-street parking being preferable to an undersupply (Shoup, 2005, p. 41). Resulting in local zoning requirements that mandate most businesses to provide enough parking for days of peak demand, such as the day after Thanksgiving (Black Friday) or Sunday services at churches (Shoup, 2005, p. 85), even though at least half of the spaces are vacant 40% of the time (Urban Land Institute, 1982, p. 12). The public is critical of a perceived lack of parking spaces. This view of parking availability is due to the most visible parking spaces being the first to be occupied, causing a parking lot to appear full (Wilson, 1995, p. 32). The public views parking as undersupplied, professionals respond by increasing MPRs, creating an oversupply.

The oversupply of off-street parking creates large areas of impervious surfaces impacting the environment in several ways. Stormwater runoff is increased; Davis, Pijanowski, Robinson, and Engel (2010) found runoff increased by more than 900% (p. 259). Impervious surfaces contribute to a heat island effect and further air pollution (McPherson, 2001). Many alternatives to MPRs have been developed, including setting metered parking prices at market value, implementing employer cash payouts, instituting parking maximums, and eliminating parking requirements altogether (Shoup, 2005). Despite the effectiveness of these strategies, most metropolitan areas already have extensive vehicle infrastructure. Knowing the amount that exists is an important element of greater comprehensive reform in transportation planning.

What is lacking is a true understanding of the amount of vehicle infrastructure that exists on a national level. While there are a few studies that examine vehicle infrastructure on the local and regional levels, these studies do not provide enough information to allow an extrapolation of their estimations to the national level. The purpose of this thesis is to: 1) analyze the available parking supply at the local level in the Downtown Core of Albuquerque, New Mexico; and 2) highlight the importance of accurately estimating vehicle infrastructure by analyzing the benefits and costs of replacing a portion of it with various tree species.

CHAPTER 2: REVIEW OF RELATED LITERATURE

Previous literature on vehicle infrastructure reveals that it has a complex relationship with the environment, the economy, and transportation systems. Additionally, research on the area dedicated to vehicle infrastructure is limited in number, the majority of which focuses on parking infrastructure. This section draws from the previous literature to show the relationship vehicle infrastructure has with the environment, the economy, and transportation systems.

2.1 Environmental and Health Effects

Parking lots are an integral component of our current transportation system, but an oversupply of them can have environmental consequences. Parking lots have a negative impact on water quality, which can be measured by an increase in runoff and the pollutants it carries. For example, in Tippecanoe County, Indiana, Davis, Pijanowski, Robinson, and Engel (2010) found that runoff increased by 900% when compared to runoff of the land before it was a parking lot. Additionally, they found that heavy metals and other pollutants increased as well, including a 200% increase in nitrogen and phosphorus losses.

An oversupply of parking increases traffic congestion by increasing vehicle miles traveled (VMT); this also leads to an increase in greenhouse gases and other harmful pollutants, such as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOCs), sulfur dioxide (SO_2), ozone (O_3), and particulate matter (PM) (Environmental Protection Agency [EPA], n.d.-a; n.d.-b; n.d.-c; n.d.-d; n.d.-e; n.d.-f). Greenhouse gases contribute to climate change by trapping heat from the sun. In 2019, CO_2 accounted for 80% of all U.S. greenhouse gas emissions, with 35% of it coming from transportation (EPA, n.d.-c). In high concentrations, CO reduces the amount of oxygen in the blood stream and can lead to dizziness, confusion, unconsciousness, and death (EPA, n.d.-a). In 2019, nitrous oxide (N_2O) comprised 7% of all greenhouse gas emissions in the United States, but compared to CO_2, it had 300 times the impact on atmospheric warming (EPA, n.d.-d). NO_x and VOCs emitted from industrial facilities, vehicles, and other sources combine in the presence of heat and sunlight to create ground level ozone. Ozone can aggravate lung diseases in people and can slow plant growth (EPA, n.d.-b). Power plants that use fossil fuels are the largest source of sulfur dioxide (SO_2). In the atmosphere, it reacts with other compounds to form small PM and contributes to acid rain (EPA, n.d.-e). Furthermore, parking lots, because of their dark color, absorb and hold heat during the day then release it at night. This is known as the heat island effect, and it further increases greenhouse gas emissions. The heat radiating from parking lots during the night raises the ambient temperature, causing air conditioning systems to be used more frequently, increasing demand for electricity generation (Akbari et al., 2003).

2.2 Economic Cost

Aside from the environmental costs of parking lots, they also carry economic costs. When spaces are oversupplied, parking lots can lead to lower land values and increase construction costs (Wilson, 1995). Wilson determined this by conducting case studies of 10 office buildings in Southern California, of which five were typical of their communities and five had special parking characteristics. For each group, their average parking requirements were calculated (typical: 4.1 spaces per 1,000 gross ft^2; special: 2.9 spaces per 1,000 gross ft^2). A research team conducted parking utilization studies to find the average parking supply of each group (typical: 3.8 spaces per 1,000 gross ft^2; special: 3.4 spaces per 1,000 gross ft^2). During peak demand hours, the average parking utilization for typical sites was 56% and 72% for the special sites. Three building scenarios were then created, where scenario A represented as built; scenario B represented a reduced site size; and scenario C represented more building area (in scenarios B and C, a parking supply of 2.5 was used). Wilson assumed a supportable land value of $11 per square foot in scenario A. By bringing the parking supply closer to real demand, he calculated that for scenarios B and C the supportable land value increased by up to 50% ($16.25–$16.50). It is important to note that the study was specifically discussing the value of the excess parking. While an oversupply of parking can lead to lower land values, lower land values can also lead to an oversupply of parking. Wilson explained how high MPRs give lower valued land (often suburban) a comparative advantage (p. 39). Low-cost land in the suburbs is more desirable because parking (or the oversupply of it mandated by MPRs) can be provided at a lower cost than in urban areas. Lower-cost land lowers the cost of providing surface parking and allows developers to avoid building parking structures ($6,280 compared to $12,300 per space).

Just as MPRs can lower land values and increase construction costs for office buildings, the same can be true for residential housing (specifically apartments). In 1961, Oakland, California, introduced new parking requirements for apartments, stating one parking space per dwelling unit. Bertha (1964) collected data from 64 apartment projects, 45 of which were developed in the four years prior to the new parking requirements, and 19 were developed in the two years after (pp. 108–120, as cited in Shoup, 1997, p. 10). After the new parking was required, cost of construction per dwelling unit rose by 18%, housing density fell by 30%, and land values fell by 33%. When interviewed, developers stated that an increased pre-development land cost encouraged the development of apartments with higher rent, and to receive higher rents, larger units where offered. In this way, requiring more parking than what the market demanded also made housing less affordable.

Parking lots also lead to increases in product prices. Initially, a developer pays for the required parking, but soon the tenants do, and they pass those price increases on to the customer (Shoup, 2005, p. 2). So, it is not just those that own a vehicle that pay for parking in this way, but everyone in the economy.

Creating walkable streets is an essential feature of a downtown area. Walkability has been correlated with better physical and mental health, decreased air pollution, decreased vehicle crash rates, increased property values, and decreased congestion. Streets that are walkable can benefit a downtown economically by increasing pedestrian traffic in the area, leading to more spending. Speck (2012) outlined 10 steps to creating a walkable street, one of which was to shape the spaces. A component of this is to provide a sense of spatial enclosure, created by storefronts that are built right up to the sidewalk. A parking lot that is placed at the front of a building can interrupt the spatial enclosure of a street – these lots are known as “missing teeth” in the planning community. This single interruption can ruin the walkability of an entire street (Speck, 2012, p. 214). Walkability can further be undermined by parking lots as they lead to an increase in distances from one place to another, making walking unreasonable and driving the only option. Although these missing teeth are often created by MPRs, they can also be created by a lack of shopping demand in the area. Duany et al. (2000) note that not all parking is detrimental to walkability; they argued that on-street parallel parking provides a barrier between moving traffic and sidewalks, helping pedestrians feel safer (p. 71).

Given these effects that vehicle infrastructure have on the environment and the economy, it is important to measure the amount of vehicle infrastructure within the Downtown Core area from a land use perspective. Without knowing how much parking there is, it is impossible to say whether there is too much or not enough. Thus, effective policy changes cannot be made.

2.3 Urban Forest

Many studies have advocated for creating urban forests to help solve some of these issues. For example, a tree's leaves and branches intercept rainfall; its roots increase rainfall infiltration rates; and transpiration (which reduces soil moisture) increases soil's capacity to store rainfall. Two previous studies have been conducted on the rainfall intercepted by trees in Albuquerque. The study conducted in 2006 found that 11.1 million gallons (1.48 million ft^3) of stormwater were intercepted annually by municipal trees (Vargas et al., 2006, p. 22). A study by Davey Resource Group (2014) found that Albuquerque's trees intercepted 51.4 million ft^3 of rainfall annually (p. 26). Trees not only reduce the volume of runoff, but also slow water down, delaying peak flows (Vargas et al., 2007, p. 13).

Urban forests can provide a repository for CO_2 from vehicle exhaust by incorporating the carbon into new annual growth; this is known as carbon sequestration. The Davey Resource Group (2014) found that Albuquerque's trees sequestered 9,710 tons of carbon per year (p. 24). Additionally, the shade cast by a tree's canopy cools nearby buildings and pavement, resulting in a reduction of air conditioning use, further reducing CO_2 output from power plants. A study conducted in Sacramento, California, showed the economic benefits of planting trees as part of parking lot landscaping (McPherson, 2001). The study found that increasing the total paved area shaded by trees from 22% to 50% would add an additional $2.2 million in annual benefits, of which 17% was related to CO_2 reduction and 11% from cooling energy savings (McPherson, 2001, p. 114). The reduction in CO_2 is not the only benefit to air quality that trees provide; they also reduce NO_x, VOCs, SO_2, O_3, and PM, either through interception or absorption. McPherson (2001) found that 42% of annual benefits were from improvements to air quality (p. 114). Likewise, the Davey Resource Group (2014) estimated the value of air pollution removal in Albuquerque to be $1.1 million annually (p. 22).

Several studies found that trees can have a positive impact on local economies, increasing residential property values, commercial shopping revenue, and road safety. Anderson and Cordell (1988) found that each large tree in a front yard increased the sales price by 0.88%. Wolf (1999) conducted a survey and found that on average, prices were 12% higher for products in landscaped districts compared to no-tree districts (p. 57). A study conducted in Toronto, Canada, found that mid-block crashes decreased between 5% and 20% on roads with trees (Naderi, 2003, p. 120).

2.4 Urban Sprawl

Urban sprawl is described as the rapid expansion of cities and towns, often characterized by low-density residential housing, single-use zoning, and increased dependence on private vehicles (Rafferty, n.d.). Although, the primary drivers of sprawl are population growth and a desire for increased living space, oversupplied parking can also be a significant contributor.

Parking lots contribute to urban sprawl in two ways: by decreasing densities and by decreasing land values (by increasing construction costs) in a city's urban core. This gives cheaper land outside of the urban core a comparative advantage, giving developers a monetary incentive to build further out. The combination of a desire for increased living space and inexpensive land results in developers building low-density housing. With commercial and retail jobs still located in the urban core, the new suburban residents must use private vehicles to commute to work. The low densities and farther distance of the suburbs makes providing transit options to them costly and often inefficient. Whereas, residents of urban cores usually have access to transit options, as well as bicycling or walking.

2.5 Traffic Congestion and Vehicle Miles Traveled (VMT)

The relationship of oversupplied parking increasing VMT, thereby causing traffic congestion, can be explained as follows. When there is an overabundant supply of free parking, densities and land values are decreased, leading to urban sprawl. In this way, urban sprawl contributes to VMT as it lengthens the distance from origin and destination for each trip, meaning that not only are more trips made, but they are also made longer. An increase of VMT on a roadway results in vehicles occupying it longer, thus decreasing the capacity and leading to traffic congestion. Tam and Lam (2000) illustrated how parking supply effects traffic congestion. They used a bi-level programming problem to model whether existing road networks and parking supply could accommodate future zonal car ownership growth. The upper-level problem was to maximize the sum of zonal car ownership by considering a traveler's route and destination choice and satisfying the network capacity and parking space constraints.

They found that as parking was added to the model, the total maximum number of cars increased. This is further compounded by the fact that free parking is not just provided by businesses and workplaces, but also at home in the form of driveways (Guo, 2013; Weinberger, 2012).

To relieve traffic congestion caused by an increase in VMT, one of the tools traffic engineers use is to add more lanes to a street (when right-of-way allows it). This, in theory, should solve the problem of traffic congestion by creating more capacity with the same number of vehicles, but instead, it induces demand. Induced demand occurs when increased capacity prompts behavioral shifts in the form of some formerly suppressed trips now occurring, and some drivers switching modes, routes, and travel times to exploit the new available capacity (Downs, 1962, p. 1992). This will eventually drive more people to use vehicles as their preferred mode of transportation, filling the street to capacity soon after it is expanded (Duany et al., 2000, pp. 87–89). Furthermore, in 2004, a meta-analysis of dozens of studies found, on average, a 10% increase in lane miles induced an immediate 4% increase in VMT, rising to 10% in a few years (Salzman, 2010, December 21). Cervero (2003) had tested this by implementing both a short-term and long-term path model to determine the presence of induced demand on highway projects. He specifically studied speed to conclude that induced demand occurred.

2.6 Parking Supply and Demand Relationships

The literature measuring vehicle infrastructure demonstrates that parking supply effects car ownership rates. Furthermore, parking supply has increasingly become a recognized factor in mode choice (Kuzmyak et al., 2003; Shoup, 1995). This is because the amount of vehicle infrastructure that has been built (supply) is related to vehicle ownership and use rates (demand).

Parking supply can be divided into two categories: residential and nonresidential. An abundant supply of either can influence car ownership rates and mode choice. Residential parking supply is looked at in two ways. First, as off-street supply, such as garages and driveways, and second, as on-street supply, such as permit parking or metered parking in central business districts (CBDs) (on-street parking is often free outside of CBDs). Past research has tended to focus on parking supply's effect on mode choice at the destination end and has been limited on the origin end, but there are some exceptions. Weinberger, Seaman, and Johnson (2008), Weinberger, Seaman, Johnson, and Kaehny (2008), and Weinberger et al. (2009) found that there was an increased probability of commuting to work in Manhattan by car if there was on-site off-street residential parking. Guo (2013) found that in New York City, New York, residential parking supply could largely determine household car ownership decisions. This parking effect outperformed household income and demographic characteristics. Furthermore, Guo found that households with different parking types (on-street vs. off-street) have different effects. For example, he found that more than half of households without off-street parking did not own cars. The study also noted that 18% of households with an on-site garage did not have a car. On the other side of the car ownership spectrum, 12% (44 households) of on-street parking households had two or more cars, and 16 of those had three or more cars (p. 23). These findings contradicted other research that had found that household income and demographics had dominant effects on car ownership. For example, car ownership was often assumed to increase based on an increase in income or per capita gross domestic product (GDP) (Button et al., 1993; Dargay & Gately, 1999; Dargay et al., 2007). Adding to this, Weinberger (2012) found that "there is a relationship between guaranteed parking at home and the greater propensity to use the automobile for journey to work trips even between origin and destinations pairs that are reasonably well and very well served by transit" (p. 8).

Similar to residential parking supply, nonresidential parking supply has also been looked at in two ways: on-street metered parking spaces and off-street in the form of parking lots and parking structures. Many studies have been done on this subject, focusing on parking cost as a gauge of nonresidential parking supply (Hess, 2001; Shoup, 2005). Hess (2001) used a multinomial logit model to evaluate commuters that did and did not receive free parking at work and their mode choices. The study used information gathered from a Household Activity and Travel Survey in Portland, Oregon, and divided mode share to those that chose to drive alone, ride in a carpool, or use transit. It found that "raising the cost of parking at work sites and decreasing the transit travel time (by improving service and decreasing headways) will reduce the percentage of people who drive alone to work" (p. 19). Shoup (2005) stated that providing free on-street parking begins the process of planning for free off-street parking (p. 295). He explained that if on-street parking is free and developers fail to provide adequate off-street parking, then neighbors will complain about the parking spillover. Planners respond by increasing off-street parking minimums until the spillover problems are resolved. However, this in turn creates more demand for owning a vehicle, while the supply of roads and parking stay constant. Additionally, free on-street parking creates more congestion. When the price to park is zero, drivers tend to park for longer, using up the supply of parking spaces. One study in Seattle, Washington, looked at 35 areas and found that the average parking duration in spaces with a one-hour time limit was 2.1 hours (City of Seattle, 2000, p. 16). As a result, when new drivers arrive, instead of parking they must now search for a space. This is known as cruising, and it in turn creates congestion by using up the road supply. Reducing parking demand by adjusting its pricing (and by extension reducing the convenience of owning a vehicle) instead of increasing parking supply can reduce the problems associated with driving. To accomplish this, Shoup (2005) advocated for increasing on-street metered parking prices to reflect market conditions rather than limit the duration of on-street parking. Vickrey (1954) recommended charging variable prices to achieve a 15% vacancy rate, charging zero when the demand is below 85% occupancy, and increasing the charge as demand increases (p. 64 as cited in Shoup, 2005, p. 298). This research shows that while parking supply at the nonresidential end is not in itself a cause for increased vehicle ownership and mode share, the supply of it at little or no cost does increase vehicle ownership and mode share.

The relationships between MPRs policy, free parking, land value, urban sprawl, transit, VMT, and congestion can be summarized as follows. MPRs policies mandate an oversupply of free parking spaces in urban cores and widespread free parking devalues land, increases construction costs, decreases densities, and leads to higher rents. This results in land located outside of urban cores, where construction is less costly, to become more attractive, creating urban sprawl. Urban sprawl furthers the distances between home, now located in a suburb, and work, still located in the urban core. Furthermore, the increase in distance makes providing transit options to the suburbs costly and inefficient, creating a situation where residents must use private vehicles. The increased distance and higher vehicle ownership rates lead to an increase in VMT. As VMT on a roadway increases, vehicles occupy it longer, decreasing its capacity and leading to traffic congestion. Meanwhile, in the urban core, the demand for parking spaces increases as vehicle ownership rates increase, but the supply remains relatively constant. This further increases congestion. When few on-street parking spaces are available (because of high demand and a constant supply), a motorist will "cruise" for a space, using up roadway capacity. When parking demand exceeds parking supply, vehicles spill over into neighborhoods, prompting planners to increase off-street parking minimums. These relationships form a cycle of MPRs increasing vehicle dependency, which leads to congestion, prompting more MPR policies.

2.7 Research on Estimating Parking

I reviewed five studies that estimated parking lot area and street area. They were the most recent studies that I found on the subject, by following their literary references. Each study used different methods, this section describes and compares the different methods used in the following academic findings.

The work done by Chester et al. (2015) examined parking infrastructure and location in L.A. County as well as the growth of parking infrastructure between the years 1900–2010. The study estimated the amount and location of off-street and on-street parking separately. For both, a decade-by-decade assessment of parking design and requirements was created. This was done to account for changes in parking requirements that happened over time. Parking was categorized into three types: residential off-street, nonresidential off-street, and on-street. The inventory looked at formal infrastructure only (asphalt or concrete) and did not include informal parking, such as in front yards or lots not designated as parking. Results found that there were an estimated 18.6 million parking spaces in L.A. County in 2010, measuring 200 mi^2, or 14% of the incorporate land area, and streets and freeways measuring 140 mi^2.

The study conducted by Akbari et al. (2003) developed a database of surface-type and city-fabric makeup for various land uses to assess the heat island effect in the Sacramento area. They examined five land use types: downtown and city center, industrial, offices, commercial, and residential. Aerial photographs were obtained using a camera aboard a low-altitude aircraft. Using these photographs, a list of surface-types was prepared and grouped into categories. They used random sampling on the pixel level on the photographs to determine the percent of each surface-type. This data was then extrapolated to determine the percentage of surface-types for the entire area. The findings concluded that, on average, paved surfaces accounted for 39% in downtown, 29–44% in industrial areas, 49% in office areas, 44–68% in commercial areas, and 28% for residential areas.

The work done by Davis, Pijanowski, Robinson, and Engel (2010) looked at the environmental and economic costs of parking lots in Tippecanoe County, Indiana. To do this, they estimated the parking area. Using GIS and high-resolution aerial photography, they digitized areas that were clearly parking lots (defined as having more than three cars parked in an organized fashion or areas where stripes or concrete bumpers could be identified). They also estimated the ecosystems service value (ESV), or the lost economic value to the ecosystem from the presence of parking lots. The findings concluded that the parking lots contained 202,714 spaces that covered 5.65 km^2 (0.44%) of Tippecanoe

County and that replacing them with wetlands would increase ESV by $22.5 million (38.4%).

The research by Davis, Pijanowski, Robinson, and Kidwell (2010) quantified the aerial footprint of parking lots across four states: Illinois, Indiana, Michigan, and Wisconsin. The study used regression models to aggregate data by ZIP code, then used digitized orthophotos, with methods similar to Akbari et al. (2003), to determine estimates. In total, the study estimated 1,260 km^2 of the land was dedicated to parking lots with an estimated 43 million parking spaces.

Hoehne et al. (2019) analyzed the growth of parking in Phoenix, Arizona metropolitan area. The study estimated the growth of on-street parking and off-street parking from 1960 to 2017. To estimate the on-street parking, geospatial road network data was cross-referenced with city-level on-street parking restrictions. Roadway obstructions and areas where codes restrict parking were eliminated. The remaining curbside was assumed to have a 22-foot length and 8.5-foot width per space. To estimate off-street parking, parcel-level data was used and cross-referenced with municipal MPRs for land use types. Historical analysis was conducted by using the assigned construction year linked to each parcel. A validation check was then conducted in two steps: first, by using satellite imagery; and second, by manually counting a diverse selection of property types. The findings concluded that there were 12.2 million parking spaces in the metropolitan area.

The five studies described above provided the basis for the methodology of this thesis. Like Chester et al. (2015) and Hoehne et al. (2019), this thesis applied parking requirements based on land use to determine parking lot size. However, unlike those studies, I did not analyze the growth of parking over time. My definition of parking types were influenced by Chester et al. (2015) and Hoehne et al. (2019), although it differs slightly. Chester et al. (2015) identified three parking types: 1) off-street residential (home driveways and dedicated covered spaces); 2) off-street nonresidential (surface lot or structure spaces associated with nonresidential buildings); and 3) on-street (including metered and unmetered spaces, both marked and unmarked) (p. 271). Hoehne et al. (2019) identified two parking types: 1) on-street (roadway shoulder space able to accommodate and legally park a vehicle); and 2) off-street (dedicated parking area located off the road network, including residential driveways or nonresidential parking lots) (p. 187). I found it necessary to differentiate spaces in parking structures from other off-street parking as the method for estimating them was not related to land use MPRs. For parking structures, the total number of spaces was estimated by multiplying the visible spaces on the top floor by the number of stories, following Hoehne et al. (2019, p. 189). The previous studies used different values for the area of a parking space. Davis, Pijanowski, Robinson, and Engel (2010) and Davis, Pijanowski, Robinson, and Kidwell (2010) measured the area of a parking space to be 300 ft^2. Hoehne et al. (2019) used 330 ft^2 (p. 189). Chester et al. (2015) used 300 ft^2 (p. 283) but did not include internal driveways and landscaping. Other studies provided more variability in parking space areas. For example, Cutter and Franco (2012) used both 300 and 350 ft^2 (p. 909). Given the range of areas found, a lower limit of 300 ft^2 and an upper limit of 350 ft^2 were used to measure the area of a parking space. The remaining three studies discussed in this section used aerial photography to estimate parking area. Davis, Pijanowski, Robinson, and Engel (2010) and Davis, Pijanowski, Robinson, and Kidwell (2010) estimated the number of parking spaces from the parking area, while Akbari et al. (2003) estimated the paved surface area. After reviewing these studies, the use of aerial photography to estimate parking area was determined to not be feasible for this thesis as it was limited by cost and access to the necessary programs to digitize the imagery. The previous studies shared a common characteristic of emphasizing the link between parking and the environment. They provided the initial idea and framework for using trees to illustrate the need to accurately estimate vehicle infrastructure.

CHAPTER 3: METHODOLOGY

This chapter describes the site and the methods used to estimate vehicle infrastructure and the replacement benefits and costs of trees, as well as a pilot study. The chapter is divided into two sections. The first describes the sites' employment characteristics, locations, and land uses. The second section explains the methods used in four subsections. The first of these reviews a pilot study conducted on a similar site. the second and third subsections explain the methods used to estimate vehicle infrastructure, and to estimate the benefits and costs of replacing 10%, 25%, or 50% of the infrastructure area with various tree species. The fourth subsection outlines the limitations of the study, these include the assumptions made, addressing potential errors, and describes how they were overcome.

3.1 Site

The Downtown Core area of Albuquerque was chosen for its higher population and job density, similarities in urban form to other downtown cores, and Albuquerque's commitment to revitalization efforts. As of 2015, the Downtown Core area had a job market of 17,443 employees, while the Albuquerque area had a job market of 289,989 employees for the same period. The Downtown Core area represented 6.02% of the total jobs, but only comprised 0.40% of the land area in Albuquerque. 17,443 people worked downtown and 843 people lived there. Of the residents, only 119 (14.1%) were also employed there, and 724 (85.9%) were employed outside of the area. The remaining 17,324 (99.3%) people that were employed in the area lived outside of it (U.S. Census Bureau, 2015a).

A new Integrated Development Ordinance (IDO) was adopted in May of 2018. The IDO provides guidance on reducing parking minimums for some uses. Out of the 151 uses listed in the IDO, 45 had their MPRs reduced compared to the previous land use codes, while 75 were kept the same and 31 were undetermined. In addition to the changes in MPRs, the IDO also provides language for maximum parking requirements (City of Albuquerque, 2018b, May 17, pp. 228–234).

The Downtown Core area is generally bounded by Marble Boulevard, Slate Boulevard, and Lomas Boulevard on the north, the AT and SF railroad tracks and Broadway Boulevard on the east, Coal Avenue on the south, and 10th Street, 9th Street, and 7th Street on the west (City of Albuquerque, 2014, p. 4). The site contained 84 different land uses ranging from residential homes to government facilities. These land uses were applied to the 765 different parcels contained within the study area. The area that these parcels cover was approximately 20,959,234 ft^2 or approximately 3/4 mi^2.

3.2 Methods

This thesis attempts to answer two questions: 1) what percentage of area is devoted to vehicle infrastructure in Albuquerque's Downtown Core; and 2) what are the benefits and costs of converting a percentage of the vehicle infrastructure to an urban forest? This section details the methods used to answer these questions.

3.2.1 Pilot Study

Prior to conducting this study, a pilot study was done for the 5th Street corridor in Albuquerque. It included all parcels between 4th Street (east) and 6th Street (west) extending from I-40 (north) to the north side of Santa Fe Avenue (south). This site was chosen because it traversed the Downtown area and had a mix of land uses, cross-section of densities, and low new development level.

Using data collected from onthemap.ces.census.gov on labor force characteristics, specifically the number of jobs located in the study site compared to where employees traveled in 2015, a total of 11,259 people were employed in the study site, but only 535 employees lived in the area. Of those, 38 lived and worked in the area, while 11,221 employees commuted from outside the site (U.S. Census Bureau, 2015b). The site contained 91 different land uses ranging from government facilities to junkyards. These land uses were applied to the 587 different parcels contained within the site. The area that these parcels covered was approximately 8,483,405 ft^2 or almost 1/3 mi^2.

The Bernalillo County Assessor Office database and various shapefiles in GIS provided by the City of Albuquerque Planning Department were used to analyze the 5th Street corridor (Bernalillo County, 2017; City of Albuquerque, 2016a; 2016b; 2016c). After applying the appropriate MPR rules to the land use codes, there were an estimated 13,750 parking spaces within the site. Using a high and low threshold (350 ft^2 and 300 ft^2, respectively) to calculate total square feet, a total of 4,812,500 ft^2 (high), or 17.26% of a mi^2, and 4,125,000 ft^2 (low), or 14.80% of a mi^2, were calculated. Given that the total site was 8,483,405 ft^2, it was estimated that 56.73% to 48.62% of the site was dedicated to vehicle infrastructure. Parking credits were not applied to this study nor were on-street parking spaces counted.

The results of the pilot study were not what was important for this study. Rather, the methods and problems that arose during the pilot study were important. During the pilot study, the methods that were used in this study were refined. For example, during the pilot study, it became apparent that the parking requirements in the land use code were difficult to understand, and that there was a need to consult with the Code Enforcement and the Zoning Department. Likewise, some parcels (government uses and religious facilities) were difficult to estimate. This helped inform the need to manually count some uses in this study.

3.2.2 Estimating Vehicle Infrastructure

To answer the first question, I estimated the area of vehicle infrastructure from the land use MPRs, and then subtracted parking credits and other reductions. Parking in structures and on-street, as well as the street area itself, was estimated separately, then added together.

3.2.2.1 Parcels and Land Use. Two data sources were employed in the following analysis. The Bernalillo County Assessor Office maintains a database of all parcels in Bernalillo County. This database contains information in the form of an Excel spreadsheet across 40 variables, of which include parcel ID number, property address, primary land use, acres, year built, number of buildings, and building square footage, for each parcel. The database is updated annually to reflect changes in ownership, new construction, and other changes that may have occurred. The database used was for the 2017 tax year (Bernalillo County, 2017).

The second data source constitutes various shapefiles provided by the City of Albuquerque Planning Department and Transit Department. I use a Geographic Information System (GIS) to view, modify, and interpret the shapefiles. These shapefiles included annexations, land use, city parcels, streets, and transit bus routes and stops (City of Albuquerque, 2016a; 2016b; 2016c; 2016d; 2016e). The city parcel shapefile contained 14 variables, which included a property address, lot, block, and subdivision for each parcel. The parcel data from the City of Albuquerque and parcel data from the Bernalillo County Assessor Office have been combined into one layer that yielded a parcel ID number, property address, primary land use, acres, year built, number of buildings, and sum of building square footage, linking the variables to the parcel's geocoordinates. Before the data sources were combined, some addresses were modified using the Advanced Map Viewer 2.0 application (City of Albuquerque, n.d.-b). This was done because there were inconsistencies in some parcel addresses, where the county address was used instead of the city address, or where the address was left blank. Otherwise, some parcels would not be included in the final layer.

Next, the land use codes were applied to each parcel. When applied, the geographic coordinates of the land use did not always correspond to the geographic coordinates of the city or county parcels. To rectify this, the Street View function of Google Maps was used as well as observation to determine the correct land use code for each parcel (Google, n.d.).

A Comprehensive Plan is a policy document that guides future development of a city. Information on MRPs was gathered from the Albuquerque Comprehensive Plan based on land use types (City of Albuquerque, 2016f, pp. 3-1–3-3). Combining this information with a list of all land use codes yielded a comprehensive list of land use codes and the MPRs that corresponded to them. The MPRs were then converted from a text format to a mathematical format to predict the total MPRs for each parcel. However, the Comprehensive Plan lacked clear language about the MPRs for certain land uses. To clarify which MPRs belonged to which land uses, I consulted with the Code Enforcement and Zoning Department. For example, banks and related functions (land use code 3310) are classified as an office in the land use code. This code dictates parking at one space per 200 ft^2 for the first 15,000 ft^2 net leasable area, then one space per 250 ft^2 for the next 45,000 ft^2 net leasable area, and finally one space per 300 ft^2 for a net leasable area exceeding 60,000 ft^2. After consultation with Code Enforcement, it was decided to calculate spaces at one space per 1,000 ft^2 net leasable area. For example, one of the bank parcels under the original rule would have received 382 spaces, but under the clarified rule it receives 98 spaces, which is a more accurate estimation (City of Albuquerque, 2016f, pp. 3-1–3-3).

Likewise, religious facilities (land use code 7310) and churches (land use code 7311) were difficult to estimate, as the code requires one space per four seats. The problem with these land uses was that there was no way of knowing how many seats were inside without visiting them. Instead, I counted the parking spaces manually using satellite imagery from Google Maps (Google, n.d.).

3.2.2.2 Parking Credits and Reductions. Next, parking credits and reductions were applied based on provisions in the Albuquerque Comprehensive Plan. There were three types of parking credits and reductions: transit, on-street parking, and mixed-use shared parking. Per the Albuquerque Comprehensive Plan, a building or use shall have its parking requirements reduced by 10% if it is within 300 feet of a regular Albuquerque Transit System route (City of Albuquerque, 2016f, p. 3-5). To find which parcels this applied to, a GIS shapefile that contained transit routes was downloaded from the Albuquerque Transit Department (City of Albuquerque, 2016e). Next, a 300-foot buffer was applied to the routes. Parcels that were contained within this buffer were then given a parking reduction of 10%. As the shape of the buffer was oval, some parcels were only partially within the buffer. At this point, a decision was made whether to include them or not based on if the structure or majority of structures for that parcel were within the buffer. The parking reduction did not apply to single-family residences, townhouses, and multi-family two units land use codes (land use codes 1111, 1120, and 1211). Aside from those land uses, 55 parcels were outside of the 300-foot buffer. The Albuquerque Comprehensive Plan also allows for an additional 5% reduction to buildings that provided transit-rider shelters at the owner's cost and for another 5% reduction to buildings of five acres or more that provide transit pull-offs at the owner's cost. However, these reductions were not applied in the calculations for two reasons (City of Albuquerque, 2016f, p. 3-5). First, due to recent construction on the Albuquerque Rapid Transit (ART) line and the adding of bike lanes throughout the downtown area, it was not possible to determine where transit-rider shelters and transit pull-offs were. Second, if transit-rider shelters and transit pull-offs could have been identified, it would not have been possible to determine if they were constructed at the owner's cost without looking at the original construction plans.

Next, on-street parking was identified and counted. This was done by first creating a new layer in GIS and inputting the features using an existing downtown parking map from the Municipal Development Department (City of Albuquerque, n.d.-a). Next, a combination of satellite imagery from Google Maps and Google Maps Street View was used to verify the existence, length, and type of on-street parking (Google, n.d.). For most of the imagery, 2018 data was used because earlier images showed construction of some streets and did not accurately reflect on-street parking. During this process, seven types of on-street parking were identified: free on-street parking, free residential on-street parking, accessible on-street parking, metered on-street parking, pay station on-street parking, permit residential on-street parking, and reserved on-street parking. To estimate the number of parking spaces, the length of each line where parking had been identified was calculated. It was then divided by 20 feet (City of Albuquerque, 2019, p. 408) and rounded to the nearest whole number, shown in Equation 1. For two lines (representing parking for one parcel), parking spaces were counted manually as the parking spaces are angled instead of in a line. In total, it was estimated that there were 1,899 on-street parking spaces. However, not all these spaces were eligible to be counted for on-street parking credits. The Albuquerque Comprehensive Plan does not allow for residential developments of 10 dwelling units per acre or less to be eligible for on-street parking credits (City of Albuquerque, 2016f, p. 3-6). To calculate the number of spaces that are not eligible in this way, residential parcels were identified and the parking spaces (205) adjacent to them were subtracted from the total in Equation 2. The Albuquerque Comprehensive Plan further designates that only half of the on-street parking may be counted toward the off-street parking requirements (City of Albuquerque, 2016f, p. 3-6). Simply dividing the eligible on-street parking spaces (1,694) by two yields a total of 847 using Equation 3, but this meant that some parcels would receive only a half parking space credit. These half parking spaces were manually changed to one giving a total on-street parking credit of 861 (Table 1).

$$\sum_{i=1}^{380}(OSL_i/20) = TOSP \qquad (1)$$

OSL_i = On-street length

TOSP = Total on-street parking spaces (1,899)

$$TOSP - 205 = EOSP \tag{1}$$

TOSP = Total on-street parking spaces (1,899)

EOSP = Eligible on-street parking spaces (1,694)

$$\sum_{i=1}^{380}(EOSP_i/2) = OSPEC \tag{2}$$

$EOSP_i$ = Eligible on-street parking spaces (1,694)

OSPEC = On-street parking spaces estimated credit (847)

The Albuquerque Comprehensive Plan designates that "in situations where a mix of uses creates staggered peak periods of parking demand, shared parking calculations can be made" (City of Albuquerque, 2016f, p. 3-5). Although shared parking reductions do exist, I did not have information on their locations or quantity. As a result, mixed-use shared parking reductions were not applied to these calculations.

Using these totals, the number of parking spaces for each parcel was calculated. From these equations, the number of parking spaces was multiplied by 300 ft^2 and 350 ft^2. These measurements represented the minimum and maximum square feet that a single parking space required, including the space itself, curb cutouts, internal medians, and internal travel lanes. Next, all parking lot areas were then summed, and the on-street parking minus the credits were added together to yield the total area of all parking lots (not including parking structures).

3.2.2.3 Parking Structures . While conducting the study, it became apparent that separating parking spaces in structures from the rest of the parking estimations would need to be done. This conclusion was reached based on two reasons. First, only the parking spaces on the ground floor were to be counted as surface parking. Second, the square feet dedicated to each parking space for structured parking was not estimated using land use MPRs. A total of 19 structures were identified within the study area. To calculate the parking spaces in each, a new layer was created in GIS. This layer contained a polygon that matched the perimeter of each structure. This gave the area in square feet of the building footprint. Next, using the Google Maps Street View function, the floors of each structure were counted (Google, n.d.). As both the number of spaces and the square feet dedicated to each space was unknown, several calculations were employed to estimate them. First, the area of the structure was divided by 350 ft^2 and 300 ft^2 using Equations 4a and 4b. This yielded the estimated parking on each floor as a low and high estimate, respectively. In Equations 5a and 5b, these numbers were then multiplied by the number of floors to estimate the low and high of total parking (Table 2). After further research, the actual number of parking spaces could be found for 14 of the parking structures. Two of these were excluded from further calculations: one was underground and an accurate count of the floors was unable to be obtained, and the building footprint was unable to be calculated for the other parking structure.

Next, to estimate the remaining five structures' parking more accurately, the percent change between the original estimate and the actual number of parking was calculated for both the low and high estimates in Equations 6a and 6b (Table 3). These were then averaged together using Equations 7a and 7b, creating a normalized value representing the difference between estimated parking and the actual parking. Then, using Equations 8a and 8b, those numbers were multiplied by the original estimates and then added to the original estimates for the remaining five structures to find a more accurate estimation of the low and high parking (Table 4). The total estimated parking spaces in parking structures was estimated at 8,639 on the low end and the high end. Of these spaces, 725 were either underground or their area was not able to be calculated. It was estimated that 1,505 parking spaces were on the ground floor.

$$APS_i/350 = ELPSF_i \quad (3a)$$

$$APS_i/300 = EHPSF_i \quad (4b)$$

APS_i = Area of parking structure

$ELPSF_i$ = Estimated low parking spaces on first floor

$EHPSF_i$ = Estimated high parking spaces on first floor

$$ELPSF_i \times F_i = ELTPS_i \quad (4a)$$

$$EHPSF_i \times F_i = EHTPS_i \quad (5b)$$

$ELPSF_i$ = Estimated low parking spaces on first floor

F_i = Number of floors

$ELTPS_i$ = Estimated low total parking spaces

$EHPSF_i$ = Estimated high parking spaces on first floor

$EHTPS_i$ = Estimated high total parking spaces

$$(RLTPS_i - ELTPS_i)/ELTPS_i = LTPSPC_i \quad (5a)$$

$$(RHTPS_i - EHTPS_i)/EHTPS_i = HTPSPC_i \quad (6b)$$

$RLTPS_i$ = Real low total parking spaces

$ELTPS_i$ = Estimated low total parking spaces

$LTPSPC_i$ = Low total parking spaces percent change

$RHTPS_i$ = Real high total parking spaces

$EHTPS_i$ = Estimated high total parking spaces

$HTPSPC_i$ = High total parking spaces percent change

$$\frac{1}{12} \sum_{i=1}^{12} LTPSPC_i = ALTPSPC \quad (6a)$$

$$\frac{1}{12} \sum_{i=1}^{12} HTPSPC_i = AHTPSPC \quad (7b)$$

$LTPSPC_i$ = Low total parking spaces percent change

ALTPSPC = Average low total parking spaces percent change (0.0929)

$HTPSPC_i$ = High total parking spaces percent change

AHTPSPC = Average high total parking spaces percent change (-0.0632)

$$(ALTPSPC \times ELTPS_i) + ELTPS_i = FLTPS_i \quad (7a)$$

$$(AHTPSPC \times EHTPS_i) + EHTPS_i = FHTPS_i \quad (8b)$$

ALTPSPC = Average low total parking spaces percent change (0.0929)

$ELTPS_i$ = Estimated low total parking spaces

$FLTPS_i$ = Final low total parking spaces

AHTPSPC = Average high total parking spaces percent change (-0.0632)

$EHTPS_i$ = Estimated high total parking spaces

$FHTPS_i$ = Final high total parking spaces

The method for estimating spaces in parking structures was complicated, and at first looks like it could have been simplified by counting the parking spaces on the first floor and multiplying that by the number of floors. Originally, that was the method I planned on implementing, as shown in Equations 4a, 4b, 5a, and 5b and Table 2. After finding the actual parking spaces for 14 of the structures, it became apparent that counting spaces was not accurate. For example, comparing the sum of spaces from Equations 5a and 5b to the sum of spaces from Equations 8a and 8b yielded a discrepancy of 1,232 spaces (and an undercount of 523 on the low estimate and an overcount of 709 on the high estimate). Likewise, leaving the estimated spaces for the remaining five structures as is resulted in an undercount of 168 spaces on the low end and an overcount of 134 spaces on the high end, or a total discrepancy of 302 spaces. An additional methodology was developed to normalize the discrepancies between the estimated parking spaces and the actual parking spaces for 12 of the 14 structures. This methodology and represented by the addition of Equations 6a, 6b, 7a, 7b, 8a, and 8b and Tables 3 and 4.

3.2.2.4 Streets. The parking estimates outlined above were added to the street area to find the total area dedicated to vehicle infrastructure. The area dedicated to streets was calculated by first utilizing GIS data from the City of Albuquerque Planning Department (City of Albuquerque, 2016d). The data was in a shapefile that contained information on the street network, including length and number of lanes. The appropriate lines were first identified then clipped to match the boundaries of the study area. The number of lanes was entered manually as many of the lane numbers from the city were inaccurate. Turning lanes were excluded as they did not run the entire length of the street.

The length of each line segment was then measured in feet. Lastly, in Equation 9, the lane number was multiplied by the length and then multiplied by 12 feet (Mid-Region Metropolitan Planning Organization, 2014, pp. 55–61). From these calculations, the street network was found to be 2,163,944 ft^2 (Table 5).

$$NL_i \times SL_i \times 12 = SSF_i \tag{8}$$

NL_i = Number of lanes

SL_i = Segment length

SSF_i = Segment square feet

3.2.3 Tree Benefits and Costs

To answer the second question about the benefit from replacing vehicle infrastructure with urban forests, I estimated the area dedicated to vehicle infrastructure, and the costs and benefits of replacing 10%, 25%, or 50% of the area with various tree species. Planting urban trees decreases stormwater runoff, increases carbon sequestration, improves air quality, increases property values, and decreases energy consumption. The benefits were calculated annually for each tree species then multiplied by the tree's projected lifespan.

Urban trees also require planting and maintenance. The costs of maintaining urban trees includes pruning, irrigation, administration, inspection and service, infrastructure repairs, tree and stump removal, and litter clean up. (The tree and stump removal were excluded from the maintenance calculations, as discussed in the limitations of the study in chapter 5). The cost of maintenance was calculated annually for each tree species, then multiplied by the tree's projected lifespan. The cost to initially plant the trees was then added to the maintenance cost.

3.2.3.1 Number of Trees and Reduced Area. Before calculating any benefits or costs, the reduced area (the area to be replaced by trees) was calculated. Parking on the first floor of structures was not included as part of the reduced area as demolishing a structure to plant trees is unlikely. The number of parking spaces on the first floor in parking structures (1,505) was subtracted from the total number of surface parking spaces (21,986), totaling 20,481. In Equations 10a and 10b, 20,481 parking spaces was multiplied by the reduction factor, giving the total number of parking spaces that would be replaced with trees. Multiply the number of spaces reduced by both 300 ft^2 and 350 ft^2 to find the reduced area for the low and high estimates (Table 7).

$$(20{,}481 \times RF_i) \times 300 = RA_i \tag{9a}$$

$$(20{,}481 \times RF_i) \times 350 = RA_i \tag{10b}$$

RF_i = Reduction factor (0.1, 0.25, or 0.5)

RA_i = Reduced Area

To calculate the number of each tree species that would be planted within the reduced area, first the area of mature crown diameter was found. Mature crown diameters for each tree species were taken from sources on the internet and were used in Equation 11 (Albuquerque Bernalillo County Water Utility Authority [ABCWUA], 2018; U.S. Department of Agriculture [USDA], n.d.). The six areas found in Equations 10a and 10b were divided by the mature crown diameter area by species in Equation 12 to find the number of each tree species that would fit within the reduced area (Table 8). Of the 64 tree species described in the Albuquerque, New Mexico, Project Area Community Forest Assessment calculations were only done for 32 (Davey Resource Group, 2014). The other 32 were excluded as they were classified as invasive species or shrubs or were discouraged by the city (ABCWUA, 2018; USDA, n.d.).

$$\pi \times (SCD_i/2)^2 = ASCD_i \tag{10}$$

SCD_i = Species crown diameter

$ASCD_i$ = Area of species crown diameter

$$RA_i/ASCD_i = NS_i \tag{11}$$

RA_i = Reduced Area

$ASCD_i$ = Area of species crown diameter

NS_i = Number of species

3.2.3.2 Tree Characteristics. Before calculating the benefits and cost for each species, various characteristics need to be determined, including lifespan, growth rate, height at maturity, height at planting, species leaf area, years old at planting, years old at mature height, and years during mature height. Lifespan, growth rate, and height at maturity were found through sources on the internet (ABCWUA, 2018; USDA, n.d.). Height at planting (Table 9) and species leaf area (Table 18) were calculated from equations derived from the Urban Tree Database and Allometric Equations (McPherson et al., 2016). Years old at planting was a function of height at planting divided by growth rate, as seen in Equation 13. Years old at mature height was calculated by subtracting height at planting from height at maturity, then dividing by growth rate, and then adding years old at planting as shown in Equation 14. Years during mature height was calculated in Equation 15 by subtracting years old at mature height from life span (Table 9).

$$SHP_i / GR_i = SYOP_i \tag{12}$$

SHP_i = Species height at planting

GR_i = Growth rate

$SYOP_i$ = Species years old at planting

$$(SHM_i - SHP_i)/GR_i) + SYOP_i = SYOMH_i \tag{13}$$

SHM_i = Species height at maturity

SHP_i = Species height at planting

GR_i = Growth rate

$SYOP_i$ = Species years old at planting

$SYOMH_i$ = Species years old at mature height

$$SLS_i - SYOMH_i = SYDMH_i \tag{14}$$

SLS_i = Species life span

$SYOMH_i$ = Species years old at mature height

$SYDMH_i$ = Species years during mature height

3.2.3.3 Stormwater Runoff. When calculating the runoff, the rainfall of an average storm event and the yearly rainfall were used. The cost saving is presented in U.S. dollars (USD). First, to calculate the amount of money the city spends on each cubic foot (ft^3) of runoff, a calculation was done using data from a community forest assessment conducted in 2014 (Davey Resource Group, 2014). The assessment determined that the tree population in Albuquerque reduced stormwater runoff by 51,400,000 ft^3 each year, and that it is valued at $3.42 million. The cost savings was then calculated in Equation 16 by dividing the total cost savings ($3.42 million) by the reduced runoff (51,400,000 ft^3). The rational method was used to calculate the current runoff volume and the current runoff volume minus the reduced areas. The rational method formula was defined as: Q=CIA, where C was the runoff coefficient (percentage of area X land use factor [land use factor was the percentage of impervious surface for a land use]); I was the rainfall intensity; and A was the area. Next, the cubic feet of runoff generated by the vehicle infrastructure during an average storm event was calculated using Equation 17a, where C was calculated as the percentage of surface vehicle infrastructure (1.0) multiplied by the land use factor for parking (0.9) for both the low and the high estimate in Equation 19a; I was calculated at 0.1602 in. or 0.01335 ft for an average storm event, and 9.45 in. or 0.7875 ft for the year (Hydrometeorological Design Studies Center, n.d.); and A was the original surface area for the low (8,795,559 ft^2) and the high (9,819,609 ft^2) estimates (21,986 parking spaces multiplied by 300 and 350 ft^2 respectively added to the street area of 2,163,944 ft^2). Solving Equation 17a gave the total runoff in cubic feet for both the low and high estimates. In Equation 20a, each estimate was then multiplied by the value found in Equation 16 to find the runoff cost during a storm event (Table 10).

To calculate the benefit of a 10%, 25%, or 50% reduction of vehicle infrastructure, Equation 17b was used. Although Equation 17b was the same as Equation 17a, the value of C was calculated differently. To calculate C, the values found in Equations 10a and 10b were divided by the area for the low (8,795,559 ft^2) and the high (9,819,609 ft^2) estimates in Equation 18b to give the percent area reduced. The percent area reduced was multiplied by the land use factor for trees (0.1) and added to the runoff coefficient of the remaining area of parking, giving the C value, using Equation 19b. The runoff generated during a storm event for the reduced area using Equation 17b was multiplied by the value found in Equation 16 to find the reduced runoff cost during a storm event using Equation 20b. Using Equation 21, the reduced runoff during a storm event was found by subtracting Equation 17b from Equation 17a. Equation 20b was subtracted from the cost of the entire area found in Equation 20a. This gave the cost savings for the reduced area per storm event in Equation 22. This was multiplied by the number of storm events in 2018 (59) to find the total savings per year in Equation 23 (Table 11). Lastly, in Equation 24, the total savings per year was multiplied by each species years during mature height from Equation 15 (Table 12).

$$RC/RR = RRC \tag{15}$$

RC = Runoff cost savings ($3.42 million)

RR = Reduced runoff (51,400,000 ft^3)

RRC = Reduced runoff cost savings ($0.0665)

$$C_i \times I \times A_i = RSE_i \quad (16a)$$

$$C_i \times I \times A_i = RSERA_i \quad (17b)$$

C_i = Runoff coefficient

I = Rainfall intensity (0.01335 ft)

A_i = Original area

RSE_i = Runoff generated during storm event

$RSERA_i$ = Runoff generated during storm event for reduced area

$$1 = PA_i \quad (17a)$$

$$RA_i / A_i = PA_i \quad (18b)$$

RA_i = Reduced Area

A_i = Original Area

PA_i = Percent Area

$$PA_i \times 0.9 = C_i \quad (18a)$$

$$(PA_i \times 0.1) + ((1 - PA_i) \times 0.9) = C_i \quad (19b)$$

PA_i = Percent Area

C_i = Runoff coefficient

$$RSE_i \times RRC = RCSE_i \quad (19a)$$

$$RSERA_i \times RRC = RRCSE_i \quad (20b)$$

RSE_i = Runoff generated during storm event

RRC = Reduced runoff cost savings

$RCSE_i$ =Runoff cost during storm event

$RSERA_i$ = Runoff generated during storm event for reduced area

$RRCSE_i$ = Reduced runoff cost during storm event

$$RSE_i - RSERA_i = RRSE_i \tag{20}$$

RSE_i = Runoff generated during storm event

$RSERA_i$ = Runoff generated during storm event for reduced area

$RRSE_i$ = Reduced runoff generated during storm event

$$RCSE_i - RRCSE_i = RACSSE_i \tag{21}$$

$RCSE_i$ =Runoff cost during storm event

$RRCSE_i$ = Reduced runoff cost during storm event

$RACSSE_i$ = Reduced area cost savings during storm event

$$RACSSE_i \times NSE = RACSY_i \tag{22}$$

$RACSSE_i$ = Reduced area cost savings during storm event

NSE = Number of storm events in 2018 (59)

$RACSY_i$ = Reduced area cost savings per year

$$RACSY_i \times SYDMH_i = TSRRCS_i \tag{23}$$

$RACSY_i$ = Reduced area cost savings per year

$SYDMH_i$ = Species years during mature height

$TSRRCS_i$ = Total species reduced runoff cost savings

3.2.3.4 Carbon Sequestration. To calculate the possible carbon sequestered per year by various tree species, information from the community forest assessment was used (Davey Resource Group, 2014). Using this information presented some difficulties. For example, both population and net carbon sequestration were only given for 18 of the 64 species (Davey Resource Group, 2014, p. 25). The carbon sequestration of these 18 species totals 7,236 tons per year, while the total for all tree species is 9,710. The remaining 2,474 difference was the carbon sequestered by the remaining 46 species and would need to be estimated. However, estimating the populations of the remaining 46 species is required first.

To estimate the populations of the remaining tree species, their percentage of population was divided by 100 then multiplied by the total tree population (1,504,000) given in Equation 25 (Davey Resource Group, 2014, pp. 37–38, p. 9). Next, the net carbon sequestration for the known 18 species was divided by their populations as shown in Equation 26. These values were then averaged together using Equation 27. This number represented the average net carbon sequestration per tree for known species as 0.0071 (Table 13). This average was then multiplied in Equation 28 by the estimated population for each species, which yielded an estimate of net carbon sequestration for all species. Equations 29 and 30 were used to increase the accuracy of the estimates for the remaining species. The percent change between the estimated number of the net carbon sequestration and the known number for the 18 species that have a known value was calculated using Equation 29. Next, these percent changes were averaged together in Equation 30 to calculate a normalized value for the known species. The normalized value was multiplied by the original estimate for the unknown species then added to it as given in Equation 31. Lastly, that estimate of net carbon sequestration was divided by the population for each species, as shown in Equation 32, to give the final total of net carbon sequestration per tree (Table 14).

$$TTP \times (SPP_i/100) = SP_i \tag{24}$$

TTP = Total tree population (1,504,000)

SPP_i = Species percentage population

SP_i = Species population

$$CS_i/SP_i = CSP_i \tag{25}$$

CS_i = Net carbon sequestration

SP_i = Species population

CSP_i = Net carbon sequestration per tree

$$\frac{1}{18}\sum_{i=1}^{18} CSP_i = ACSP \tag{26}$$

CSP_i = Net carbon sequestration per tree

ACSP = Average net carbon sequestration per tree (0.0071)

$$SP_i \times ACSP = ECS_i \tag{27}$$

SP_i = Species population

ACSP = Average net carbon sequestration per tree (0.0071)

ECS_i = Estimated net carbon sequestration

$$(CS_i - ECS_i)/ECS_i = CPC_i \tag{28}$$

CS_i = Net carbon sequestration

ECS_i = Estimated net carbon sequestration

CPC_i = Net carbon sequestration percent change

$$\frac{1}{18}\sum_{i=1}^{18} CPC_i = ACPC \tag{29}$$

CPC_i = Net carbon sequestration percent change

ACPC = Average net carbon sequestration percent change (-1.4803×10^{-16})

$$(ACPC \times ECS_i) + ECS_i = FCS_i \tag{30}$$

ACPC = Average net carbon sequestration percent change (-1.4803×10^{-16})

ECS_i = Estimated net carbon sequestration

FCS_i = Final net carbon sequestration

$$FCS_i/SP_i = FCSP_i \tag{31}$$

FCS_i = Final net carbon sequestration

SP_i = Species population

$FCSP_i$ = Final net carbon sequestration per tree

The net carbon sequestration (tons/year/tree) for each species from Equation 32 was multiplied by the number of trees for each reduced area from Equation 12, the value of each ton of carbon sequestered ($71.21) (Davey Resource Group, 2014, p. 24), and by species years during mature height from Equation 15 using Equation 33, producing the benefit value of replacing the reduced areas with each species over their lifespan (Table 15).

$$FCSP_i \times NS_i \times VCS \times SYDMH_i = RACSV_i \tag{32}$$

$FCSP_i$ = Final net carbon sequestration per tree
NS_i = Number of species
VCS = Value of carbon sequestration ($71.21)
$SYDMH_i$ = Species years during mature height
$RACSV_i$ = Reduced area carbon sequestration value

3.2.3.5 Air Quality. In order to calculate the possible benefits of reduced air pollution per year by various tree species, data from the community forest assessment was used (Davey Resource Group, 2014). The estimates of reductions in air pollution were based on the current crown leaf area (ft^2) of each species. The area of tree cover was found in square feet (490,174,755 ft^2) using Equation 34, where the study area (132.2 mi^2) (Davey Resource Group, 2014, p. 4) was multiplied by the area tree cover percentage (13.3%) (Davey Resource Group, 2014, p. 9) then multiplied by 27,878,400 ft^2 (the square feet within a square mile). Then the square feet of tree cover of a single tree of each species was calculated. This was done by dividing the percent leaf area (Davey Resource Group, 2014: 37-38) by 100, then multiplying it by the value found in Equation 34, and then dividing that by the population from Equation 12, as shown in Equation 35. The next step was to multiply the population by the square feet of a single tree for each species, then sum those values together using Equation 36. This gave the new estimate for the area of tree cover within the study area. Next, the total tons of air pollution removed (366) was divided by the new estimate for the area of tree cover using Equation 37 (Davey Resource Group, 2014, p. 22). This yielded tons of air pollution removed per square foot. In Equation 38, the tons of air pollution removed per square foot were multiplied by the square feet of tree cover of a single tree for each species to yield the air pollution in tons removed per tree for each species (Table 16).

$$SA \times (ATC/100) \times 27{,}878{,}400 = ATCSF \tag{33}$$

SA = Study area (132.3 mi^2)

ATC = Area tree cover percentage (13.3)

ATCSF = Area tree cover in square feet (490,174,755)

$$(ATCSF \times (SPLA_i/100))/SP_i = SSFTCP_i \tag{34}$$

ATCSF = Area tree cover in square feet (490,174,755)

$SPLA_i$ = Species percentage leaf area

SP_i = Species population

$SSFTCP_i$ = Species square feet of tree cover per tree

$$\sum_{i=1}^{64} SP_i \, SSFTCP_i = EATCSF \tag{35}$$

SP_i = Species population

$SSFTCP_i$ = Species square feet of tree cover per tree

EATCSF = Estimate area tree cover in square feet (490,419,843)

$$TAP/EATCSF = APP \tag{36}$$

TAP = Total tons of air pollution removed (366)

EATCSF = Estimate area tree cover in square feet (490,419,843)

APP = Tons of air pollution removed per square foot (7.4630×10^{-7})

$$APP \times SSFTCP_i = SAPP_i \tag{37}$$

APP = Tons of air pollution removed per square foot (7.4630×10^{-7})

$SSFTCP_i$ = Species square feet of tree cover per tree

$SAPP_i$ = Species tons of air pollution removed per tree

The value of a ton of air pollution ($3,005.46) was calculated using Equation 39 where the total value ($1.1 million) was divided by the tons removed (366) (Davey Resource Group, 2014, p. 22). As shown in Equation 40, the air pollution removed (tons/year/tree) from Equation 38 was multiplied by $3,005.46, the number of trees for each reduced area from Equation 12, and by species years during mature height from Equation 15 to find the benefit value of air pollution removed by species during its lifespan (Table 17).

$$APC/TAP = VAP \tag{38}$$

APC = Air pollution cost savings ($1.1 million)

TAP = Total tons of air pollution removed (366)

VAP = Value of air pollution ($3,005.46)

$$SAPP_i \times NS_i \times VAP \times SYDMH_i = RAAPV_i \tag{39}$$

$SAPP_i$ = Species tons of air pollution removed per tree

NS_i = Number of species

VAP = Value of air pollution ($3,005.46)

$SYDMH_i$ = Species years during mature height

$RAAPV_i$ = Reduced area air pollution value

3.2.3.6 Property Values. To find the potential increase in property values for the reduced areas, first the increase in a home's value was calculated in Equation 41. In the 3rd quarter of 2015, the median home sales price in Albuquerque was $179,270 (Zillow.com, 2022). Assuming a 0.88% increase in property values (Anderson & Cordell, 1988), each tree would be worth $1,577.58. However, not all trees are the same given their differences in growth rates, sizes, and lifespans. First, the price increase per square foot for each species was calculated using Equation 42, where $1,577.58 was divided by the species leaf area (ft^2) at full crown diameter and then multiplied by a 0.5 park reduction factor (McPherson et al., 2001), assuming the trees in this study will be planted in parks. Next, each species leaf area growth per year was calculated. In Equation 43, 20 ft^2 was subtracted from species leaf area (ft^2) to account for the current leaf area of a newly planted tree. This was then divided by the difference between Equations 13 and 14. By multiplying the values found in Equations 42 and 43 together, the species price increase per year was found for Equation 44 (Table 18). The value of each tree ($1,577.58) from Equation 41 was multiplied by Equation 12 and then multiplied by the park reduction factor to find the species price increase for each reduced area in Equation 45 (Table 19).

$$MSP \times HPPI = TPI \tag{40}$$

MSP = Median home sales price in 2015 ($179,270)

HPPI = Home price percent increase (0.0088)

TPI = Tree price increase ($1,577.58)

$$(TPI/SLA_i) \times PRF = SPISF_i \tag{41}$$

TPI = Tree price increase ($1,577.58)

SLA_i = Species leaf area

PRF = Park reduction factor (0.5)

$SPISF_i$ = Species price increase per square feet

$$(SLA_i - 20)/(SYOMH_i - SYOP_i) = SLAG_i \tag{42}$$

SLA_i = Species leaf area

$SYOMH_i$ = Species years old at mature height

$SYOP_i$ = Species years old at planting

$SLAG_i$ = Species leaf area growth per year

$$SPISF_i \times SLAG_i = SPIY_i \tag{43}$$

$SPISF_i$ = Species price increase per square feet

$SLAG_i$ = Species leaf area growth per year

$SPIY_i$ = Species price increase per year

$$TPI_i \times NS_i \times PRF = SPIRA_i \tag{44}$$

TPI_i = Tree price increase ($1,577.58)

NS_i = Number of species

PRF = Park reduction factor (0.5)

$SPIRA_i$ = Species price increase for reduced area

3.2.3.7 Energy Use. To estimate building energy use reductions, the values found in the community forest assessment were used (Davey Resource Group, 2014, p. 28). These included one million British thermal units (MBTU), megawatt hours (MWH), and carbon avoided (tons). For each of these units, separate calculations were made, and then the values were summed together.

The first step for calculating all three values was to estimate the number of units per tree. This was done by dividing each unit found in the community forest assessment by the sum of species population from Equation 25 (Davey Resource Group, 2014, p. 28). The equations for MBTU, MWH, and carbon avoided are expressed in Equations 46, 47, and 48, respectively.

$$MBTU/\sum_{i=1}^{64} SP_i = MBTUPT \quad (45)$$

MBTU = One million British thermal units

SP_i = Species population

MBTUPT = One million British thermal units per tree

$$MWH/\sum_{i=1}^{64} SP_i = MWHPT \quad (46)$$

MWH = Megawatt-hour

SP_i = Species population

MWHPT = Megawatt-hour per tree

$$CA/\sum_{i=1}^{64} SP_i = CAPT \quad (47)$$

CA = Carbon avoided

SP_i = Species population

CAPT = Carbon avoided per tree

The next step was to estimate the value of each unit per tree. The community forest assessment provided the value of each unit (Davey Resource Group, 2014, p. 32). Multiplying these values by the number of units per tree from Equations 46, 47, and 48 yielded the value per tree. The equations for MBTU, MWH, and carbon avoided are expressed in Equations 49, 50, and 51, respectively.

$$MBTUPT \times VMBTU = VMBTUPT \quad (48)$$

MBTUPT = One million British thermal units per tree

VMBTU = Value of one million British thermal units ($10.63)

VMBTUPT = Value of one million British thermal units per tree

$$MWHPT \times VMWH = VMWHPT \tag{49}$$

MWHPT = Megawatt-hour per tree

VMWH = Value of megawatt-hour ($108.10)

VMWHPT = Value of megawatt-hour per tree

$$CAPT \times VCA = VCAPT \tag{50}$$

CAPT = Carbon avoided per tree

VCA = Value of carbon avoided ($71.21)

VCAPT = Value of carbon avoided per tree

The third step was to multiply the values found in Equations 49, 50, and 51 by the number of species for each reduced area from Equation 12 and then by each species years old during mature height from Equation 15. This yielded the estimated value for each unit by species and reduced area. The equations for MBTU, MWH, and carbon avoided are expressed in Equations 52, 53, and 54, respectively.

$$(VMBTUPT \times NS_i) \times SYDMH_i = RAMBTUV_i \tag{51}$$

VMBTUPT = Value of one million British thermal units per tree

NS_i = Number of species

$SYDMH_i$ = Species years during mature height

$RAMBTUV_i$ = Reduced area one million British thermal units value

$$(VMWHPT \times NS_i) \times SYDMH_i = RAMWHV_i \quad (52)$$

VMWHPT = Value of megawatt hour per tree

NS_i = Number of species

$SYDMH_i$ = Species years during mature height

$RAMWHV_i$ = Reduced area megawatt hour value

$$(VCAPT \times NS_i) \times SYDMH_i = RACAV_i \quad (53)$$

VCAPT = Value of carbon avoided per tree

NS_i = Number of species

$SYDMH_i$ = Species years during mature height

$RACAV_i$ = Reduced area carbon avoided value

The final step was to sum these values together for each reduced area to estimate the total energy cost savings per species as found in Equation 55 (Table 23). The calculations made for MBTU, MWH, and carbon avoided are expressed in Tables 20, 21, and 22, respectively.

$$RAMBTUV_i + RAMWHV_i + RACAV_i = TRAEV_i \quad (54)$$

$RAMBTUV_i$ = Reduced area one million British thermal units value

$RAMWHV_i$ = Reduced area megawatt-hour value

$RACAV_i$ = Reduced area carbon avoided value

$TRAEV_i$ = Total reduced area energy value

3.2.3.8 Maintenance Cost. When estimating the maintenance cost, the values obtained from a City of Albuquerque Municipal Forest Resource Analysis were used (Vargas et al., 2006, p. 15). Due to these values pertaining to the fiscal year 2005, they were extrapolated to a 2015 inflationary cost (U.S. Bureau of Labor Statistics, n.d.). These values were for annual expenditures, including purchasing trees and planting, contract pruning, irrigation, removal, administration, inspection/service, infrastructure repairs, and litter cleanup. For this thesis, purchasing trees and planting are addressed in the following section. The cost to remove trees was not included as calculating die-off rates was outside of the scope of this thesis. To calculate the maintenance cost of the reduced areas for each tree species over its projected lifespan, the cost per tree ($20.96) was multiplied by the remainder of its projected lifespan after planting. This was then multiplied by the number of trees from Equation 12 as shown in Equation 56 (Table 24).

$$MC \times (SLS_\mathrm{i} - SYOP_i) \times NS_i = MCAR_i \tag{55}$$

MC = Maintenance cost per tree per year ($20.96)

SLS_i = Species life span

$SYOP_i$ = Species years old at planting

NS_i = Number of species

$MCAR_i$ = Maintenance cost for area reduced

3.2.3.9 Planting Cost. To estimate the cost of planting each species for the reduced areas, prices were obtained from the City of Albuquerque's Unit Price Guide (City of Albuquerque, 2018a). When calculating the species height at planting, a caliper size of 2 inches was assumed, and that assumption was continued here. According to the Unit Price Guide, planting 2-inch caliper trees cost $247.50 each. In Equation 57, this cost was multiplied by the number of trees from Equation 12 for each reduced area (Table 25).

$$PCT \times NS_i = PCAD_i \tag{56}$$

PCT = Planting cost per tree ($247.50)

NS_i = Number of species

$PCAD_i$ = Planting cost area reduced

3.2.3.10 Total Net Benefits. The total net benefits for each tree species by reduced area were calculated in Equation 58 by subtracting cost from benefits (Table 26). The total estimate of benefits was the summation of the values from Equations 24, 33, 40, 45, and 55. The total estimate of cost was the summation of the values from Equations 56 and 57.

$$(TSRRCS_i + RACSV_i + RAAPV_i + SPIRA_i + TRAEV_i) - (MCAR_i + PCAD_i) = TNSBRA_i \tag{58}$$

$TSRRCS_i$ = Total species reduced runoff cost savings

$RACSV_i$ = Reduced area carbon sequestration value

$RAAPV_i$ = Reduced area air pollution value

$SPIRA_i$ = Species price increase for reduced area

$TRAEV_i$ = Total reduced area energy value

$MCAR_i$ = Maintenance cost for area reduced

$PCAD_i$ = Planting cost area reduced

$TNSBRA_i$ = Total net species benefits for reduced area

3.2.4 Limitations of the Study

When the land use codes were applied to each parcel that they corresponded to, the geographic coordinates of the land use did not always correspond to the geographic coordinates of the city or county parcels. The Street View function of Google Maps was utilized to visually determine what the use was for that specific parcel (Google, n.d.). Although this method yielded favorable results for most parcels affected, several parcels appeared to have the incorrect land use when factoring in building square feet. When this was found to be the case, manual counting of parking spaces was implemented.

There were uses that were given a “none” value as per the Comprehensive Plan (City of Albuquerque, 2016f, pp. 3-1–3-3). These uses likely led to an undercount of spaces as there were indeed spaces present; although in the case of the parking lot use, the spaces may already have been counted as spaces for another use even though the parking lot itself was assigned a “none” value.

Determining on-street parking spaces posed some problems, as the study area had recently gone through significant changes related to the ART project. These changes included the adding and subtracting of bike lanes and on-street parking spaces that were not accounted for in the difference between when this study began in 2016 and when

2018 satellite imagery from Google Maps and Google Maps Street View was used (Google, n.d.). This means that the number of on-street parking spaces observed in the 2018 imagery could be different than what was there originally when this study started. This could have affected the results of this study.

Estimating the number of parking spaces in structures presented several problems. First, two parking structure areas were unknown and thus were unable to be accurately estimated. One was underground, meaning that its area would not count in calculations for the surface area of total vehicle infrastructure. However, data on the number of spaces in each could be found. To overcome this, they were excluded from calculations to estimate the number of spaces in the remaining structures. Second, the method used to estimate the unknown parking spaces in the remaining structures was subject to error. The method relied on finding the average percent change between what the original estimate was for structures with known parking spaces and the actual number of spaces in them. This average percent change was then multiplied by the estimate for structures where their parking spaces were unknown and adding (or subtracting if the number was negative) the estimate and this new number together. This made the mathematical assumption that the original estimates were equally different from what the final estimate was at the same rate. The percent change between the original estimate for structures with known parking spaces and their actual number varied, suggesting that the final estimates could be different. Lastly, the estimates could be different depending on differences between the actual number of floors and area and what was counted/observed using satellite imagery from Google Maps and Google Maps Street View (Google, n.d.). It was possible that there were additional underground floors in some structures or that some building footprints were measured incorrectly as portions of some floors were hidden by other buildings above them.

This study did not look at construction years for buildings in the study area as the data provided for it was incomplete. Failing to do this could have affected the outcome of parking estimates as parking requirements could have changed in the time between when a specific building was constructed and when this study began. It is unknown whether parking requirements have changed over time.

Reductions in parking requirements for buildings that provide transit-rider shelters or transit pull-offs were not applied which may have resulted in an overcount of parking spaces. Additionally, mixed-use shared parking reductions were not applied, also resulting in a likely overcount of parking spaces. However, some of these mixed-use shared parking reductions might have already been applied to parking structures and accounted for in the calculations used when constructing the spaces to be built in the structure based on demand at that time.

The length, width, and number of turning lanes were not measured when estimating the area of vehicle infrastructure that was on the street. This was done because turning lanes vary in dimensions from intersection to intersection, making it difficult to have included them in this study. This likely led to an undercount of the street area.

A tree's benefits and costs were calculated with the assumption that all trees live to their expected lifespans and grow to their full crown diameters and heights. Urban tree mortality rates were not included in the calculations. As a result, the replacement cost of deceased trees was not included. Including these calculations was outside the scope of this study as it focused on the initial creation of an urban forest and not its long-term maintenance. These assumptions run contradictory to previous research. McPherson (1992) assumes a total mortality rate of 45% and a life expectancy of 40 years for urban trees (p. 26). By excluding mortality rates and assuming trees grow to their maximum size, the values of both benefits and costs were overstated.

Tree population data from Davey Resource Group (2014, p. 9) was incomplete, requiring the remaining species populations to be estimated. The summed estimate for tree populations was greater than the total (1,504,000) found in the Davey Resource Group study (p. 9) by 451 trees, a difference of 0.03%. Using these estimated populations for individual tree species likely had little effect on the final calculations.

Expecting parking structures to be removed and street widths reduced would not be reasonable. Based on these assumptions, the reduction factor was only applied to surface parking spaces not in a parking structure. The areas of the first floor in parking structures and the roadway were held constant. The rational method is typically used to find the runoff volume of a single storm event, where Q is given in cubic feet per second (cfs). To estimate the average runoff of a storm event and the yearly runoff given in ft^3, the average rainfall was used instead of the specific rainfall of an event. The average rainfall of a storm event was determined by dividing the 30-year average (9.45 in./year) by the average precipitation days (59) during the same period (1981–2010). This value (0.01335 ft) replaced rainfall intensity (I) in the rational method equation Q=CIA. All tree species were assigned a land use factor of 0.1, translating to 10% of the rainfall generating runoff, while 90% was intercepted. Although, realistically, runoff volume avoided was influenced by the seasons and a tree's characteristics, such as health, age, foliage density, and whether it was deciduous or coniferous.

The tons of carbon sequestered per year for each tree species were estimated using the average of an existing individual tree. This could be misleading as the current reported values used were given for the entire population for 18 species, not by an individual tree. There were two concerns with using these values: 1) 46 of the species were not represented in the data; and 2) the carbon sequestered each year by a tree is influenced by its age and growth rate. The tons of carbon sequestered were calculated for the remaining 46 species in Equations 25–32. The summed estimate for tons of carbon sequestered (9,714) was greater than the total (9,710) found in the Davey Resource Group study (2014, p. 24). This difference was small and likely had little effect on the final calculations. Large trees with dense canopies can sequester more carbon than smaller trees. Additionally, as a tree ages and grows, it can sequester more carbon than the previous year, plateauing when it reaches its mature height. However, these equations did not account for the change in sequestration rates resulting from growth. Instead, I assumed the net carbon sequestration per tree (tons/year) was the maximum rate and applied it to the species years during the mature height. The reliance on calculating the carbon sequestration for mature trees using data pertaining to existing trees understated the benefit value. The calculations done using Equations 29 and 30 attempted to increase the estimation accuracy of the remaining 46 species. The normalized value (-1.4803×10^{-16}) from Equation 30 did not influence the final carbon sequestration values compared to the estimated values.

The area (ft^2) of the crown diameter for existing individual trees of each species was given as the average area per tree, not the aggregate of areas by diameter at breast height (DBH) class (Davey Resource Group, 2014, p. 13). Each species air pollution ton/year removed was estimated using the average area per tree, possibly overstating the benefit values. Removal of one ton of air pollution was valued at $3,005.46, found by dividing $1.1 million by 366 tons (p. 22). The equation assumed all pollutants (CO, NO_x, SO_2, O_3, and PM) had the same monetary value, concentration in the air, and species removal rate. However, the Davey Resource Group (2014) used the values per ton of $1,136 (CO), $1,260 ($O_3$), $226 ($NO_x$), $110 ($SO_2$), $5,840 ($PM_{10}$), and $17,993 ($PM_{25}$) but did not specify the tons removed for each pollutant (p. 33). Lacking this data, pollutants were treated as a homogenized unit when finding their value (see Equation 39).

During the development and implementation of this study, it became apparent that the Albuquerque Geographic Information System (AGIS) department of the City of Albuquerque did not communicate well with the Bernalillo County Assessor Office. A significant portion of the time spent on this study was dedicated to merging parcels in GIS and renaming them in order to make both of their databases compatible with each other. During the study, an employee of the AGIS department was contacted, and that person agreed with this assessment. The hope is that this study shows the need for these two departments to communicate better with each other to increase efficiency and reduce waste and confusion.

CHAPTER 4: RESULTS

The results are divided into three sections. The first gives the numerical and statistical values of the vehicle infrastructure, including total parking spaces, on-street spaces, spaces in structures, street area, and total surface area. The second section details the results of the urban forest analysis. This section is further divided into eight subsections, which give the results for stormwater runoff, carbon sequestration, air quality, property values, energy use, maintenance cost, planting cost, and total net benefits. For each subsection the tree species with the highest benefits or cost is detailed. Discussion of the results takes place in the third section.

4.1 Vehicle Infrastructure Summary

In 2017 there were an estimated 29,120 parking spaces located within the study area (Table 6a). Of those, it was estimated that 8,639 were in parking structures, and 1,899 were on-street parking spaces (Tables 6b and 6c). The total area dedicated to parking was estimated at between 8,976,801 ft^2 (0.3220 mi^2) and 10,000,851 ft^2 (0.3587 mi^2), or 42.8% to 47.7% of the study area (Table 6a). The estimated total number of parking spaces (29,120) was misleading though, as it included spaces above and below the first floor in parking structures. Subtracting these parking spaces gave the total surface parking, estimated at 21,986 spaces. The total surface parking area was estimated at between 6,631,615 ft^2 (0.2379 mi^2) and 7,655,665 ft^2 (0.2746 mi^2), or 31.6% to 36.5% of the study area. The area of streets was estimated at 2,163,944 ft^2 (0.0776 mi^2) or 10.3% of the study area. Combining the area of surface parking and the area of streets, it was estimated that between 8,795,559 ft^2 (0.3155 mi^2) and 9,819,609 ft^2 (0.3522 mi^2), or

41.9% to 46.9% of the study surface area, was dedicated to vehicle infrastructure (Table 6d).

4.2 Urban Forest Summary

The following subsections outline the benefits and costs of replacing 10%, 25%, or 50% of surface parking with various tree species, creating an urban forest. The results are presented by category with the tree species that had the highest benefit value (or lowest cost).

4.2.1 Stormwater Runoff

Using the rational method (described in 3.2.3.3), the runoff of the vehicle infrastructure area during an average storm event was between 105,679 ft^3 and 117,983 ft^3. The cost of each cubic foot of runoff was calculated at $0.0665 to the city (Davey Resource Group, 2014, p. 26). Using this calculation, between $7,032 and $7,850 could be spent on the runoff generated from the vehicle infrastructure of the site (Table 10). A 10% reduction in parking spaces that are not in parking structures would generate between 99,117 ft^3 and 110,327 ft^3 of runoff at a cost of between $6,595 and $7,341, or a savings of between $437 and $509 per storm event. This would save the city between $25,761 and $30,054 a year. A 25% reduction in parking spaces that are not in parking structures would generate between 89,273 ft^3 and 98,843 ft^3 of runoff at a cost of between $5,940 and $6,577, or a savings of between $1,092 and $1,273 per storm event. This would save the city between $64,402 and $75,136 a year. A 50% reduction in parking spaces that are not in parking structures would generate between 72,868 ft^3 and 79,704 ft^3 of runoff at a cost of between $4,848 and $5,303, or a savings of between $2,183 and $2,547 per storm event. This would save the city between $128,804 and $150,271 a year

(Table 11). After applying these cost savings to each species years during mature height in Equation 24, the Chinese Pistache would result in the greatest savings: 10%) $3,520,639 to $4,107,412; 25%) $8,801,597 to $10,268,530; and 50%) $17,603,195 to $20,537,061 (Table 12).

4.2.2 Carbon Sequestration

With the total yearly carbon sequestration for 18 species provided by the Davey Resource Group (2014, p. 25) and using Equations 25–32 to calculate the remainder, the Cottonwood was found to sequester the most tons per year per tree (0.014) (Tables 13 and 14). However, after using Equation 33 to account for the number of each species that could fit within the reduced areas and their years during mature height, the Oriental Arborvitae was found to sequester the most carbon within these reduced areas. Each ton of carbon sequestered was valued at $71.21 (Davey Resource Group, 2014, p. 24). Using this, replacing 10% of the parking spaces with the Oriental Arborvitae would sequester between 24.13 and 28.15 tons of carbon per year, valued at between $1,718 and $2,005. Replacing 25% of the area would sequester between 60.32 and 70.38 tons of carbon each year, valued at between $4,296 and $5,012. Replacing 50% of the area would sequester between 120.65 and 140.75 tons of carbon each year, valued at between $8,591 and $10,023. Projecting these values to their years during mature height, the value of sequestered carbon would be: 10%) $154,641 to $180,414; 25%) $386,601 to $451,035; and 50%) $773,203 to $902,070 (Table 15).

4.2.3 Air Quality

The tons of air pollution removed per year per tree were found using Equation 38. The two species with the highest value for air pollution removal per tree, the Scotch Pine

(0.000929 ton/year) and the Arizona Cypress (0.000676 ton/year), were discouraged by the city (ABCWUA, 2017) and will not be discussed. Following these, the Texas Pistache had the next highest value for air pollution removal (0.000641 ton/year) (Table 16). When the number of each species that could fit within the reduced areas and their years during mature height were calculated using Equation 39, the Black Locus was found to have the largest effect on reducing air pollution. Each ton of air pollution intercepted was valued at $3,005.46 (Davey Resource Group, 2014, p. 22). Replacing 10% of the parking spaces with the Black Locust would remove between 0.72 and 0.84 tons of air pollution per year with a value of $2,166 to $2,528. By replacing 25% of the area with Black Locus, between 1.8 and 2.1 tons of air pollution would be removed per year with a value of $5,417 to $6,39. By replacing 50% of the parking spaces, between 3.6 and 4.2 tons of air pollution would be removed per year with a value between $10,833 and $12,639. When these values for the air pollution removed were multiplied by the years during mature height, they were found to be: 10%) $187,775 to $219,070; 25%) $469,437 to $547,676; and 50%) $938,873 to $1,095,352 (Table 17).

4.2.4 Property Values

An individual, large front-yard tree accounted for a 0.88% increase in average home resale values (Anderson & Cordell, 1988). Assuming the 0.88% increase in property value was true for Albuquerque, each large tree was worth $1,577.58, based on the 3rd quarter median sale price in 2015 ($179,270) (Zillow.com, 2022). However, the urban forest being proposed would not be located in residents' front yards; therefore a park reduction factor (0.5) was applied (McPherson et al., 2001). The adjusted increase in property value ($788.79) was held constant for all reduced areas and multiplied by the number of each species that could fit within the area using Equation 45. The Oriental Arborvitae and the Common Pear were found to have the largest impact on property values. Replacing 10% of the parking spaces with either tree, property values would increase between $2,692,528 and $3,141,282. By replacing 25% of the area, property values would increase between $6,731,320 and $7,853,206. Replacing 50% of the parking spaces, property values would increase between $13,462,639 and $15,706,412 (Table 19). The increase in property values was diffused throughout the adjacent areas and would only be fully realized when the trees reached the end of their lifespans. Each tree, therefore, was adding to the property values as it grew, increasing its leaf area. Leaf area at full crown diameter was used in Equation 42 to determine the species price increase per square foot. Equation 43 was used to find the leaf area growth per year for the years between planting and years old at mature height. The species property value increase per year was found by multiplying price increase per square foot by leaf area growth per year using Equation 44. The Hawthorn Spp increased property values the most per year ($248.51) (Table 18).

4.2.5 Energy Use

A tree's effect on residential energy use is the sum of MBTU, MWH, and carbon avoided. The value of each was provided by Davey Resource Group for the entire city (2014, p. 28). The value of MBTU per tree was found to be -$0.35 (negative numbers represent an increase in cost) using Equations 46 and 49. The total increase in MBTU for each species was found using Equation 52, where -$0.35 was multiplied by the number of each species for the reduced areas and again by their years during mature height. The Cottonwood increased the cost of MBTU the least: 10%) -$3,656 to-$4,266; 25%) -

$9,141 to -$10,664); and 50%) -$18,282 to -$21,329). The Oriental Arborvitae was found to have the highest increase in MBTU: 10%) -$107,742 to -$125,699); 25%) -$269,354 to -$314,247); and 50%) -$538,709 to -$628,493) (Table 20). Using Equations 47 and 50, the value of MWH per tree was found to be $2.55. The total savings from reduced MWH consumption for each species was calculated in Equation 53 by multiplying $2.55, number of species, and species years during mature height together. The Oriental Arborvitae reduced MHW consumption the most: 10%) $784,239 to $914,946; 25%) $1,960,598 to $2,287,364; and 50%) $3,921,196 to $4,574,729 (Table 21). Using Equations 48 and 51, the value of avoided carbon per tree was found to be $0.30. The total savings from carbon avoided for each species was calculated in Equation 54 by multiplying $0.30, number of species, and species years during mature height together. The Oriental Arborvitae had the highest savings for avoided carbon: 10%) $91,454 to $106,696; 25%) $228,635 to $266,740; and 50%) $457,269 to $533,481 (Table 22). Using Equation 55, the Oriental Arborvitae had the largest effect on residential energy use in total: 10%) $767,951 to $895,943; 25%) $1,919,878 to $2,239,858; and 50%) $3,839,757 to $4,479,716 (Table 23).

4.2.6 Maintenance Cost

Values obtained from a City of Albuquerque Municipal Forest Resource Analysis (Vargas et al., 2006, p. 15) were used to find the maintenance cost per tree annually after adjusting for inflation (U.S. Bureau of Labor Statistics, n.d.). The cost of maintaining a tree includes contract pruning, irrigation, administration, inspection/service, infrastructure repairs, and litter cleanup. To calculate the maintenance cost of the reduced areas for each tree species over its projected lifespan, the cost per tree ($20.96) was multiplied by the remainder of its projected lifespan after planting and by the number of trees using Equation 56. The Oriental Arborvitae had the largest maintenance cost: 10%) $6,976,051 to $8,138,726; 25%) $17,440,127 to $20,346,814; and 50%) $34,880,253 to $40,693,629. The Cottonwood was found to have the least maintenance cost for the reduced areas: 10%) $270,237 to $315,277; 25%) $675,594 to $788,193; and 50%) $1,351,187 to $1,576,385 (Table 24).

4.2.7 Planting Cost

The City of Albuquerque's Unit Price Guide (2018a) was used to obtain planting prices. Each 2-inch caliper tree cost $247.50 to plant. In Equation 57, this cost was multiplied by the number of each species for the reduced areas. The Oriental Arborvitae and the Common Pear were found to have the highest planting costs. Planting 10% of the parking spaces with either tree would cost between $844,841 and $985,648. To plant 25% of the area would cost between $2,112,103 and $2,464,120. Planting 50% of the parking spaces with either tree would cost between $4,224,206 and $4,928,241. The cost to plant the reduced areas with the Cottonwood would cost the least: 10%) $34,405 to $40,140; 25%) $86,013 to $100,349; and 50%) $172,026 to $200,698 (Table 25).

4.2.8 Total Net Benefits

The total net benefits for each species were found by adding the benefits (reduced stormwater runoff, increase in carbon sequestration, increase in air quality, increase in property values, and reduced energy use) together and subtracting the costs (maintenance cost and planting cost) using Equation 58. Converting the reduced areas to an urban forest of Northern Red Oaks would provide the greatest net benefits. Replacing 10% of the parking would provide between $2,583,028 and $3,013,532 of benefits during the life of the trees. At 25% the benefits will be between $6,457,569 and $7,533,831. Converting 50% of the parking spaces would yield benefits valued between $12,915,139 and $15,067,662. All species of tree do not yield a positive net benefit: the Oriental Arborvitae, Common Pear, Japanese Maple, and Mexican Pinyon would cost more to plant and maintain than the value of benefits they would provide. Oriental Arborvitae would have the highest cost: 10%) -$1,827,188 to -$2,131,719; 25%) -$4,567,970 to -$5,329,298); and 50%) -$9,135,939 to -$10,658,596 (Table 26).

4.3 Discussion of Results

The results of the vehicle infrastructure study estimated that there were 29,120 parking spaces located within the Albuquerque Downtown Core area (Table 6a), as mandated by the MPRs for each land use. When combining the parking spaces that were surface parking with the area of streets, the total vehicle infrastructure was estimated at between 41.9% to 46.9% of the study area. This is likely an overestimation of total parking spaces. As discussed earlier in the methods section, both parking reductions for transit-rider shelters or transit pull-offs and mixed-use shared parking were not applied.

There were several other studies that could be compared to the estimated area in this study. Chester et al. (2015) found that in the incorporated L.A. County, 41% of land area was dedicated to vehicle infrastructure. Akbari et al. (2003) found that in downtown Sacramento, paved surfaces accounted for 41% of land area. Hoehne et al. (2019) found that in Metro Phoenix, 36% of the urban area was covered by parking and streets. Although the results of this study were higher than these three studies, the findings were still relatively close when using the low-end estimation. The difference in these results could be explained by the decision to not include all parking credits in the calculations.

The amount of parking spaces (29,120) in the downtown core surpasses the number of people employed (17,443) there by 11,677. If every person drove alone there would be 1.67 spaces for each vehicle. However, the downtown core is accessible through other transit modes, including multiple bus routes, ART, and bicycle facilities. With the availability of these transit modes, it is unlikely that every person would commute using a vehicle. This applies to residents of the area who are also employed there (119). Assuming the remaining 17,324 employees (that live outside of the area) drove alone there would be 1.68 spaces for each vehicle. The change in parking ratios appears negligible but is likely an underestimation of transit mode share. It is not known where employees reside outside of the downtown core, or their mode of transportation. If some people live on the fringes of the downtown core or along transit routes, they are more likely to use transit than drive alone, increasing the parking ratio.

Comparing the number of parking spaces to the number of parcels (765), gives an average of 38.07 parking spaces per parcel. This includes both residential parcels (199) and nonresidential parcels (566). The 199 residential parcels have an estimated 1,804 parking spaces (as on-street parking, off-street parking, and driveways), with an average of 9.07 parking spaces for each parcel. MPRs for residential land uses assumed two parking spaces per dwelling unit. With an average of 9.07 parking spaces per parcel and two spaces per dwelling unit the average density is 4.5 dwelling units per parcel. However, the resident density is 4.24 per parcel, or about one person per dwelling unit. This runs contrary to the assumption of two parking spaces per dwelling unit (implying two residents per dwelling unit). The actual MPRs for residential land uses are determined by number of bathrooms or bedrooms, which were not able to be counted. I chose to use two spaces per dwelling unit to represent driveways of single-family residents, which constitute a quarter of the residential parcels. For these parcels two parking spaces is appropriate, but by extending the same MPRs to parcels with muti-family units residential parking supply could be overestimated.

Nonresidential parcels (566) have an estimated 27,316 parking spaces with an average 48.26 parking spaces per parcel. The 17,324 employees (that live outside of the area) would use an average of 30.61 spaces per parcel (assuming all drive alone). This would mean that 9,992 parking spaces would be available for customers of nonresidential parcels, with an average of 17.65 spaces for each. This average does not account for the different MPRs of each land use. Parking demand varies by land use and is not evenly distributed among parcels. Parking studies would need to be conducted to assess the parking demand, and without them it is difficult to conclude if parking is oversupplied.

Results from the urban forest analysis showed that planting only Northern Red Oaks would have the greatest overall positive impact. Conversely, the results showed that four tree species (the Oriental Arborvitae, Common Pear, Japanese Maple, and Mexican Pinyon) would have an overall negative impact. The negative value for these species was primarily due to their small crown diameters (15 ft, 15 ft, 20 ft, and 20 ft, respectively). A species with a small crown diameter resulted in a higher population being planted to cover the same area than a species with a larger crown diameter did. This higher population increased the costs of initial planting and maintenance, surpassing the value of the benefits. However, smaller trees tended to have the highest benefit value by benefit category. The high population of small trees could also explain this pattern. For example, an increase in property values was determined by multiplying a fixed value ($788.79) by the species population. Higher populations yielded a greater increase to property values.

These results show how an urban forest can be designed to achieve specific outcomes. For example, if a city's goal is to improve air quality, the Black Locust should be planted as the primary species. However, primarily planting a single species creates a monoculture, which would leave the urban forest susceptible to disease and pest. Three examples are provided to show how different tree species can be "mixed and matched" to achieve different goals, while creating an urban forest that is resilient.

Example 1

The city of Albuquerque decides to create an urban forest by replacing 10% of the parking in the Downtown urban core. The city's main goal is to create a long-lasting urban forest with species that are moderately tall, allowing the existing street network to remain in place. The city chooses five tree species that will accomplish its goal: Austrian Pine, Ponderosa Pine, Chinese Pistache, Live Oak, and Norther Red Oak. Each species is to account for 20% of the urban forest area.

Urban forest characteristics:

- 835 trees to be planted.
- All species have an expected life span of 150 years.
- Stormwater runoff avoided valued at $3,293,085.49.
- Carbon sequestered valued at $44,448.09.
- Air pollution removed valued at $51,572.19.
- Property values increase by $658,543.24.

- Energy use decrease valued at $264,612.23.
- Maintenance cost of $2,517,432.45.
- Planting cost of $206,632.77.
- Total net benefits valued at $1,588,196.01.

Example 2

The city of Albuquerque decides to create an urban forest by replacing 10% of the parking in the Downtown urban core. The city wants to keep initial planting and maintenance cost to a minimum. A tree's crown diameter determines how many can be planted in an area. By planting only large trees the city will require less of them initially, keeping planting and maintenance cost lower. The city chooses eight tree species with a crown diameter of 40 ft or larger: Cottonwood, Honeylocust, Texas Red Oak, Live Oak, Pine Spp, Chir Pine, Northern Red Oak, and Locust Spp. Each species is to account for 12.5% of the urban forest area.

Urban forest characteristics:

- 388 trees planted.
- All species have a crown diameter of 40 ft or larger.
- Stormwater runoff avoided valued at $2,283,585.20.
- Carbon sequestered valued at $18,658.52.
- Air pollution removed valued at $11,066.68.
- Property values increase by $305,949.77.
- Energy use decrease valued at $85,914.01.

- Maintenance cost of $877,475.24.
- Planting cost of $95,998.63.
- Total net benefits valued at $1,731,700.31.

Example 3

The city of Albuquerque decides to create an urban forest by replacing 10% of the parking in the Downtown urban core. The city's goal is to create an urban forest that increases property values and maintains a total net benefit. Small trees increase property values the most, but also have the highest planting and maintenance cost. To keep costs from outweighing benefits the city chooses to plant a mix of small and large trees. Five tree species are selected to account for varying proportions of the urban forest: Cottonwood (20%), Oriental Arborvitae (10%), Live Oak (40%), Common Pear (10%), and Norther Red Oak (20%).

Urban forest characteristics:

- 968 trees planted.
- Stormwater runoff avoided valued at $2,853,005.62.
- Carbon sequestered valued at $49,527.60.
- Air pollution removed valued at $23,753.51.
- Property values increase by $763,748.99.
- Energy use decrease valued at $240,865.43.
- Maintenance cost of $2,199,424.05.
- Planting cost of $239,643.45.

- Total net benefits valued at $1,491,833.65.

In 2018, the City of Albuquerque joined the Paris Climate Agreement, committing to reducing greenhouse gas emissions by 26-28% from 2005 levels by 2025 (City of Albuquerque, 2018c). To achieve this goal the city and community developed the Climate Action Plan (CAP). The plan's policy recommendations are organized under seven themes: sustainable buildings, renewable energy, clean transportation, waste and recycling, economic development, education and awareness, and climate conscious neighborhoods and resources (City of Albuquerque, 2021, p. 7). How does the urban forest analysis fit in to these themes? Replacing parking with an urban forest illustrates both the negative impacts of vehicle infrastructure, and the positive impacts of urban trees. However, creating an urban forest in this way would have its challenges. For example, the cost of acquiring land could eclipse the benefits, achieving community consensus could be difficult, or there could be right of way and utility conflicts. These challenges can be mitigated by targeting tree planting efforts in smaller sites. Instead of replacing entire parking lots with trees, a couple of spaces from each could be converted into green spaces. Choosing a handful of parking spaces to replace allows the design, implementation, and impact of green spaces to be flexible while the desired outcome is achieved. The example below explains this further.

Example 4

The City of Albuquerque has identified a parking lot with 5% shade cover throughout the day. The CAP identifies increasing canopy cover as a strategy for reducing the heat island effect (City of Albuquerque, 2021, p. 31). The parking lot area is 8,050 ft^2 containing 23 spaces (350 ft^2 each). The city wants to achieve a 50% shade cover (4,025 ft^2). During the design phase the community communicates they want fruit trees to be incorporated in the green space. The city and community decided that planting a Texas Red Oak, Live Oak, and two Cherry Plum trees will increase shade cover to 50%, while meeting the communities request for fruit trees. As the parking lot is private property the city purchased the required parking spaces from the owner (at fair market value). Four parking spaces are converted to green spaces for the trees leaving 19 in the parking lot. At maturity the trees (including current 5% shade cover) are expected to shade 3,903ft^2 of the parking lot or 48.5%. In this example, land acquisition by the city increased the cost of the project. However, the city could mitigate the need to purchase private land by restricting green space projects to publicly owned land (owned by the City of Albuquerque). The creation of the four green spaces corresponds with two of the strategies in the CAP. Reducing the heat island effect by increasing canopy cover, and the inclusion of fruit trees supports the recommendation “greening efforts in frontline communities” (City of Albuquerque, 2021, p. 31).

CHAPTER 5: ADDITIONAL NOTES

This chapter will provide a brief personal note on the research. This includes the importance of this information for the planning profession, and the importance of trees to the urban form.

5.1 A Note from the Author

This thesis aims to highlight to planning professionals the importance of creating an accurate count of vehicle infrastructure. Without it, decisions made regarding transportation networks, community health, environmental sustainability, and the economy are missing part of the equation. The inefficiencies on how urban space is used and allocated have been highlighted in this thesis and other studies. Given the many inequalities that exist within our society, such as the rise in homelessness and obesity rates; a more efficient use of space can play a role in solving these issues. Homelessness could be solved by converting parking to affordable housing and creating a more walkable space could help lower obesity rates. Additionally, during the research process related to the urban forest analysis, I learned the incredible value of trees. The value they have isn't just in aesthetics or monetary value. It goes deeper than that, urban trees change the look of an area, its feel, its very character.

This study does not advocate for the specific reductions in the vehicle infrastructure to be implemented. However, the vehicle infrastructure reductions outlined and the suggestion to replace some of it with trees are provided to highlight the importance of measuring vehicle infrastructure and the effect it has on many aspects of people's lives. The example of replacing parking with an urban forest is just one of many ways our urban spaces can be rethought of.

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TABLES

Table 1: *On-Street Parking Data*

Parking Zone		-	Equations			-
			(1) [a]	(2) [b]	(3) [c]	
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
1	Free	224	11	11	5.5	5.5
2	Free	161	8	8	4	4
3	Free	168	8	8	4	4
4	Free	24	1	1	0.5	1
5	Free	117	6	6	3	3
6	Free	83	4	4	2	2
7	Free	190	10	10	5	5
8	Free	73	4	0	0	0
9	Free	214	11	11	5.5	5.5
10	Free	265	13	13	6.5	6.5
11	Free	119	6	6	3	3
12	Free	130	7	7	3.5	3.5
13	Free	105	5	5	2.5	2.5
14	Free	110	6	6	3	3
15	Metered	105	5	5	2.5	2.5
16	Metered	96	5	5	2.5	2.5
17	Metered	117	6	6	3	3
18	Metered	68	3	3	1.5	1.5
19	Metered	96	5	5	2.5	2.5
20	Metered	138	7	7	3.5	3.5

Parking Zone		-	Equations			-
			(1) [a]	(2) [b]	(3) [c]	
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
21	Metered	97	5	5	2.5	2.5
22	Pay station	116	6	6	3	3
23	Pay station	323	16	16	8	8
24	Metered	45	2	2	1	1
25	Free	86	4	4	2	2
26	Metered	102	5	5	2.5	2.5
27	Metered	106	5	5	2.5	2.5
28	Metered	91	5	5	2.5	2.5
29	Metered	112	6	6	3	3
30	Metered	98	5	5	2.5	2.5
31	Pay station	87	4	4	2	2
32	Pay station	118	6	6	3	3
33	Free residential	37	2	2	1	1
34	Metered	133	7	7	3.5	3.5
35	Metered	48	2	2	1	1
36	Metered	117	6	6	3	3
37	Metered	101	5	5	2.5	2.5
38	Metered	69	3	3	1.5	1.5
39	Metered	99	5	5	2.5	2.5
40	Free	190	10	10	5	5
41	Permit residential	126	6	6	3	3

Parking Zone		-	Equations (1) [a]	(2) [b]	(3) [c]	-
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
42	Permit residential	112	6	6	3	3
43	Metered	114	6	6	3	3
44	Metered	125	6	6	3	3
45	Metered	92	5	5	2.5	2.5
46	Metered	109	5	5	2.5	2.5
47	Metered	37	2	2	1	1
48	Metered	36	2	2	1	1
49	Metered	136	7	7	3.5	3.5
50	Metered	43	2	2	1	1
51	Metered	110	6	6	3	3
52	Metered	127	6	6	3	3
53	Free	41	2	2	1	1
54	Free	61	3	3	1.5	1.5
55	Free	125	6	0	0	0
56	Free	122	6	6	3	3
57	Free	89	4	4	2	2
58	Free	39	2	2	1	1
59	Metered	237	12	12	6	6
60	Metered	232	12	12	6	6
61	Metered	67	3	3	1.5	1.5
62	Metered	161	8	8	4	4

Parking Zone		-	Equations			-
			(1) [a]	(2) [b]	(3) [c]	
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
63	Metered	152	8	8	4	4
64	Pay station	189	9	9	4.5	4.5
65	Pay station	188	9	9	4.5	4.5
66	Metered	90	5	5	2.5	2.5
67	Metered	148	7	7	3.5	3.5
68	Metered	264	13	13	6.5	6.5
69	Metered	166	8	8	4	4
70	Metered	108	5	5	2.5	2.5
71	Metered	73	4	4	2	2
72	Free	37	2	2	1	1
73	Free	109	5	5	2.5	2.5
74	Free	83	4	4	2	2
75	Free	106	5	5	2.5	2.5
76	Pay station	140	7	7	3.5	3.5
77	Pay station	220	11	11	5.5	5.5
78	Pay station	125	6	6	3	3
79	Pay station	144	7	7	3.5	3.5
80	Pay station	218	11	11	5.5	5.5
81	Pay station	151	8	8	4	4
82	Pay station	227	11	11	5.5	5.5
83	Pay station	158	8	8	4	4
84	Pay station	76	4	4	2	2

Parking Zone		-	Equations (1) [a]	(2) [b]	(3) [c]	-
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
85	Metered	255	13	13	6.5	6.5
86	Metered	206	10	10	5	5
87	Pay station	174	9	9	4.5	4.5
88	Pay station	156	8	8	4	4
89	Pay station	198	10	10	5	5
90	Pay station	194	10	10	5	5
91	Pay station	210	11	11	5.5	5.5
92	Pay station	200	10	10	5	5
93	Pay station	203	10	10	5	5
94	Pay station	209	10	10	5	5
95	Pay station	196	10	10	5	5
96	Pay station	183	9	9	4.5	4.5
97	Pay station	192	10	10	5	5
98	Pay station	198	10	10	5	5
99	Free	125	6	6	3	3
100	Free	191	10	10	5	5
101	Accessible	37	2	2	1	1
102	Metered	53	3	3	1.5	1.5
103	Accessible	28	1	1	0.5	1
104	Pay station	180	9	9	4.5	4.5
105	Metered	162	8	8	4	4
106	Metered	210	11	11	5.5	5.5

Parking Zone		-	Equations (1) [a]	(2) [b]	(3) [c]	-
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
107	Free	179	9	9	4.5	4.5
108	Pay station	202	10	10	5	5
109	Pay station	188	9	9	4.5	4.5
110	Metered	128	6	6	3	3
111	Free	59	3	3	1.5	1.5
112	Free	240	12	12	6	6
113	Free	120	6	6	3	3
114	Free	413	21	21	10.5	10.5
115	Free	53	3	3	1.5	1.5
116	Accessible	75	4	4	2	2
117	Metered	54	3	3	1.5	1.5
118	Metered	102	5	5	2.5	2.5
119	Accessible	40	2	2	1	1
120	Pay station	154	8	8	4	4
121	Pay station	131	7	7	3.5	3.5
122	Metered	157	8	8	4	4
123	Metered	96	5	5	2.5	2.5
124	Metered	100	5	5	2.5	2.5
125	Metered	165	8	8	4	4
126	Metered	95	5	5	2.5	2.5
127	Metered	210	11	11	5.5	5.5
128	Free	91	5	5	2.5	2.5

Parking Zone		-	Equations (1) [a]	(2) [b]	(3) [c]	-
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
129	Free	132	7	7	3.5	3.5
130	Free	112	6	6	3	3
131	Metered	149	7	7	3.5	3.5
132	Metered	44	2	2	1	1
133	Metered	67	3	3	1.5	1.5
134	Metered	198	10	10	5	5
135	Metered	62	3	3	1.5	1.5
136	Metered	64	3	3	1.5	1.5
137	Accessible	138	7	7	3.5	3.5
138	Accessible	130	7	7	3.5	3.5
139	Pay station	115	6	6	3	3
140	Pay station	107	5	5	2.5	2.5
141	Metered	126	6	6	3	3
142	Accessible	79	4	4	2	2
143	Metered	89	4	4	2	2
144	Metered	60	3	3	1.5	1.5
145	Metered	114	6	6	3	3
146	Accessible	55	3	3	1.5	1.5
147	Pay station	166	8	8	4	4
148	Metered	267	13	13	6.5	6.5
149	Metered	98	5	5	2.5	2.5
150	Free	101	5	5	2.5	2.5

Parking Zone		-	Equations (1) [a]	Equations (2) [b]	Equations (3) [c]	-
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
151	Free	187	9	9	4.5	4.5
152	Free	182	9	9	4.5	4.5
153	Free	130	7	7	3.5	3.5
154	Free	158	8	8	4	4
155	Reserved	96	5	5	2.5	2.5
156	Reserved	46	2	2	1	1
157	Permit residential	266	13	0	0	0
158	Free residential	224	11	11	5.5	5.5
159	Free residential	195	19	19	9.5	9.5
160	Free	77	4	4	2	2
161	Free	40	2	2	1	1
162	Free residential	98	5	0	0	0
163	Free residential	119	6	0	0	0
164	Free residential	284	14	14	7	7
165	Free residential	85	4	0	0	0
166	Free residential	36	2	2	1	1
167	Free residential	192	10	0	0	0
168	Free residential	58	3	0	0	0
169	Free residential	142	7	7	3.5	3.5
170	Free residential	211	11	0	0	0
171	Free residential	55	3	0	0	0

Parking Zone		-	Equations (1) [a]	(2) [b]	(3) [c]	-
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
172	Free residential	48	2	0	0	0
173	Free residential	32	2	0	0	0
174	Free residential	34	2	0	0	0
175	Free residential	56	3	3	1.5	1.5
176	Free residential	57	3	0	0	0
177	Free residential	125	6	6	3	3
178	Free residential	82	4	4	2	2
179	Free residential	117	6	0	0	0
180	Free residential	130	7	0	0	0
181	Free residential	108	5	5	2.5	2.5
182	Free residential	77	4	0	0	0
183	Free residential	114	6	0	0	0
184	Free residential	79	4	0	0	0
185	Free	33	2	2	1	1
186	Free	68	3	3	1.5	1.5
187	Free	147	7	7	3.5	3.5
188	Free	206	10	10	5	5
189	Free	128	6	6	3	3
190	Free	141	7	7	3.5	3.5
191	Metered	185	9	9	4.5	4.5
192	Free	137	7	7	3.5	3.5
193	Free	41	2	2	1	1

Parking Zone		-	Equations (1) [a]	(2) [b]	(3) [c]	-
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
194	Free	63	3	3	1.5	1.5
195	Free	63	3	3	1.5	1.5
196	Free	226	11	11	5.5	5.5
197	Free	79	7	7	3.5	3.5
198	Free	97	5	5	2.5	2.5
199	Free	56	3	3	1.5	1.5
200	Free	78	4	4	2	2
201	Permit residential	106	5	5	2.5	2.5
202	Permit residential	80	4	4	2	2
203	Free	93	5	5	2.5	2.5
204	Metered	253	13	13	6.5	6.5
205	Free	65	3	3	1.5	1.5
206	Free	95	5	5	2.5	2.5
207	Free	42	2	2	1	1
208	Free	88	4	4	2	2
209	Free	49	2	2	1	1
210	Free	86	4	4	2	2
211	Free	29	1	1	0.5	1
212	Permit residential	63	3	0	0	0

Parking Zone		-	Equations (1) [a]	(2) [b]	(3) [c]	-
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
213	Permit residential	35	2	2	1	1
214	Permit residential	34	2	2	1	1
215	Permit residential	71	4	0	0	0
216	Permit residential	28	1	1	0.5	1
217	Permit residential	54	3	3	1.5	1.5
218	Free	27	1	1	0.5	1
219	Free	53	3	3	1.5	1.5
220	Free	64	3	3	1.5	1.5
221	Free	94	5	5	2.5	2.5
222	Free	35	2	2	1	1
223	Reserved	86	4	4	2	2
224	Reserved	140	7	7	3.5	3.5
225	Metered	33	2	2	1	1
226	Metered	16	1	1	0.5	1
227	Metered	134	7	7	3.5	3.5
228	Metered	29	1	1	0.5	1
229	Metered	24	1	1	0.5	1
230	Metered	21	1	1	0.5	1

Parking Zone		-	Equations (1) [a]	(2) [b]	(3) [c]	-
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
231	Metered	106	5	5	2.5	2.5
232	Metered	92	5	5	2.5	2.5
233	Metered	92	5	5	2.5	2.5
234	Reserved	134	7	7	3.5	3.5
235	Reserved	159	8	8	4	4
236	Metered	76	4	4	2	2
237	Reserved	149	7	7	3.5	3.5
238	Reserved	67	3	3	1.5	1.5
239	Reserved	22	1	1	0.5	1
240	Reserved	70	4	4	2	2
241	Reserved	58	3	3	1.5	1.5
242	Reserved	109	5	5	2.5	2.5
243	Reserved	152	8	8	4	4
244	Metered	34	2	2	1	1
245	Metered	23	1	1	0.5	1
246	Metered	20	1	1	0.5	1
247	Metered	42	2	2	1	1
248	Metered	22	1	1	0.5	1
249	Metered	41	2	2	1	1
250	Accessible	42	2	2	1	1
251	Free	97	5	5	2.5	2.5
252	Free	174	9	9	4.5	4.5

Parking Zone		-	Equations			-
			(1) [a]	(2) [b]	(3) [c]	
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
253	Free	137	7	7	3.5	3.5
254	Free	25	1	1	0.5	1
255	Free	177	9	9	4.5	4.5
256	Free	125	6	6	3	3
257	Free	21	1	1	0.5	1
258	Metered	22	1	1	0.5	1
259	Reserved	47	2	2	1	1
260	Free	26	1	1	0.5	1
261	Permit residential	71	4	0	0	0
262	Permit residential	106	5	0	0	0
263	Permit residential	123	6	0	0	0
264	Free	41	2	2	1	1
265	Accessible	21	1	1	0.5	1
266	Free	53	3	3	1.5	1.5
267	Free residential	98	5	5	2.5	2.5
268	Free	101	5	5	2.5	2.5
269	Free	57	3	3	1.5	1.5
270	Free residential	45	2	0	0	0
271	Free residential	33	2	0	0	0
272	Free residential	41	2	0	0	0

Parking Zone		-	Equations (1) [a]	(2) [b]	(3) [c]	-
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
273	Free residential	41	2	2	1	1
274	Free residential	145	7	7	3.5	3.5
275	Free residential	29	1	0	0	0
276	Free residential	36	2	0	0	0
277	Free residential	36	2	2	1	1
278	Free residential	30	2	2	1	1
279	Free residential	49	2	2	1	1
280	Free residential	108	5	5	2.5	2.5
281	Free residential	45	2	2	1	1
282	Free	39	2	0	0	0
283	Free	39	2	0	0	0
284	Free	17	1	1	0.5	1
285	Free residential	114	6	6	3	3
286	Free residential	48	2	2	1	1
287	Free residential	61	3	3	1.5	1.5
288	Free residential	27	1	1	0.5	1
289	Free residential	66	3	0	0	0
290	Free residential	53	3	0	0	0
291	Free residential	29	1	0	0	0
292	Free residential	72	4	0	0	0
293	Free residential	27	1	0	0	0
294	Free residential	40	2	2	1	1

Parking Zone		-	Equations (1) [a]	(2) [b]	(3) [c]	-
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
295	Free residential	40	2	0	0	0
296	Free residential	41	2	0	0	0
297	Free residential	26	1	1	0.5	1
298	Free residential	39	2	0	0	0
299	Free residential	58	3	0	0	0
300	Free residential	32	2	0	0	0
301	Free residential	46	2	0	0	0
302	Free residential	30	2	0	0	0
303	Free residential	37	2	0	0	0
304	Free residential	22	1	0	0	0
305	Free residential	28	1	0	0	0
306	Free residential	54	3	0	0	0
307	Free residential	36	2	0	0	0
308	Free residential	47	2	2	1	1
309	Reserved	124	6	6	3	3
310	Free residential	79	4	0	0	0
311	Free residential	26	1	0	0	0
312	Free residential	35	2	0	0	0
313	Free residential	36	2	0	0	0
314	Free residential	24	1	0	0	0
315	Free residential	35	2	0	0	0
316	Free residential	64	3	0	0	0

Parking Zone		-	Equations			-
			(1) [a]	(2) [b]	(3) [c]	
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
317	Free residential	66	3	3	1.5	1.5
318	Free residential	49	2	2	1	1
319	Free residential	40	2	2	1	1
320	Free residential	51	3	0	0	0
321	Free residential	138	7	7	3.5	3.5
322	Free residential	34	2	0	0	0
323	Free residential	47	2	0	0	0
324	Free residential	59	3	0	0	0
325	Free residential	25	1	0	0	0
326	Free residential	85	4	4	2	2
327	Free residential	36	2	0	0	0
328	Free residential	64	3	0	0	0
329	Free residential	127	6	6	3	3
330	Free residential	38	2	0	0	0
331	Metered	48	2	2	1	1
332	Pay station	63	3	3	1.5	1.5
333	Accessible	17	1	1	0.5	1
334	Metered	29	1	1	0.5	1
335	Metered	21	1	1	0.5	1
336	Metered	77	4	4	2	2
337	Accessible	38	2	2	1	1
338	Metered	52	3	3	1.5	1.5

Parking Zone		-	Equations (1) [a]	Equations (2) [b]	Equations (3) [c]	-
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
339	Free	157	8	8	4	4
340	Accessible	63	3	3	1.5	1.5
341	Pay station	69	3	3	1.5	1.5
342	Metered	43	2	2	1	1
343	Metered	54	3	3	1.5	1.5
344	Metered	75	4	4	2	2
345	Metered	128	6	6	3	3
346	Metered	56	3	3	1.5	1.5
347	Accessible	23	1	1	0.5	1
348	Metered	132	7	7	3.5	3.5
349	Metered	50	3	3	1.5	1.5
350	Free	98	5	5	2.5	2.5
351	Free	117	6	6	3	3
352	Metered	51	3	3	1.5	1.5
353	Pay station	274	14	14	7	7
354	Metered	39	2	2	1	1
355	Metered	50	3	3	1.5	1.5
356	Metered	57	3	3	1.5	1.5
357	Metered	116	6	6	3	3
358	Metered	97	5	5	2.5	2.5
359	Metered	151	8	8	4	4
360	Metered	31	2	2	1	1

Parking Zone		-	Equations (1) [a]	(2) [b]	(3) [c]	-
i	On-street parking type	On-street length (ft)	Total on-street parking spaces	Eligible on-street parking spaces	On-street parking spaces estimated credit	Eligible on-street parking spaces total [d]
361	Metered	43	2	2	1	1
362	Metered	39	2	2	1	1
363	Metered	77	4	4	2	2
364	Free	99	5	5	2.5	2.5
365	Reserved	274	14	14	7	7
366	Metered	275	14	14	7	7
367	Reserved	91	5	5	2.5	2.5
368	Pay station	98	5	5	2.5	2.5
369	Metered	46	2	2	1	1
370	Metered	132	7	7	3.5	3.5
371	Metered	46	2	2	1	1
372	Metered	199	10	10	5	5
373	Metered	21	1	1	0.5	1
374	Metered	126	6	6	3	3
375	Metered	19	1	1	0.5	1
376	Metered	63	3	3	1.5	1.5
377	Metered	117	6	6	3	3
378	Metered	99	5	5	2.5	2.5
379	Metered	21	1	1	0.5	1
380	Free	55	3	3	1.5	1.5
TOTAL		37,627	1,899	1,694	847	861

Note. On-street length = OSL; Eligible on-street parking = EOSP; Total on-street parking spaces = TOSP; On-street parking spaces estimated credit = OSPEC

[a] Equation 1: $OSL_i/20 = TOSP$

[b] Equation 2: $TOSP - 205 = EOSP$

[c] Equation 3: $EOSP_i/2 = OSPEC$

[d] $EOSP_i/2$ $i > 1$

Table 2: *Estimated Parking Structures Calculations*

			Equations			
	-	-	(4a) [a]	(4b) [b]	(5a) [c]	(5b) [d]
i	Area of parking structure (ft^2)	Number of floors	Estimated low parking spaces on first floor	Estimated high parking spaces on first floor	Estimated low total parking spaces	Estimated high total parking spaces
1	35,287	7	100.82	117.62	705.74	823.36
2	23,356	4	66.73	77.85	266.93	311.41
3	36,614	6	104.61	122.05	627.67	732.28
4	27,667	6	79.05	92.22	474.29	553.34
5	55,248	4	157.85	184.16	631.41	736.64
6	17,113	8	48.89	57.04	391.15	456.35
7	31,335	6	89.53	104.45	537.17	626.70
8	36,759	6	105.03	122.53	630.15	735.18
9	27,834	4	79.53	92.78	318.10	371.12
10	21,897	5	62.56	72.99	312.81	364.95
11	37,731	5	107.80	125.77	539.01	628.85
12	9,379	3	26.80	31.26	80.39	93.79
13	19,509	6	55.74	65.03	334.44	390.18
14	26,257	7	75.02	87.52	525.14	612.66
15	23,133	2	66.09	77.11	132.19	154.22
16	31,283	2	89.38	104.28	178.76	208.55
17	43,240	6	123.54	144.13	741.26	864.80
18	6,806	5	19.45	22.69	97.23	113.43
19	-	1	443	443	443	443

Note. APS = Area of parking structure; ELPSF = Estimated low parking spaces on first floor; EHPSF = Estimated high parking spaces on first floor; F = Number of floors; ELTPS = Estimated low total parking spaces; EHTPS = Estimated high total parking spaces

[a] Equation 4a: $APS_i/350 = ELPSF_i$

[b] Equation 4b: $APS_i/300 = EHPSF_i$

[c] Equation 5a: $ELPSF_i \times F_i = ELTPS_i$

[d] Equation 5b: $EHPSF_i \times F_i = EHTPS_i$

Table 3: *Parking Structure Adjustment Calculations*

i	Real low total parking spaces	Real high total parking spaces	Equations: (6a) [a] Low total parking spaces percent change	Equations: (6b) [b] High total parking spaces percent change
	-	-		
1	805	805	0.14	-0.02
2	266.93	311.41	0	0
3	627.67	732.28	0	0
4	540	540	0.14	-0.02
5	740	740	0.17	0.00
6	344	344	-0.12	-0.25
7	618	618	0.15	-0.01
8	534	534	-0.15	-0.27
9	336	336	0.06	-0.09
10	312.81	364.95	0	0
11	535	535	-0.01	-0.15
12	80.39	93.79	0	0
13	282	282	-0.16	-0.28
14	525.14	612.66	0	0
15	282	282	0	0
16	210	210	0.17	0.01
17	834	834	0.13	-0.04
18	155	155	0.59	0.37
19	443	443	0	0

Note. $RLTPS_i$ = Real low total parking spaces; $ELTPS_i$ = Estimated low total parking spaces; $LTPSPC_i$ = Low total parking spaces percent change; $RHTPS_i$ = Real high total parking spaces; $EHTPS_i$ = Estimated high total parking spaces; $HTPSPC_i$ = High total parking spaces percent change.

[a] Equation 6a: $(RLTPS_i - ELTPS_i)/ELTPS_i = LTPSPC_i$

[b] Equation 6b: $(RHTPS_i - EHTPS_i)/EHTPS_i = HTPSPC_i$

Table 4: *Final Parking Structure Calculations*

	Equations			
	(7a) [a]	(7b) [b]	(8a) [c]	(8b) [d]
i	Average of low total parking spaces percent change	Average of high total parking spaces percent change	Final low total parking spaces	Final high total parking spaces
1	-	-	805	805
2	0.09	-0.06	291.72	291.72
3	0.09	-0.06	685.97	685.97
4	-	-	540	540
5	-	-	740	740
6	-	-	344	344
7	-	-	618	618
8	-	-	534	534
9	-	-	336	336
10	0.09	-0.06	341.87	341.87
11	-	-	535	535
12	0.09	-0.06	87.86	87.86
13	-	-	282	282
14	0.09	-0.06	573.92	573.92
15	-	-	282	282
16	-	-	210	210
17	-	-	834	834
18	-	-	155	155
19	-	-	443	443

Note. $LTPSPC_i$ = Low total parking spaces percent change; ALTPSPC = Average low total parking spaces percent change (0.0929); $HTPSPC_i$ = High total parking spaces percent change; AHTPSPC = Average high total parking spaces percent change (-0.0632); ALTPSPC = Average low total parking spaces percent change (0.0929); $ELTPS_i$ = Estimated low total parking spaces; $FLTPS_i$ = Final low total parking spaces; $EHTPS_i$ = Estimated high total parking spaces; $FHTPS_i$ = Final high total parking spaces.

[a] Equations 7a: $\frac{1}{12}\sum_{i=1}^{12} LTPSPC_i = ALTPSPC$

[b] Equation 7b: $\frac{1}{12}\sum_{i=1}^{12} HTPSPC_i = AHTPSPC$

[c] Equation 8a: $(ALTPSPC \times ELTPS_i) + ELTPS_i = FLTPS_i$

[d] Equation 8b: $(AHTPSPC \times EHTPS_i) + EHTPS_i = FHTPS_i$

Table 5: *Street Area Data*

			Equation
	-	-	(9) [a]
i	Number of lanes	Segment length (ft)	Segment square feet
1	1	213	2,552
2	1	319	3,826
3	1	199	2,389
4	1	369	4,427
5	2	717	17,202
6	2	695	16,682
7	2	679	16,302
8	2	406	9,755
9	2	311	7,469
10	2	408	9,795
11	2	333	7,996
12	2	329	7,891
13	2	738	17,712
14	2	569	13,664
15	2	193	4,644
16	2	177	4,239
17	2	162	3,888
18	2	210	5,043
19	2	354	8,487
20	2	352	8,445
21	2	732	17,563
22	2	730	17,521

			Equation
	-	-	(9) [a]
i	Number of lanes	Segment length (ft)	Segment square feet
23	2	240	5,770
24	2	352	8,441
25	2	196	4,715
26	2	135	3,234
27	2	250	6,011
28	2	202	4,857
29	2	356	8,540
30	2	173	4,159
31	2	505	12,111
32	2	748	17,959
33	2	722	17,317
34	2	726	17,432
35	2	266	6,372
36	2	179	4,286
37	2	573	13,749
38	2	650	15,598
39	2	241	5,777
40	2	358	8,591
41	2	413	9,904
42	2	351	8,430
43	2	373	8,945
44	2	471	11,314
45	2	421	10,096

			Equation
	-	-	(9) [a]
i	Number of lanes	Segment length (ft)	Segment square feet
46	2	352	8,455
47	2	421	10,094
48	2	360	8,638
49	2	360	8,642
50	2	369	8,859
51	2	364	8,736
52	2	365	8,751
53	2	129	3,102
54	2	373	8,957
55	2	109	2,617
56	2	113	2,707
57	2	357	8,566
58	2	187	4,491
59	2	347	8,333
60	2	183	4,392
61	2	369	8,845
62	2	359	8,617
63	2	357	8,560
64	2	219	5,264
65	2	145	3,476
66	2	355	8,516
67	2	62	1,480
68	2	313	7,520

			Equation
	-	-	(9) [a]
i	Number of lanes	Segment length (ft)	Segment square feet
69	2	364	8,744
70	2	249	5,987
71	2	109	2,620
72	2	354	8,487
73	2	247	5,934
74	2	120	2,868
75	2	118	2,841
76	2	356	8,554
77	2	230	5,516
78	2	360	8,634
79	2	202	4,850
80	2	351	8,412
81	2	721	17,295
82	2	370	8,883
83	2	712	17,081
84	2	277	6,656
85	2	185	4,431
86	2	154	3,705
87	2	185	4,447
88	2	411	9,860
89	2	168	4,025
90	2	202	4,850
91	2	163	3,910

			Equation
	-	-	(9) [a]
i	Number of lanes	Segment length (ft)	Segment square feet
92	2	305	7,308
93	2	179	4,305
94	2	171	4,104
95	2	712	17,085
96	2	368	8,826
97	2	354	8,499
98	2	361	8,675
99	2	356	8,538
100	2	367	8,808
101	2	358	8,598
102	2	367	8,811
103	2	366	8,782
104	2	351	8,421
105	2	150	3,596
106	2	221	5,312
107	2	362	8,677
108	2	354	8,506
109	2	332	7,970
110	2	355	8,523
111	2	355	8,511
112	2	382	9,167
113	2	360	8,633
114	2	185	4,435

	-	-	Equation (9) [a]
i	Number of lanes	Segment length (ft)	Segment square feet
115	2	348	8,350
116	2	358	8,584
117	2	298	7,158
118	2	243	5,829
119	2	405	9,721
120	2	438	10,513
121	2	356	8,551
122	2	361	8,665
123	2	393	9,438
124	2	676	16,224
125	2	468	11,229
126	2	367	8,800
127	2	369	8,864
128	2	383	9,199
129	2	348	8,349
130	2	366	8,779
131	2	361	8,657
132	2	736	17,671
133	2	370	8,870
134	2	349	8,365
135	2	191	4,593
136	2	370	8,891
137	2	373	8,950

			Equation
	-	-	(9) [a]
i	Number of lanes	Segment length (ft)	Segment square feet
138	2	354	8,494
139	2	296	7,109
140	2	353	8,466
141	2	342	8,203
142	2	430	10,327
143	2	672	16,132
144	2	731	17,552
145	2	369	8,845
146	2	357	8,563
147	2	362	8,700
148	2	360	8,648
149	2	360	8,649
150	2	366	8,792
151	2	362	8,692
152	2	358	8,594
153	2	365	8,767
154	2	353	8,463
155	2	356	8,538
156	2	174	4,173
157	2	495	11,873
158	2	136	3,274
159	2	364	8,740
160	2	365	8,753

	-	-	Equation (9) [a]
i	Number of lanes	Segment length (ft)	Segment square feet
161	2	363	8,704
162	2	376	9,012
163	2	355	8,531
164	2	657	15,760
165	2	373	8,962
166	2	363	8,710
167	2	363	8,707
168	2	362	8,689
169	2	361	8,665
170	2	361	8,674
171	2	360	8,636
172	2	359	8,609
173	2	369	8,868
174	2	362	8,691
175	2	357	8,569
176	2	354	8,499
177	2	399	9,573
178	2	128	3,063
179	2	88	2,118
180	3	367	13,220
181	3	361	12,998
182	3	192	6,907
183	3	167	5,996

			Equation
	-	-	(9) [a]
i	Number of lanes	Segment length (ft)	Segment square feet
184	3	75	2,699
185	3	376	13,548
186	3	364	13,109
187	3	151	5,433
188	3	370	13,328
189	3	122	4,404
190	3	499	17,968
191	3	717	25,802
192	4	734	35,253
193	4	357	17,140
194	4	745	35,755
195	4	351	16,828
196	4	369	17,692
197	4	166	7,970
198	4	98	4,691
199	4	365	17,532
200	4	214	10,258
201	4	164	7,854
202	4	130	6,252
203	4	364	17,495
204	4	611	29,316
205	4	182	8,723
206	4	316	15,183

			Equation
	-	-	(9) [a]
i	Number of lanes	Segment length (ft)	Segment square feet
207	4	368	17,668
208	4	203	9,722
209	4	167	8,020
210	4	340	16,343
211	4	187	8,996
212	4	196	9,430
213	4	353	16,959
214	4	248	11,901
215	6	354	25,521
216	6	178	12,843
217	6	203	14,651
218	6	361	25,998
219	6	354	25,509
220	6	373	26,863
221	6	385	27,746
222	6	241	17,382
TOTAL	-	-	2,163,944

Note. NL_i = Number of lanes; SL_i = Segment length; SSF_i = Segment square feet.

[a] $NL_i \times SL_i \times 12 = SSF_i$

Table 6a: *Total Parking Spaces and Areas in the Study Area*

Vehicle infrastructure description	Parking spaces	Area (ft^2)		Area (mi^2)		Percent of study area (%)	
		HIGH	LOW	HIGH	LOW	HIGH	LOW
Total study area		20,959,234	20,959,234	0.7518	0.7518	100.0	100.0
Total spaces	29,120	10,000,851	8,976,801	0.3587	0.3220	47.7	42.8

Table 6b: *Total Parking Spaces and Areas of Parking Structures*

Vehicle infrastructure description	Parking spaces	Area (ft^2)		Area (mi^2)		Percent of study area (%)	
		HIGH	LOW	HIGH	LOW	HIGH	LOW
First floor	1,505	487,315	487,315	0.0175	0.0175	2.3	2.3
Total spaces	8,639	2,832,501	2,832,501	0.1016	0.1016	13.5	13.5

Table 6c: *Total Parking Spaces and Areas of On-Street Parking*

Vehicle infrastructure description	Parking spaces	Area (ft^2)		Area (mi^2)		Percent of study area (%)	
		HIGH	LOW	HIGH	LOW	HIGH	LOW
Total spaces	1,899	664,650	569,700	0.0238	0.0204	3.2	2.7
Parking credits	861	301,350	258,300	0.0108	0.0093	1.4	1.2
Total spaces minus credits	1,038	363,300	311,400	0.0130	0.0112	1.7	1.5

Table 6d: *Total Parking Spaces and Areas for Lanes, Surface Parking, and Surface Vehicle Infrastructure*

Vehicle infrastructure description	Parking spaces	Area (ft^2)		Area (mi^2)		Percent of study area (%)	
		HIGH	LOW	HIGH	LOW	HIGH	LOW
Lanes		2,163,944	2,163,944	0.0776	0.0776	10.3	10.3
Total surface parking [a]	21,986	7,655,665	6,631,615	0.2746	0.2379	36.5	31.6
Total surface vehicle infrastructure	21,986	9,819,609	8,795,559	0.3522	0.3155	46.9	42.0

[a] Total spaces (29,120) – (Parking structure total spaces [8,639] – Parking structure first floor spaces [1,505]). See Tables 6a and 6b.

Table 7: *Reduced Area Calculations*

Description		-	Equations
			(10a) [a] (10b) [b]
i	Reduction factor	Number of parking spaces reduced	Reduced area (ft^2)
-	10%	-	-
1	LOW	2,048	614,430
2	HIGH	2,048	716,835
-	25%	-	-
3	LOW	5,120	1,536,075
4	HIGH	5,120	1,792,088
-	50%	-	-
5	LOW	10,241	3,072,150
6	HIGH	10,241	3,584,175

Note. RF_i = Reduction factor (0.1, 0.25, or 0.5); RA_i = Reduced area

[a] Equation 10a: $(20{,}481 \times RF_i) \times 300 = RA_i$

[b] Equation 10b: $(20{,}481 \times RF_i) \times 350 = RA_i$

Table 8: *Reduced Area Tree Calculations*

				Equations					
		-	(11) [a]	(12) [b]					
		Species crown diameter (ft)	Area of species crown diameter (ft^2)	Number of species in reduced area					
Tree Description		-	-	10%		25%		50%	
i	Common Name	-	-	Low [c]	High [d]	Low [e]	High [f]	Low [g]	High [h]
1	Siberian Elm	-	-	-	-	-	-	-	-
2	White Mulberry	-	-	-	-	-	-	-	-
3	Cottonwood	75	4,420	139	162	348	405	695	811
4	Desert Olive	-	-	-	-	-	-	-	-
5	Desert Willow	25	490	1,254	1,463	3,135	3,657	6,270	7,315
6	Firethorn Spp	-	-	-	-	-	-	-	-
7	Velvet Ash	-	-	-	-	-	-	-	-
8	Honey Locust	45	1,590	386	451	966	1,127	1,932	2,254
9	Pinyon Pine	-	-	-	-	-	-	-	-
10	Austrian Pine	25	490	1,254	1,463	3,135	3,657	6,270	7,315
11	Tree of Heaven	-	-	-	-	-	-	-	-
12	Purpleleaf Plum	20	315	1,951	2,276	4,876	5,689	9,753	11,378
13	Callery Pear	-	-	-	-	-	-	-	-
14	Oriental Arborvitae	15	180	3,414	3,982	8,534	9,956	17,068	19,912
15	Other Species	-	-	-	-	-	-	-	-

Tree Description		Species crown diameter (ft)	Area of species crown diameter (ft^2)	Number of species in reduced area					
		-	(11) [a]	(12) [b]					
		-	-	10%		25%		50%	
i	Common Name	-	-	Low [c]	High [d]	Low [e]	High [f]	Low [g]	High [h]
16	Mimosa	20	315	1,951	2,276	4,876	5,689	9,753	11,378
17	Raywood Ash	-	-	-	-	-	-	-	-
18	Arizona Cypress	-	-	-	-	-	-	-	-
19	Ponderosa Pine	25	490	1,254	1,463	3,135	3,657	6,270	7,315
20	London Plane	-	-	-	-	-	-	-	-
21	White Ash	-	-	-	-	-	-	-	-
22	Common Crape Myrtle	-	-	-	-	-	-	-	-
23	Chinese Pistache	30	710	865	1,010	2,163	2,524	4,327	5,048
24	Chitalpa	-	-	-	-	-	-	-	-
25	Almond	30	710	865	1,010	2,163	2,524	4,327	5,048
26	Yucca Spp	-	-	-	-	-	-	-	-
27	Aleppo Pine	-	-	-	-	-	-	-	-
28	Chaste Tree	20	315	1,951	2,276	4,876	5,689	9,753	11,378
29	Crabapple	25	490	1,254	1,463	3,135	3,657	6,270	7,315
30	Texas Red Oak	40	1,260	488	569	1,219	1,422	2,438	2,845
31	Cherry Plum	25	490	1,254	1,463	3,135	3,657	6,270	7,315

Equations: (11) [a] applies to Area of species crown diameter; (12) [b] applies to Number of species in reduced area.

				Equations					
		-	(11) [a]	(12) [b]					
		Species crown diameter (ft)	Area of species crown diameter (ft^2)	Number of species in reduced area					
Tree Description		-	-	10%		25%		50%	
i	Common Name	-	-	Low [c]	High [d]	Low [e]	High [f]	Low [g]	High [h]
32	Live Oak	40	1,260	488	569	1,219	1,422	2,438	2,845
33	Boxelder	30	710	865	1,010	2,163	2,524	4,327	5,048
34	Evergreen Ash	-	-	-	-	-	-	-	-
35	Apple Spp	25	490	1,254	1,463	3,135	3,657	6,270	7,315
36	Plum Spp	25	490	1,254	1,463	3,135	3,657	6,270	7,315
37	Sweet Cherry	30	710	865	1,010	2,163	2,524	4,327	5,048
38	Common Pear	15	180	3,414	3,982	8,534	9,956	17,068	19,912
39	Soapberry Spp	30	710	865	1,010	2,163	2,524	4,327	5,048
40	Pine Spp	40	1,260	488	569	1,219	1,422	2,438	2,845
41	Chir Pine	40	1,260	488	569	1,219	1,422	2,438	2,845
42	Soaptree Yucca	-	-	-	-	-	-	-	-
43	Leyland Cypress	-	-	-	-	-	-	-	-
44	Japanese Maple	20	315	1,951	2,276	4,876	5,689	9,753	11,378
45	Northern Red Oak	50	1,960	313	366	784	914	1,567	1,829
46	Chinese Elm	-	-	-	-	-	-	-	-
47	Freeman Maple	-	-	-	-	-	-	-	-
48	Northern Catalpa	-	-	-	-	-	-	-	-

			Equations						
		-	(11) [a]	(12) [b]					
		Species crown diameter (ft)	Area of species crown diameter (ft^2)	Number of species in reduced area					
Tree Description		-	-	10%		25%		50%	
i	Common Name	-	-	Low [c]	High [d]	Low [e]	High [f]	Low [g]	High [h]
49	Eastern Redbud	-	-	-	-	-	-	-	-
50	Hawthorn Spp	20	315	1,951	2,276	4,876	5,689	9,753	11,378
51	Russian Olive	-	-	-	-	-	-	-	-
52	Spindle Tree Spp	20	315	1,951	2,276	4,876	5,689	9,753	11,378
53	Swamp Privet Spp	-	-	-	-	-	-	-	-
54	Locust Spp	50	1,960	313	366	784	914	1,567	1,829
55	Chokeberry Spp	-	-	-	-	-	-	-	-
56	Blue Spruce	-	-	-	-	-	-	-	-
57	Scotch Pine	-	-	-	-	-	-	-	-
58	Texas Pistache	30	710	865	1,010	2,163	2,524	4,327	5,048
59	Black Cottonwood	-	-	-	-	-	-	-	-
60	Black Locust	25	490	1,254	1,463	3,135	3,657	6,270	7,315
61	Ash Spp	-	-	-	-	-	-	-	-
62	Mexican Pinyon	20	315	1,951	2,276	4,876	5,689	9,753	11,378
63	Rocky Mountain Juniper	-	-	-	-	-	-	-	-
64	Goldenrain Tree	25	490	1,254	1,463	3,135	3,657	6,270	7,315

Note. SCD_i = Species crown diameter; $ASCD_i$ = Area of species crown diameter; RA_i = Reduced Area; NS_i = Number of species.

[a] Equation 11: $\pi \times (SCD_i/2)^2 = ASCD_i$

[b] Equation 12: $RA_i/ASCD_i = NS_i$

[c] 614,430 (ft^2)/Area of species crown diameter (ft^2)

[d] 716,835 (ft^2)/Area of species crown diameter (ft^2)

[e] 1,536,075 (ft^2)/Area of species crown diameter (ft^2)

[f] 1,792,088 (ft^2)/Area of species crown diameter (ft^2)

[g] 3,072,150 (ft^2)/Area of species crown diameter (ft^2)

[h] 3,584,175 (ft^2)/Area of species crown diameter (ft^2)

Table 9: *Tree Characteristics*

Tree description		-	-	-	-	Equations		
						(13) [a]	(14) [b]	(15) [c]
i	Common Name	Species life span (yr)	Growth rate (ft)	Species height at maturity (ft)	Species height at planting (ft)	Species years old at planting	Species years old at mature height	Species years during mature height
1	Siberian Elm	-	-	-	-	-	-	-
2	White Mulberry	-	-	-	-	-	-	-
3	Cottonwood	95	5	100	11	2	20	75
4	Desert Olive	-	-	-	-	-	-	-
5	Desert Willow	95	3	20	10	3	7	88
6	Firethorn Spp	-	-	-	-	-	-	-
7	Velvet Ash	-	-	-	-	-	-	-
8	Honey Locust	100	3	50	12	4	17	83

Tree description		-	-	-	-	Equations		
						(13) [a]	(14) [b]	(15) [c]
i	Common Name	Species life span (yr)	Growth rate (ft)	Species height at maturity (ft)	Species height at planting (ft)	Species years old at planting	Species years old at mature height	Species years during mature height
9	Pinyon Pine	-	-	-	-	-	-	-
10	Austrian Pine	150	1	35	9	9	35	115
11	Tree of Heaven	-	-	-	-	-	-	-
12	Purpleleaf Plum	50	2	20	9	5	10	40
13	Callery Pear	-	-	-	-	-	-	-
14	Oriental Arborvitae	100	2	20	5	2	10	90
15	Other Species	-	-	-	-	-	-	-
16	Mimosa	50	3	20	9	3	7	43
17	Raywood Ash	-	-	-	-	-	-	-

Tree description		-	-	-	-	Equations (13) [a]	Equations (14) [b]	Equations (15) [c]
i	Common Name	Species life span (yr)	Growth rate (ft)	Species height at maturity (ft)	Species height at planting (ft)	Species years old at planting	Species years old at mature height	Species years during mature height
18	Arizona Cypress	-	-	-	-	-	-	-
19	Ponderosa Pine	150	2	40	6	3	20	130
20	London Plane	-	-	-	-	-	-	-
21	White Ash	-	-	-	-	-	-	-
22	Common Crape Myrtle	-	-	-	-	-	-	-
23	Chinese Pistache	150	3	40	14	5	13	137
24	Chitalpa	-	-	-	-	-	-	-
25	Almond	95	2	30	9	5	15	80
26	Yucca Spp	-	-	-	-	-	-	-

Tree description		-	-	-	-	Equations (13) [a]	(14) [b]	(15) [c]
i	Common Name	Species life span (yr)	Growth rate (ft)	Species height at maturity (ft)	Species height at planting (ft)	Species years old at planting	Species years old at mature height	Species years during mature height
27	Aleppo Pine	-	-	-	-	-	-	-
28	Chaste Tree	100	2	20	10	5	10	90
29	Crabapple	100	2	25	9	5	13	88
30	Texas Red Oak	100	2	40	12	6	20	80
31	Cherry Plum	50	2	25	9	5	13	38
32	Live Oak	150	2	35	12	6	18	133
33	Boxelder	100	3	40	12	4	13	87
34	Evergreen Ash	-	-	-	-	-	-	-
35	Apple Spp	100	2	25	9	5	13	88

Tree description		-	-	-	-	Equations (13) [a]	Equations (14) [b]	Equations (15) [c]
i	Common Name	Species life span (yr)	Growth rate (ft)	Species height at maturity (ft)	Species height at planting (ft)	Species years old at planting	Species years old at mature height	Species years during mature height
36	Plum Spp	95	2	25	12	6	13	83
37	Sweet Cherry	50	2	25	12	6	13	38
38	Common Pear	100	2	25	12	6	13	88
39	Soapberry Spp	100	2	30	14	7	15	85
40	Pine Spp	100	2	60	6	3	30	70
41	Chir Pine	100	2	80	6	3	40	60
42	Soaptree Yucca	-	-	-	-	-	-	-
43	Leyland Cypress	-	-	-	-	-	-	-

Tree description		-	-	-	-	Equations		
						(13) [a]	(14) [b]	(15) [c]
i	Common Name	Species life span (yr)	Growth rate (ft)	Species height at maturity (ft)	Species height at planting (ft)	Species years old at planting	Species years old at mature height	Species years during mature height
44	Japanese Maple	100	1	20	12	12	20	80
45	Northern Red Oak	150	2	50	18	9	25	125
46	Chinese Elm	-	-	-	-	-	-	-
47	Freeman Maple	-	-	-	-	-	-	-
48	Northern Catalpa	-	-	-	-	-	-	-
49	Eastern Redbud	-	-	-	-	-	-	-
50	Hawthorn Spp	100	2	20	14	7	10	90
51	Russian Olive	-	-	-	-	-	-	-

Tree description		-	-	-	-	Equations (13) [a]	(14) [b]	(15) [c]
i	Common Name	Species life span (yr)	Growth rate (ft)	Species height at maturity (ft)	Species height at planting (ft)	Species years old at planting	Species years old at mature height	Species years during mature height
52	Spindle Tree Spp	95	2	20	9	5	10	85
53	Swamp Privet Spp	-	-	-	-	-	-	-
54	Locust Spp	100	3	50	12	4	17	83
55	Chokeberry Spp	-	-	-	-	-	-	-
56	Blue Spruce	-	-	-	-	-	-	-
57	Scotch Pine	-	-	-	-	-	-	-
58	Texas Pistache	100	2	30	14	7	15	85
59	Black Cottonwood	-	-	-	-	-	-	-

Tree description		-	-	-	-	Equations (13) [a]	(14) [b]	(15) [c]
i	Common Name	Species life span (yr)	Growth rate (ft)	Species height at maturity (ft)	Species height at planting (ft)	Species years old at planting	Species years old at mature height	Species years during mature height
60	Black Locust	100	3	40	12	4	13	87
61	Ash Spp	-	-	-	-	-	-	-
62	Mexican Pinyon	150	1	30	6	6	30	120
63	Rocky Mountain Juniper	-	-	-	-	-	-	-
64	Goldenrain Tree	100	1	25	12	12	25	75

Note. SHP_i = Species height at planting; GR_i = Growth rate; $SYOP_i$ = Species years old at planting; SHM_i = Species height at maturity; GR_i = Growth rate; $SYOMH_i$ = Species years old at mature height; SLS_i = Species life span; $SYDMH_i$ = Species years during mature height

[a] Equation 13: $SHP_i/GR_i = SYOP_i$

[b] Equation 14: $((SHM_i - SHP_i)/GR_i) + SYOP_i = SYOMH_i$

[c] Equation 15: $SLS_i - SYOMH_i = SYDMH_i$

Table 10: *Current Stormwater Runoff*

		Equations			
	-	(18a) [a]	(19a) [b]	(17a) [c]	(20a) [d]
i	Original area (ft^2)	Percent Area (%)	Runoff coefficient	Runoff generated during storm event (ft^3)	Runoff cost during storm event ($)
LOW	8,795,559	1.000	0.900	105,679	7,032
HIGH	9,819,609	1.000	0.900	117,983	7,850

Note. PA_i = Percent Area; C_i = Runoff coefficient; I = Rainfall intensity (0.01335 ft); A_i = Original area; RSE_i = Runoff generated during storm event; RRC = Reduced runoff cost savings; $RCSE_i$ =Runoff cost during storm event

[a] Equation 18a: $1 = PA_i$

[b] Equation 19a: $PA_i \times 0.9 = C_i$

[c] Equation 17a: $C_i \times I \times A_i = RSE_i$

[d] Equation 20a: $RSE_i \times RRC = RCSE_i$

Table 11: *Reduced Areas Stormwater Runoff*

	Equations							
	(10a) [a] (10b) [b]	(18b) [c]	(19b) [d]	(17b) [e]	(20b) [f]	(21) [g]	(22) [h]	(23) [i]
Reduction factor	Reduced area (ft^2)	Percent area (%)	Runoff coefficient	Runoff generated during storm event for reduced area (ft^3)	Reduced runoff cost during storm event ($)	Reduced runoff generated during storm event (ft^3)	Reduced area cost savings during storm event ($)	Reduced area cost savings per year ($)
10%								
LOW	614,430	0.070	0.844	99,117	6,595	6,562	437	25,761
HIGH	716,835	0.073	0.842	110,327	7,341	7,656	509	30,054
25%								
LOW	1,536,075	0.175	0.760	89,273	5,940	16,405	1,092	64,402
HIGH	1,792,088	0.183	0.754	98,843	6,577	19,139	1,273	75,136
50%								
LOW	3,072,150	0.349	0.621	72,868	4,848	32,811	2,183	128,804
HIGH	3,584,175	0.365	0.608	79,704	5,303	38,279	2,547	150,271

Note. RF_i = Reduction factor (0.1, 0.25, or 0.5); RA_i = Reduced Area; A_i = Original Area; PA_i = Percent Area; C_i = Runoff coefficient; I = Rainfall intensity (0.01335 ft); RSE_i = Runoff generated during storm event; $RSERA_i$ = Runoff generated during storm event for reduced area; RRC = Reduced runoff cost savings; $RCSE_i$ =Runoff cost during storm event; $RRCSE_i$ = Reduced runoff cost during storm event; $RRSE_i$ = Reduced runoff generated during storm event; $RACSSE_i$ = Reduced area cost savings during storm event; NSE = Number of storm events in 2018 (59); $RACSY_i$ = Reduced area cost savings per year

[a] Equation 10a: $(20{,}481 \times RF_i) \times 300 = RA_i$

[b] Equation 10b: $(20{,}481 \times RF_i) \times 350 = RA_i$

[c] Equation 18b: $RA_i / A_i = PA_i$

[d] Equation 19b: $(PA_i \times 0.1) + ((1 - PA_i) \times 0.9) = C_i$

[e] Equation 17b: $C_i \times I \times A_i = RSERA_i$

[f] Equation 20b: $RSERA_i \times RRC = RRCSE_i$

[g] Equation 21: $RSE_i - RSERA_i = RRSE_i$

[h] Equation 22: $RCSE_i - RRCSE_i = RACSSE_i$

[i] Equation 23: $RACSSE_i \times NSE = RACSY_i$

Table 12: *Reduced Areas Benefits to Stormwater Runoff*

		Equation					
		(24) [a]					
		Total species reduced runoff cost savings ($)					
Tree description		10%		25%		50%	
i	Common name	Low [b]	High [c]	Low [d]	High [e]	Low [f]	High [g]
1	Siberian Elm	-	-	-	-	-	-
2	White Mulberry	-	-	-	-	-	-
3	Cottonwood	1,932,057.98	2,254,067.65	4,830,144.95	5,635,169.11	9,660,289.91	11,270,338.23
4	Desert Olive	-	-	-	-	-	-
5	Desert Willow	2,275,534.96	2,654,790.78	5,688,837.39	6,636,976.96	11,377,674.78	13,273,953.91
6	Firethorn Spp	-	-	-	-	-	-
7	Velvet Ash	-	-	-	-	-	-
8	Honey Locust	2,146,731.09	2,504,519.61	5,366,827.73	6,261,299.02	10,733,655.46	12,522,598.03
9	Pinyon Pine	-	-	-	-	-	-
10	Austrian Pine	2,962,488.91	3,456,237.06	7,406,222.26	8,640,592.64	14,812,444.53	17,281,185.28
11	Tree of Heaven	-	-	-	-	-	-
12	Purpleleaf Plum	1,030,430.92	1,202,169.41	2,576,077.31	3,005,423.53	5,152,154.62	6,010,847.05

Tree description		Equation (24) [a] Total species reduced runoff cost savings ($)					
		10%		25%		50%	
i	Common name	Low [b]	High [c]	Low [d]	High [e]	Low [f]	High [g]
13	Callery Pear	-	-	-	-	-	-
14	Oriental Arborvitae	2,318,469.58	2,704,881.17	5,796,173.95	6,762,202.94	11,592,347.89	13,524,405.87
15	Other Species	-	-	-	-	-	-
16	Mimosa	1,116,300.17	1,302,350.20	2,790,750.42	3,255,875.49	5,581,500.84	6,511,750.98
17	Raywood Ash	-	-	-	-	-	-
18	Arizona Cypress	-	-	-	-	-	-
19	Ponderosa Pine	3,348,900.50	3,907,050.59	8,372,251.26	9,767,626.46	16,744,502.51	19,535,252.93
20	London Plane	-	-	-	-	-	-
21	White Ash	-	-	-	-	-	-
22	Common Crape Myrtle	-	-	-	-	-	-
23	Chinese Pistache	3,520,638.99	4,107,412.15	8,801,597.47	10,268,530.39	17,603,194.95	20,537,060.77
24	Chitalpa	-	-	-	-	-	-

Tree description		Equation (24) [a] Total species reduced runoff cost savings ($)					
		10%		25%		50%	
i	Common name	Low [b]	High [c]	Low [d]	High [e]	Low [f]	High [g]
25	Almond	2,060,861.85	2,404,338.82	5152,154.62	6,010,847.05	10,304,309.24	12,021,694.11
26	Yucca Spp	-	-	-	-	-	-
27	Aleppo Pine	-	-	-	-	-	-
28	Chaste Tree	2,318,469.58	2,704,881.17	5,796,173.95	6,762,202.94	11,592,347.89	13,524,405.87
29	Crabapple	2,254,067.65	2,629,745.59	5,635,169.11	6,574,363.97	11,270,338.23	13,148,727.93
30	Texas Red Oak	2,060,861.85	2,404,338.82	5,152,154.62	6,010,847.05	10,304,309.24	12,021,694.11
31	Cherry Plum	966,028.99	1,127,033.82	2,415,072.48	2,817,584.56	4,830,144.95	5,635,169.11
32	Live Oak	3,413,302.43	3,982,186.17	8,533,256.09	9,955,465.43	17,066,512.17	19,910,930.87
33	Boxelder	2,232,600.33	2,604,700.39	5,581,500.84	6,511,750.98	11,163,001.67	13,023,501.95
34	Evergreen Ash	-	-	-	-	-	-
35	Apple Spp	2,254,067.65	2,629,745.59	5,635,169.11	6,574,363.97	11,270,338.23	13,148,727.93
36	Plum Spp	2,125,263.78	2,479,474.41	5,313,159.45	6,198,686.03	10,626,318.90	12,397,372.05
37	Sweet Cherry	966,028.99	1,127,033.82	2,415,072.48	2,817,584.56	4,830,144.95	5,635,169.11

		Equation					
		(24) [a]					
		Total species reduced runoff cost savings ($)					
Tree description		10%		25%		50%	
i	Common name	Low [b]	High [c]	Low [d]	High [e]	Low [f]	High [g]
38	Common Pear	2,254,067.65	2,629,745.59	5,635,169.11	6,574,363.97	11,270,338.23	13,148,727.93
39	Soapberry Spp	2,189,665.71	2,554,610.00	5,474,164.28	6,386,525.00	10,948,328.56	12,773,049.99
40	Pine Spp	1,803,254.12	2,103,796.47	4,508,135.29	5,259,491.17	9,016,270.58	10,518,982.35
41	Chir Pine	1,545,646.39	1,803,254.12	3,864,115.96	4,508,135.29	7,728,231.93	9,016,270.58
42	Soaptree Yucca	-	-	-	-	-	-
43	Leyland Cypress	-	-	-	-	-	-
44	Japanese Maple	2,060,861.85	2,404,338.82	5,152,154.62	6,010,847.05	10,304,309.24	12,021,694.11
45	Northern Red Oak	3,220,096.64	3,756,779.41	8,050,241.59	9,391,948.52	16,100,483.18	18,783,897.05
46	Chinese Elm	-	-	-	-	-	-
47	Freeman Maple	-	-	-	-	-	-
48	Northern Catalpa	-	-	-	-	-	-
49	Eastern Redbud	-	-	-	-	-	-
50	Hawthorn Spp	2,318,469.58	2,704,881.17	5,796,173.95	6,762,202.94	11,592,347.89	13,524,405.87

		Equation					
		(24) [a]					
		Total species reduced runoff cost savings ($)					
Tree description		10%		25%		50%	
i	Common name	Low [b]	High [c]	Low [d]	High [e]	Low [f]	High [g]
51	Russian Olive	-	-	-	-	-	-
52	Spindle Tree Spp	2,189,665.71	2,554,610.00	5,474,164.28	6,386,525.00	10,948,328.56	12,773,049.99
53	Swamp Privet Spp	-	-	-	-	-	-
54	Locust Spp	2,146,731.09	2,504,519.61	5,366,827.73	6,261,299.02	10,733,655.46	12,522,598.03
55	Chokeberry Spp	-	-	-	-	-	-
56	Blue Spruce	-	-	-	-	-	-
57	Scotch Pine	-	-	-	-	-	-
58	Texas Pistache	2,189,665.71	2,554,610.00	5,474,164.28	6,386,525.00	10,948,328.56	12,773,049.99
59	Black Cottonwood	-	-	-	-	-	-
60	Black Locust	2,232,600.33	2,604,700.39	5,581,500.84	6,511,750.98	11,163,001.67	13,023,501.95
61	Ash Spp	-	-	-	-	-	-
62	Mexican Pinyon	3,091,292.77	3,606,508.23	7,728,231.93	9,016,270.58	15,456,463.86	18,032,541.16

		Equation					
		(24) [a]					
		Total species reduced runoff cost savings ($)					
Tree description		10%		25%		50%	
i	Common name	Low [b]	High [c]	Low [d]	High [e]	Low [f]	High [g]
63	Rocky Mountain Juniper	-	-	-	-	-	-
64	Goldenrain Tree	1,932,057.98	2,254,067.65	4,830,144.95	5,635,169.11	9,660,289.91	11,270,338.23

Note. $RACSY_i$ = Reduced area cost savings per year; $SYDMH_i$ = Species years during mature height; $TSRRCS_i$ = Total species reduced runoff cost savings

[a] Equation 24: $RACSY_i \times SYDMH_i = TSRRCS_i$

[b] $25,760.77 × Species years during mature height

[c] $30,054.23 × Species years during mature height

[d] $64,401.93 × Species years during mature height

[e] $75,135.59 × Species years during mature height

[f] $128,803.87 × Species years during mature height

[g] $150,271.18 × Species years during mature height

Table 13: *Carbon Sequestration Estimates*

Tree description		-		Equations		
				(25) [a]	(26) [b]	(27) [c]
i	Common name	Net carbon sequestration (tons/yr)-	Species percentage population (%)	Species population	Net carbon sequestration per tree (tons/yr)	Average net carbon sequestration per tree (tons/yr)
1	Siberian Elm	1,885	24.57	369,533	0.0051	0.0071
2	White Mulberry	1,168	5.97	89,789	0.0130	0.0071
3	Cottonwood	1,185	5.64	84,826	0.0140	0.0071
4	Desert Olive	112	5.62	84,525	0.0013	0.0071
5	Desert Willow	190	5.32	80,013	0.0024	0.0071
6	Firethorn Spp	219	4.32	64,973	0.0034	0.0071
7	Velvet Ash	449	4.16	62,566	0.0072	0.0071
8	Honey Locust	455	3.16	47,526	0.0096	0.0071
9	Pinyon Pine	157	3.12	46,925	0.0034	0.0071
10	Austrian Pine	123	2.95	44,368	0.0028	0.0071
11	Tree of Heaven	162	2.88	43,315	0.0037	0.0071

Tree description		-		Equations		
				(25) [a]	(26) [b]	(27) [c]
i	Common name	Net carbon sequestration (tons/yr)-	Species percentage population (%)	Species population	Net carbon sequestration per tree (tons/yr)	Average net carbon sequestration per tree (tons/yr)
12	Purpleleaf Plum	-	2.67	40,157	0	0.0071
13	Callery Pear	279	2.05	30,832	0.0090	0.0071
14	Oriental Arborvitae	-	1.98	29,779	0	0.0071
15	Other Species	-	1.6	24,064	0	0.0071
16	Mimosa	129	1.54	23,162	0.0056	0.0071
17	Raywood Ash	143	1.42	21,357	0.0067	0.0071
18	Arizona Cypress	148	1.35	20,304	0.0073	0.0071
19	Ponderosa Pine	-	1.1	16,544	0	0.0071
20	London Plane	124	0.98	14,739	0.0084	0.0071
21	White Ash	151	0.88	13,235	0.0114	0.0071
22	Common Crape Myrtle	-	0.88	13,235	0	0.0071

Tree description		-		Equations		
				(25) [a]	(26) [b]	(27) [c]
i	Common name	Net carbon sequestration (tons/yr)-	Species percentage population (%)	Species population	Net carbon sequestration per tree (tons/yr)	Average net carbon sequestration per tree (tons/yr)
23	Chinese Pistache	-	0.88	13,235	0	0.0071
24	Chitalpa	154	0.79	11,882	0.0130	0.0071
25	Almond	-	0.66	9,926	0	0.0071
26	Yucca Spp	-	0.66	9,926	0	0.0071
27	Aleppo Pine	-	0.65	9,776	0	0.0071
28	Chaste Tree	-	0.65	9,776	0	0.0071
29	Crabapple	-	0.64	9,626	0	0.0071
30	Texas Red Oak	-	0.64	9,626	0	0.0071
31	Cherry Plum	-	0.62	9,325	0	0.0071
32	Live Oak	-	0.54	8,122	0	0.0071
33	Boxelder	-	0.5	7,520	0	0.0071
34	Evergreen Ash	-	0.44	6,618	0	0.0071

Tree description		-		Equations		
				(25) [a]	(26) [b]	(27) [c]
i	Common name	Net carbon sequestration (tons/yr)-	Species percentage population (%)	Species population	Net carbon sequestration per tree (tons/yr)	Average net carbon sequestration per tree (tons/yr)
35	Apple Spp	-	0.44	6,618	0	0.0071
36	Plum Spp	-	0.44	6,618	0	0.0071
38	Common Pear	-	0.44	6,618	0	0.0071
39	Soapberry Spp	-	0.44	6,618	0	0.0071
40	Pine Spp	-	0.4	6,016	0	0.0071
41	Chir Pine	-	0.4	6,016	0	0.0071
42	Soaptree Yucca	-	0.37	5,565	0	0.0071
43	Leyland Cypress	-	0.3	4,512	0	0.0071
44	Japanese Maple	-	0.25	3,760	0	0.0071
45	Northern Red Oak	-	0.25	3,760	0	0.0071
46	Chinese Elm	-	0.25	3,760	0	0.0071

Tree description		-		Equations		
				(25) [a]	(26) [b]	(27) [c]
i	Common name	Net carbon sequestration (tons/yr)-	Species percentage population (%)	Species population	Net carbon sequestration per tree (tons/yr)	Average net carbon sequestration per tree (tons/yr)
47	Freeman Maple	-	0.22	3,309	0	0.0071
48	Northern Catalpa	-	0.22	3,309	0	0.0071
49	Eastern Redbud	-	0.22	3,309	0	0.0071
50	Hawthorn Spp	-	0.22	3,309	0	0.0071
51	Russian Olive	-	0.22	3,309	0	0.0071
52	Spindle Tree Spp	-	0.22	3,309	0	0.0071
53	Swamp Privet Spp	-	0.22	3,309	0	0.0071
54	Locust Spp	-	0.22	3,309	0	0.0071
55	Chokeberry Spp	-	0.22	3,309	0	0.0071
56	Blue Spruce	-	0.22	3,309	0	0.0071
57	Scotch Pine	-	0.22	3,309	0	0.0071

Tree description		-		Equations		
				(25) [a]	(26) [b]	(27) [c]
i	Common name	Net carbon sequestration (tons/yr)-	Species percentage population (%)	Species population	Net carbon sequestration per tree (tons/yr)	Average net carbon sequestration per tree (tons/yr)
58	Texas Pistache	-	0.22	3,309	0	0.0071
59	Black Cottonwood	-	0.22	3,309	0	0.0071
61	Ash Spp	-	0.2	3,008	0	0.0071
62	Mexican Pinyon	-	0.2	3,008	0	0.0071
63	Rocky Mountain Juniper	-	0.15	2,256	0	0.0071
64	Goldenrain Tree	-	0.15	2,256	0	0.0071
Total	-	-	1	1,504,451	-	-

Note. TTP = Total tree population (1,504,000); SPP_i = Species percentage population; SP_i = Species population CS_i = Net carbon sequestration; CSP_i = Net carbon sequestration per tree; ACSP = Average net carbon sequestration per tree (0.0071).

[a] Equation 25: $TTP \times (SPP_i/100) = SP_i$

[b] Equation 26: $CS_i/SP_i = CSP_i$

[c] Equation 27: $\frac{1}{18}\sum_{i=1}^{18} CSP_i = ACSP$

Table 14: *Carbon Sequestration Adjustment Estimates*

Tree description		Equations				
		(28) [a]	(29) [b]	(30) [c]	(31) [d]	(32) [e]
i	Common name	Estimated net carbon sequestration (tons/yr)	Net carbon sequestration percent change (tons/yr)	Average of net carbon sequestration percent change	Final net carbon sequestration (tons/yr)	Final net carbon sequestration per tree (tons/yr)
1	Siberian Elm	2612	-0.28	-	1885	0.0051
2	White Mulberry	635	0.84	-	1168	0.0130
3	Cottonwood	600	0.98	-	1185	0.0140
4	Desert Olive	597	-0.81	-	112	0.0013
5	Desert Willow	566	-0.66	-	190	0.0024
6	Firethorn Spp	459	-0.52	-	219	0.0034
7	Velvet Ash	442	0.02	-	449	0.0072
8	Honey Locust	336	0.35	-	455	0.0096
9	Pinyon Pine	332	-0.53	-	157	0.0034
10	Austrian Pine	314	-0.61	-	123	0.0028

Tree description		Equations				
		(28) [a]	(29) [b]	(30) [c]	(31) [d]	(32) [e]
i	Common name	Estimated net carbon sequestration (tons/yr)	Net carbon sequestration percent change (tons/yr)	Average of net carbon sequestration percent change	Final net carbon sequestration (tons/yr)	Final net carbon sequestration per tree (tons/yr)
11	Tree of Heaven	306	-0.47	-	162	0.0037
12	Purpleleaf Plum	284	0	-1.4803E-16	284	0.0071
13	Callery Pear	218	0.28	-	279	0.0090
14	Oriental Arborvitae	211	0	-1.4803E-16	211	0.0071
15	Other Species	170	0	-1.4803E-16	170	0.0071
16	Mimosa	164	-0.21	-	129	0.0056
17	Raywood Ash	151	-0.05	-	143	0.0067
18	Arizona Cypress	144	0.03	-	148	0.0073
19	Ponderosa Pine	117	0	-1.4803E-16	117	0.0071
20	London Plane	104	0.19	-	124	0.0084

Tree description		Equations				
		(28) [a]	(29) [b]	(30) [c]	(31) [d]	(32) [e]
i	Common name	Estimated net carbon sequestration (tons/yr)	Net carbon sequestration percent change (tons/yr)	Average of net carbon sequestration percent change	Final net carbon sequestration (tons/yr)	Final net carbon sequestration per tree (tons/yr)
21	White Ash	94	0.62	-	151	0.0114
22	Common Crape Myrtle	94	0	-1.4803E-16	94	0.0071
23	Chinese Pistache	94	0	-1.4803E-16	94	0.0071
24	Chitalpa	84	0.83	-	154	0.0130
25	Almond	70	0	-1.4803E-16	70	0.0071
26	Yucca Spp	70	0	-1.4803E-16	70	0.0071
27	Aleppo Pine	69	0	-1.4803E-16	69	0.0071
28	Chaste Tree	69	0	-1.4803E-16	69	0.0071
29	Crabapple	68	0	-1.4803E-16	68	0.0071
30	Texas Red Oak	68	0	-1.4803E-16	68	0.0071
31	Cherry Plum	66	0	-1.4803E-16	66	0.0071

Tree description		Equations				
		(28) [a]	(29) [b]	(30) [c]	(31) [d]	(32) [e]
i	Common name	Estimated net carbon sequestration (tons/yr)	Net carbon sequestration percent change (tons/yr)	Average of net carbon sequestration percent change	Final net carbon sequestration (tons/yr)	Final net carbon sequestration per tree (tons/yr)
32	Live Oak	57	0	-1.4803E-16	57	0.0071
33	Boxelder	53	0	-1.4803E-16	53	0.0071
34	Evergreen Ash	47	0	-1.4803E-16	47	0.0071
35	Apple Spp	47	0	-1.4803E-16	47	0.0071
36	Plum Spp	47	0	-1.4803E-16	47	0.0071
38	Common Pear	47	0	-1.4803E-16	47	0.0071
39	Soapberry Spp	47	0	-1.4803E-16	47	0.0071
40	Pine Spp	43	0	-1.4803E-16	43	0.0071
41	Chir Pine	43	0	-1.4803E-16	43	0.0071
42	Soaptree Yucca	39	0	-1.4803E-16	39	0.0071
43	Leyland Cypress	32	0	-1.4803E-16	32	0.0071

Tree description		Equations				
		(28) [a]	(29) [b]	(30) [c]	(31) [d]	(32) [e]
i	Common name	Estimated net carbon sequestration (tons/yr)	Net carbon sequestration percent change (tons/yr)	Average of net carbon sequestration percent change	Final net carbon sequestration (tons/yr)	Final net carbon sequestration per tree (tons/yr)
44	Japanese Maple	27	0	-1.4803E-16	27	0.0071
45	Northern Red Oak	27	0	-1.4803E-16	27	0.0071
46	Chinese Elm	27	0	-1.4803E-16	27	0.0071
47	Freeman Maple	23	0	-1.4803E-16	23	0.0071
48	Northern Catalpa	23	0	-1.4803E-16	23	0.0071
49	Eastern Redbud	23	0	-1.4803E-16	23	0.0071
50	Hawthorn Spp	23	0	-1.4803E-16	23	0.0071
51	Russian Olive	23	0	-1.4803E-16	23	0.0071
52	Spindle Tree Spp	23	0	-1.4803E-16	23	0.0071

Tree description		Equations				
		(28) [a]	(29) [b]	(30) [c]	(31) [d]	(32) [e]
i	Common name	Estimated net carbon sequestration (tons/yr)	Net carbon sequestration percent change (tons/yr)	Average of net carbon sequestration percent change	Final net carbon sequestration (tons/yr)	Final net carbon sequestration per tree (tons/yr)
53	Swamp Privet Spp	23	0	-1.4803E-16	23	0.0071
54	Locust Spp	23	0	-1.4803E-16	23	0.0071
55	Chokeberry Spp	23	0	-1.4803E-16	23	0.0071
56	Blue Spruce	23	0	-1.4803E-16	23	0.0071
57	Scotch Pine	23	0	-1.4803E-16	23	0.0071
58	Texas Pistache	23	0	-1.4803E-16	23	0.0071
59	Black Cottonwood	23	0	-1.4803E-16	23	0.0071
61	Ash Spp	21	0	-1.4803E-16	21	0.0071
62	Mexican Pinyon	21	0	-1.4803E-16	21	0.0071

Tree description		Equations				
		(28) [a]	(29) [b]	(30) [c]	(31) [d]	(32) [e]
i	Common name	Estimated net carbon sequestration (tons/yr)	Net carbon sequestration percent change (tons/yr)	Average of net carbon sequestration percent change	Final net carbon sequestration (tons/yr)	Final net carbon sequestration per tree (tons/yr)
63	Rocky Mountain Juniper	16	0	-1.4803E-16	16	0.0071
64	Goldenrain Tree	16	0	-1.4803E-16	16	0.0071

Note. SP_i = Species population; ACSP = Average net carbon sequestration per tree (0.0071); ECS_i = Estimated net carbon sequestration; CS_i = Net carbon sequestration; CPC_i = Net carbon sequestration percent change; ACPC = Average net carbon sequestration percent change (-1.4803×10^{-16}); FCS_i = Final net carbon sequestration; $FCSP_i$ = Final net carbon sequestration per tree

[a] Equation 28: $SP_i \times ACSP = ECS_i$

[b] Equation 29: $(CS_i - ECS_i)/ECS_i = CPC_i$

[c] Equation 30: $\frac{1}{18} \sum_{i=1}^{18} CPC_i = ACPC$

[d] Equation 31: $(ACPC \times ECS_i) + ECS_i = FCS_i$

[e] Equation 32: $FCS_i / SP_i = FCSP_i$

Table 15: *Reduced Areas Benefits to Carbon Sequestration*

Tree description		Equation (33) [a] Reduced area carbon sequestration value ($)					
		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
1	Siberian Elm	-	-	-	-	-	-
2	White Mulberry	-	-	-	-	-	-
3	Cottonwood	10,373	12,102	25,933	30,256	51,867	60,511
4	Desert Olive	-	-	-	-	-	-
5	Desert Willow	18,740	21,863	46,849	54,658	93,699	109,315
6	Firethorn Spp	-	-	-	-	-	-
7	Velvet Ash	-	-	-	-	-	-
8	Honey Locust	21,950	25,608	54,875	64,021	109,750	128,042
9	Pinyon Pine	-	-	-	-	-	-
10	Austrian Pine	28,405	33,139	71,013	82,848	142,025	165,696
11	Tree of Heaven	-	-	-	-	-	-
12	Purpleleaf Plum	39,274	45,819	98,184	114,549	196,369	229,097
13	Callery Pear	-	-	-	-	-	-
14	Oriental Arborvitae	154,641	180,414	386,601	451,035	773,203	902,070
15	Other Species	-	-	-	-	-	-
16	Mimosa	33,648	39,256	84,120	98,140	168,240	196,280
17	Raywood Ash	-	-	-	-	-	-
18	Arizona Cypress	-	-	-	-	-	-
19	Ponderosa Pine	82,054	95,730	205,135	239,325	410,271	478,649
20	London Plane	-	-	-	-	-	-

		Equation					
		(33) [a]					
		Reduced area carbon sequestration value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
21	White Ash	-	-	-	-	-	-
22	Common Crape Myrtle	-	-	-	-	-	-
23	Chinese Pistache	59,533	69,455	148,832	173,638	297,665	347,276
24	Chitalpa	-	-	-	-	-	-
25	Almond	34,849	40,657	87,121	101,642	174,243	203,283
26	Yucca Spp	-	-	-	-	-	-
27	Aleppo Pine	-	-	-	-	-	-
28	Chaste Tree	88,366	103,094	220,915	257,734	441,830	515,469
29	Crabapple	55,229	64,434	138,072	161,084	276,144	322,168
30	Texas Red Oak	19,637	22,910	49,092	57,274	98,184	114,549
31	Cherry Plum	23,669	27,614	59,174	69,036	118,347	138,072
32	Live Oak	32,524	37,944	81,309	94,861	162,618	189,721
33	Boxelder	37,753	44,045	94,382	110,112	188,763	220,224
34	Evergreen Ash	-	-	-	-	-	-
35	Apple Spp	55,229	64,434	138,072	161,084	276,144	322,168
36	Plum Spp	52,073	60,752	130,182	151,879	260,364	303,758
37	Sweet Cherry	16,335	19,058	40,838	47,645	81,676	95,289
38	Common Pear	150,345	175,403	375,863	438,506	751,725	877,013
39	Soapberry Spp	37,027	43,198	92,567	107,994	185,133	215,989
40	Pine Spp	17,182	20,046	42,956	50,115	85,911	100,230
41	Chir Pine	14,728	17,182	36,819	42,956	73,638	85,911

Tree description		Equation (33) [a] Reduced area carbon sequestration value ($)					
		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
42	Soaptree Yucca	-	-	-	-	-	-
43	Leyland Cypress	-	-	-	-	-	-
44	Japanese Maple	78,548	91,639	196,369	229,097	392,738	458,194
45	Northern Red Oak	19,725	23,012	49,311	57,530	98,623	115,060
46	Chinese Elm	-	-	-	-	-	-
47	Freeman Maple	-	-	-	-	-	-
48	Northern Catalpa	-	-	-	-	-	-
49	Eastern Redbud	-	-	-	-	-	-
50	Hawthorn Spp	88,366	103,094	220,915	257,734	441,830	515,469
51	Russian Olive	-	-	-	-	-	-
52	Spindle Tree Spp	83,457	97,366	208,642	243,416	417,284	486,831
53	Swamp Privet Spp	-	-	-	-	-	-
54	Locust Spp	13,150	15,341	32,874	38,353	65,749	76,707
55	Chokeberry Spp	-	-	-	-	-	-
56	Blue Spruce	-	-	-	-	-	-
57	Scotch Pine	-	-	-	-	-	-
58	Texas Pistache	37,027	43,198	92,567	107,994	185,133	215,989
59	Black Cottonwood	-	-	-	-	-	-
60	Black Locust	54,703	63,820	136,757	159,550	273,514	319,100
61	Ash Spp	-	-	-	-	-	-
62	Mexican Pinyon	117,821	137,458	294,553	343,646	589,107	687,291

		Equation					
		(33) [a]					
		Reduced area carbon sequestration value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
63	Rocky Mountain Juniper	-	-	-	-	-	-
64	Goldenrain Tree	47,339	55,229	118,347	138,072	236,695	276,144

Note. $FCSP_i$ = Final net carbon sequestration per tree; NS_i = Number of species; VCS = Value of carbon sequestration ($71.21); $SYDMH_i$ = Species years during mature height; $RACSV_i$ = Reduced area carbon sequestration value.

[a] Equation 33: $FCSP_i \times NS_i \times VCS \times SYDMH_i = RACSV_i$

Table 16: *Air Pollution Estimates*

Tree description		-	Equations			
			(25) [a]	(35) [b]	(36) [c]	(38) [d]
i	Common name	Species percentage leaf area (%)	Species population	Species square feet of tree cover per tree (ft^2)	Estimate area tree cover in square feet (ft^2)	Species tons of air pollution removed per tree (tons/yr/tree)
1	Siberian Elm	28.51	369,533	378	139,748,823	0.000282
2	White Mulberry	15.15	89,789	827	74,261,476	0.000617
3	Cottonwood	10.73	84,826	620	52,595,751	0.000463
4	Desert Olive	0.58	84,525	34	2,843,014	0.000025
5	Desert Willow	1.87	80,013	115	9,166,268	0.000085
6	Firethorn Spp	0.54	64,973	41	2,646,944	0.000030
7	Velvet Ash	5.7	62,566	447	27,939,961	0.000333
8	Honey Locust	2.64	47,526	272	12,940,614	0.000203
9	Pinyon Pine	2.35	46,925	245	11,519,107	0.000183
10	Austrian Pine	2.95	44,368	326	14,460,155	0.000243
11	Tree of Heaven	1.77	43,315	200	8,676,093	0.000149
12	Purpleleaf Plum	1.72	40,157	210	8,431,006	0.000157
13	Callery Pear	2.54	30,832	404	12,450,439	0.000301
14	Oriental Arborvitae	0.53	29,779	87	2,597,926	0.000065
15	Other Species	2.3	24,064	469	11,274,019	0.000350
16	Mimosa	1.53	23,162	324	7,499,674	0.000242
17	Raywood Ash	2	21,357	459	9,803,495	0.000343

Tree description		-	Equations			
			(25) [a]	(35) [b]	(36) [c]	(38) [d]
i	Common name	Species percentage leaf area (%)	Species population	Species square feet of tree cover per tree (ft^2)	Estimate area tree cover in square feet (ft^2)	Species tons of air pollution removed per tree (tons/yr/tree)
18	Arizona Cypress	3.75	20,304	905	18,381,553	0.000676
19	Ponderosa Pine	0.75	16,544	222	3,676,311	0.000166
20	London Plane	1.39	14,739	462	6,813,429	0.000345
21	White Ash	1.61	13,235	596	7,891,814	0.000445
22	Common Crape Myrtle	0.17	13,235	63	833,297	0.000047
23	Chinese Pistache	0.55	13,235	204	2,695,961	0.000152
24	Chitalpa	1.31	11,882	540	6,421,289	0.000403
25	Almond	0.08	9,926	40	392,140	0.000029
26	Yucca Spp	0.1	9,926	49	490,175	0.000037
27	Aleppo Pine	0.24	9,776	120	1,176,419	0.000090
28	Chaste Tree	0.36	9,776	181	1,764,629	0.000135
29	Crabapple	0.24	9,626	122	1,176,419	0.000091
30	Texas Red Oak	0.11	9,626	56	539,192	0.000042
31	Cherry Plum	0.1	9,325	53	490,175	0.000039
32	Live Oak	0.17	8,122	103	833,297	0.000077
33	Boxelder	0.16	7,520	104	784,280	0.000078
34	Evergreen Ash	0.21	6,618	156	1,029,367	0.000116
35	Apple Spp	0.45	6,618	333	2,205,786	0.000249

Tree description		-	Equations			
			(25) [a]	(35) [b]	(36) [c]	(38) [d]
i	Common name	Species percentage leaf area (%)	Species population	Species square feet of tree cover per tree (ft^2)	Estimate area tree cover in square feet (ft^2)	Species tons of air pollution removed per tree (tons/yr/tree)
36	Plum Spp	0.07	6,618	52	343,122	0.000039
37	Sweet Cherry	0.13	6,618	96	637,227	0.000072
38	Common Pear	0.17	6,618	126	833,297	0.000094
39	Soapberry Spp	0.15	6,618	111	735,262	0.000083
40	Pine Spp	0.13	6,016	106	637,227	0.000079
41	Chir Pine	0.42	6,016	342	2,058,734	0.000255
42	Soaptree Yucca	0.17	5,565	150	833,297	0.000112
43	Leyland Cypress	0.26	4,512	282	1,274,454	0.000211
44	Japanese Maple	0.02	3,760	26	98,035	0.000019
45	Northern Red Oak	0.02	3,760	26	98,035	0.000019
46	Chinese Elm	0.05	3,760	65	245,087	0.000049
47	Freeman Maple	0.05	3,309	74	245,087	0.000055
48	Northern Catalpa	0.19	3,309	281	931,332	0.000210
49	Eastern Redbud	0.02	3,309	30	98,035	0.000022
50	Hawthorn Spp	0.02	3,309	30	98,035	0.000022
51	Russian Olive	0.07	3,309	104	343,122	0.000077
52	Spindle Tree Spp	0.02	3,309	30	98,035	0.000022

Tree description		-	Equations			
			(25) [a]	(35) [b]	(36) [c]	(38) [d]
i	Common name	Species percentage leaf area (%)	Species population	Species square feet of tree cover per tree (ft^2)	Estimate area tree cover in square feet (ft^2)	Species tons of air pollution removed per tree (tons/yr/tree)
53	Swamp Privet Spp	0.06	3,309	89	294,105	0.000066
54	Locust Spp	0.02	3,309	30	98,035	0.000022
55	Chokeberry Spp	0.06	3,309	89	294,105	0.000066
56	Blue Spruce	0.06	3,309	89	294,105	0.000066
57	Scotch Pine	0.84	3,309	1244	4,117,468	0.000929
58	Texas Pistache	0.58	3,309	859	2,843,014	0.000641
59	Black Cottonwood	0.49	3,309	726	2,401,856	0.000542
60	Black Locust	0.52	3,309	770	2,548,909	0.000575
61	Ash Spp	0.19	3,008	310	931,332	0.000231
62	Mexican Pinyon	0.03	3,008	49	147,052	0.000036
63	Rocky Mountain Juniper	0.02	2,256	43	98,035	0.000032
64	Goldenrain Tree	0.06	2,256	130	294,105	0.000097
Total		1	1,504,451	-	490,419,843	-

Note. TTP = Total tree population (1,504,000); SPP_i = Species percentage population; SP_i = Species population; ATCSF = Area tree cover in square feet (490,174,755); $SPLA_i$ = Species percentage leaf area; $SSFTCP_i$ = Species square feet of tree cover per tree; EATCSF = Estimate area tree cover in square feet (490,419,843); APP = Tons of air pollution removed per square foot ($7.4630\text{x}10^{-7}$); $SAPP_i$ = Species tons of air pollution removed per tree

[a] Equation 25: $TTP \times (SPP_i/100) = SP_i$

[b] Equation 35: $(ATCSF \times (SPLA_i/100))/SP_i = SSFTCP_i$

[c] Equation 36: $\sum_{i=1}^{64} SP_i\, SSFTCP_i = EATCSF$

[d] Equation 38: $APP \times SSFTCP_i = SAPP_i$

Table 17: *Reduced Areas Benefits to Air Pollution*

		Equation					
		(40) [a]					
		Reduced area air pollution value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
1	Siberian Elm	-	-	-	-	-	-
2	White Mulberry	-	-	-	-	-	-
3	Cottonwood	14,500	16,916	36,249	42,291	72,499	84,582
4	Desert Olive	-	-	-	-	-	-
5	Desert Willow	28,462	33,205	71,154	83,013	142,308	166,026
6	Firethorn Spp	-	-	-	-	-	-
7	Velvet Ash	-	-	-	-	-	-
8	Honey Locust	19,667	22,945	49,168	57,362	98,335	114,724
9	Pinyon Pine	-	-	-	-	-	-
10	Austrian Pine	105,415	122,984	263,537	307,460	527,074	614,920
11	Tree of Heaven	-	-	-	-	-	-
12	Purpleleaf Plum	36,742	42,866	91,856	107,165	183,712	214,330

		Equation					
		(40) [a]					
		Reduced area air pollution value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
13	Callery Pear	-	-	-	-	-	-
14	Oriental Arborvitae	60,115	70,134	150,287	175,335	300,574	350,669
15	Other Species	-	-	-	-	-	-
16	Mimosa	61,388	71,619	153,470	179,048	306,939	358,096
17	Raywood Ash	-	-	-	-	-	-
18	Arizona Cypress	-	-	-	-	-	-
19	Ponderosa Pine	81,249	94,790	203,122	236,975	406,243	473,950
20	London Plane	-	-	-	-	-	-
21	White Ash	-	-	-	-	-	-
22	Common Crape Myrtle	-	-	-	-	-	-
23	Chinese Pistache	54,036	63,042	135,090	157,605	270,181	315,211
24	Chitalpa	-	-	-	-	-	-

		Equation					
		(40) [a]					
		Reduced area air pollution value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
25	Almond	6,134	7,157	15,336	17,892	30,672	35,784
26	Yucca Spp	-	-	-	-	-	-
27	Aleppo Pine	-	-	-	-	-	-
28	Chaste Tree	71,076	82,922	177,689	207,304	355,379	414,608
29	Crabapple	30,078	35,091	75,194	87,726	150,388	175,453
30	Texas Red Oak	4,902	5,718	12,254	14,296	24,508	28,592
31	Cherry Plum	5,544	6,468	13,861	16,171	27,721	32,342
32	Live Oak	14,870	17,348	37,174	43,370	74,348	86,740
33	Boxelder	17,545	20,469	43,862	51,172	87,723	102,344
34	Evergreen Ash	-	-	-	-	-	-
35	Apple Spp	82,030	95,702	205,075	239,254	410,149	478,508
36	Plum Spp	12,031	14,036	30,078	35,091	60,155	70,181
37	Sweet Cherry	7,009	8,177	17,523	20,443	35,046	40,887

Tree description		Equation					
		(40) [a]					
		Reduced area air pollution value ($)					
		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
38	Common Pear	84,359	98,419	210,898	246,047	421,796	492,095
39	Soapberry Spp	18,332	21,387	45,829	53,467	91,658	106,934
40	Pine Spp	8,110	9,461	20,275	23,654	40,549	47,307
41	Chir Pine	22,458	26,201	56,145	65,502	112,290	131,005
42	Soaptree Yucca	-	-	-	-	-	-
43	Leyland Cypress	-	-	-	-	-	-
44	Japanese Maple	9,126	10,647	22,814	26,617	45,629	53,234
45	Northern Red Oak	2,292	2,674	5,729	6,684	11,458	13,368
46	Chinese Elm	-	-	-	-	-	-
47	Freeman Maple	-	-	-	-	-	-
48	Northern Catalpa	-	-	-	-	-	-
49	Eastern Redbud	-	-	-	-	-	-
50	Hawthorn Spp	11,666	13,611	29,166	34,027	58,332	68,054

		Equation					
		(40) [a]					
		Reduced area air pollution value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
51	Russian Olive	-	-	-	-	-	-
52	Spindle Tree Spp	11,018	12,855	27,546	32,137	55,092	64,274
53	Swamp Privet Spp	-	-	-	-	-	-
54	Locust Spp	1,736	2,025	4,340	5,064	8,680	10,127
55	Chokeberry Spp	-	-	-	-	-	-
56	Blue Spruce	-	-	-	-	-	-
57	Scotch Pine	-	-	-	-	-	-
58	Texas Pistache	141,764	165,391	354,410	41,3478	708,820	826,957
59	Black Cottonwood	-	-	-	-	-	-
60	Black Locust	187,775	219,070	469,437	547,676	938,873	1,095,352
61	Ash Spp	-	-	-	-	-	-
62	Mexican Pinyon	25,666	29,944	64,166	74,860	128,331	149,720

		Equation					
		(40) [a]					
		Reduced area air pollution value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
63	Rocky Mountain Juniper	-	-	-	-	-	-
64	Goldenrain Tree	27,500	32,083	68,749	80,207	137,498	160,414

Note. $SAPP_i$ = Species tons of air pollution removed per tree; NS_i = Number of species; VAP = Value of air pollution ($3,005.46); $SYDMH_i$ = Species years during mature height; $RAAPV_i$ = Reduced area air pollution value

[a] Equation 40: $SAPP_i \times NS_i \times VAP \times SYDMH_i = RAAPV_i$

Table 18: *Tree Leaf Area*

Tree description		-	Equations (42) [a]	(43) [b]	(44) [c]
i	Common name	Species leaf area (ft^2)	Species price increase per square feet ($)	Species leaf area growth per year (ft^2)	Species price increase per year ($)
1	Siberian Elm	-	-	-	-
2	White Mulberry	-	-	-	-
3	Cottonwood	14,869	0.05	837	44.38
4	Desert Olive	-	-	-	-
5	Desert Willow	205	3.84	53	205.25
6	Firethorn Spp	-	-	-	-
7	Velvet Ash	-	-	-	-
8	Honey Locust	4,357	0.18	341	61.75
9	Pinyon Pine	-	-	-	-
10	Austrian Pine	989	0.80	38	30.24
11	Tree of Heaven	-	-	-	-
12	Purpleleaf Plum	134	5.88	21	124.62
13	Callery Pear	-	-	-	-
14	Oriental Arborvitae	2,360	0.33	312	104.24
15	Other Species	-	-	-	-
16	Mimosa	134	5.88	32	186.93
17	Raywood Ash	-	-	-	-
18	Arizona Cypress	-	-	-	-
19	Ponderosa Pine	1,054	0.75	61	45.92

Tree description		-	Equations		
			(42) [a]	(43) [b]	(44) [c]
i	Common name	Species leaf area (ft²)	Species price increase per square feet ($)	Species leaf area growth per year (ft^2)	Species price increase per year ($)
20	London Plane	-	-	-	-
21	White Ash	-	-	-	-
22	Common Crape Myrtle	-	-	-	-
23	Chinese Pistache	531	1.48	60	88.35
24	Chitalpa	-	-	-	-
25	Almond	281	2.80	25	70.54
26	Yucca Spp	-	-	-	-
27	Aleppo Pine	-	-	-	-
28	Chaste Tree	699	1.13	141	159.07
29	Crabapple	554	1.42	68	96.66
30	Texas Red Oak	4,726	0.17	333	55.64
31	Cherry Plum	205	3.85	23	90.27
32	Live Oak	4,726	0.17	409	68.24
33	Boxelder	4,217	0.19	449	83.91
34	Evergreen Ash	-	-	-	-
35	Apple Spp	554	1.42	68	96.66
36	Plum Spp	826	0.96	126	120.09
37	Sweet Cherry	939	0.84	143	120.45
38	Common Pear	613	1.29	89	114.64
39	Soapberry Spp	531	1.48	65	96.24

Tree description		-	Equations		
			(42) [a]	(43) [b]	(44) [c]
i	Common name	Species leaf area (ft^2)	Species price increase per square feet ($)	Species leaf area growth per year (ft^2)	Species price increase per year ($)
40	Pine Spp	4,161	0.19	154	29.23
41	Chir Pine	4,161	0.19	112	21.30
42	Soaptree Yucca	-	-	-	-
43	Leyland Cypress	-	-	-	-
44	Japanese Maple	1,892	0.42	232	96.76
45	Northern Red Oak	8,925	0.09	555	49.07
46	Chinese Elm	-	-	-	-
47	Freeman Maple	-	-	-	-
48	Northern Catalpa	-	-	-	-
49	Eastern Redbud	-	-	-	-
50	Hawthorn Spp	1,409	0.56	444	248.51
51	Russian Olive	-	-	-	-
52	Spindle Tree Spp	134	5.88	21	124.62
53	Swamp Privet Spp	-	-	-	-
54	Locust Spp	3,896	0.20	305	61.68
55	Chokeberry Spp	-	-	-	-
56	Blue Spruce	-	-	-	-
57	Scotch Pine	-	-	-	-
58	Texas Pistache	531	1.48	65	96.24

Tree description		-	Equations		
			(42) [a]	(43) [b]	(44) [c]
i	Common name	Species leaf area (ft^2)	Species price increase per square feet ($)	Species leaf area growth per year (ft^2)	Species price increase per year ($)
59	Black Cottonwood	-	-	-	-
60	Black Locust	827	0.95	86	82.05
61	Ash Spp	-	-	-	-
62	Mexican Pinyon	260	3.03	10	30.63
63	Rocky Mountain Juniper	-	-	-	-
64	Goldenrain Tree	1,383	0.57	102	58.17

Note. TPI = Tree price increase ($1,577.58); SLA_i = Species leaf area; PRF = Park reduction factor (0.5); $SPISF_i$ = Species price increase per square feet; $SYOMH_i$ = Species years old at mature height; $SYOP_i$ = Species years old at planting; $SLAG_i$ = Species leaf area growth per year; $SPIY_i$ = Species price increase per year

[a] Equation 42: $(TPI/SLA_i) \times PRF = SPISF_i$

[b] Equation 43: $(SLA_i - 20)/(SYOMH_i - SYOP_i) = SLAG_i$

[c] Equation 44: $SPISF_i \times SLAG_i = SPIY_i$

Table 19: *Reduced Areas Benefits to Property Values*

		Equation					
		(45) [a]					
		Species price increase for reduced area ($)					
Tree Description		10%		25%		50%	
i	Common Name	Low	High	Low	High	Low	High
1	Siberian Elm	-	-	-	-	-	-
2	White Mulberry	-	-	-	-	-	-
3	Cottonwood	109,650	127,926	274,126	319,814	548,252	639,628
4	Desert Olive	-	-	-	-	-	-
5	Desert Willow	989,092	1,153,941	2,472,730	2,884,851	4,945,459	5,769,703
6	Firethorn Spp	-	-	-	-	-	-
7	Velvet Ash	-	-	-	-	-	-
8	Honey Locust	304,814	355,617	762,036	889,042	1,524,072	1,778,084
9	Pinyon Pine	-	-	-	-	-	-
10	Austrian Pine	989,092	1,153,941	2,472,730	2,884,851	4,945,459	5,769,703
11	Tree of Heaven	-	-	-	-	-	-
12	Purpleleaf Plum	1,538,587	1,795,019	3,846,468	4,487,546	7,692,937	8,975,093

		Equation					
		(45) [a]					
		Species price increase for reduced area ($)					
Tree Description		10%		25%		50%	
i	Common Name	Low	High	Low	High	Low	High
13	Callery Pear	-	-	-	-	-	-
14	Oriental Arborvitae	2,692,528	3,141,282	6,731,320	7,853,206	13,462,639	15,706,412
15	Other Species	-	-	-	-	-	-
16	Mimosa	1,538,587	1,795,019	3,846,468	4,487,546	7,692,937	8,975,093
17	Raywood Ash	-	-	-	-	-	-
18	Arizona Cypress	-	-	-	-	-	-
19	Ponderosa Pine	989,092	1,153,941	2,472,730	2,884,851	4,945,459	5,769,703
20	London Plane	-	-	-	-	-	-
21	White Ash	-	-	-	-	-	-
22	Common Crape Myrtle	-	-	-	-	-	-
23	Chinese Pistache	682,613	796,381	1,706,532	1,990,954	3,413,063	3981,907
24	Chitalpa	-	-	-	-	-	-

Tree Description		Equation					
		(45) [a]					
		Species price increase for reduced area ($)					
		10%		25%		50%	
i	Common Name	Low	High	Low	High	Low	High
25	Almond	682,613	796,381	1,706,532	1,990,954	3,413,063	3981,907
26	Yucca Spp	-	-	-	-	-	-
27	Aleppo Pine	-	-	-	-	-	-
28	Chaste Tree	1,538,587	1,795,019	3,846,468	4,487,546	7,692,937	8,975,093
29	Crabapple	989,092	1,153,941	2,472,730	2,884,851	4,945,459	5,769,703
30	Texas Red Oak	384,647	448,755	961,617	1,121,887	1,923,234	2,243,773
31	Cherry Plum	989,092	1,153,941	2,472,730	2,884,851	4,945,459	5,769,703
32	Live Oak	384,647	448,755	961,617	1,121,887	1,923,234	2,243,773
33	Boxelder	682,613	796,381	1,706,532	1,990,954	3,413,063	3,981,907
34	Evergreen Ash	-	-	-	-	-	-
35	Apple Spp	989,092	1,153,941	2,472,730	2,884,851	4,945,459	5,769,703
36	Plum Spp	989,092	1,153,941	2,472,730	2,884,851	4,945,459	5,769,703
37	Sweet Cherry	682,613	796,381	1,706,532	1,990,954	3,413,063	3,981,907

		Equation					
		(45) [a]					
		Species price increase for reduced area ($)					
Tree Description		10%		25%		50%	
i	Common Name	Low	High	Low	High	Low	High
38	Common Pear	2,692,528	3,141,282	6,731,320	7,853,206	13,462,639	15,706,412
39	Soapberry Spp	682,613	796,381	1,706,532	1,990,954	3,413,063	3,981,907
40	Pine Spp	384,647	448,755	961,617	1,121,887	1,923,234	2,243,773
41	Chir Pine	384,647	448,755	961,617	1,121,887	1,923,234	2,243,773
42	Soaptree Yucca	-	-	-	-	-	-
43	Leyland Cypress	-	-	-	-	-	-
44	Japanese Maple	1,538,587	1,795,019	3,846,468	4,487,546	7,692,937	8,975,093
45	Northern Red Oak	247,273	288,485	618,182	721,213	1,236,365	1,442,426
46	Chinese Elm	-	-	-	-	-	-
47	Freeman Maple	-	-	-	-	-	-
48	Northern Catalpa	-	-	-	-	-	-
49	Eastern Redbud	-	-	-	-	-	-

Tree Description		Equation (45) [a] Species price increase for reduced area ($)					
		10%		25%		50%	
i	Common Name	Low	High	Low	High	Low	High
50	Hawthorn Spp	1,538,587	1,795,019	3,846,468	4,487,546	7,692,937	8,975,093
51	Russian Olive	-	-	-	-	-	-
52	Spindle Tree Spp	1,538,587	1,795,019	3,846,468	4,487,546	7,692,937	8,975,093
53	Swamp Privet Spp	-	-	-	-	-	-
54	Locust Spp	247,273	288,485	618,182	721,213	1,236,365	1,442,426
55	Chokeberry Spp	-	-	-	-	-	-
56	Blue Spruce	-	-	-	-	-	-
57	Scotch Pine	-	-	-	-	-	-
58	Texas Pistache	682,613	796,381	1,706,532	1,990,954	3,413,063	3,981,907
59	Black Cottonwood	-	-	-	-	-	-
60	Black Locust	989,092	1,153,941	2,472,730	2,884,851	4,945,459	5,769,703
61	Ash Spp	-	-	-	-	-	-

		Equation					
		(45) [a]					
		Species price increase for reduced area ($)					
Tree Description		10%		25%		50%	
i	Common Name	Low	High	Low	High	Low	High
62	Mexican Pinyon	1,538,587	1,795,019	3,846,468	4,487,546	7,692,937	8,975,093
63	Rocky Mountain Juniper	-	-	-	-	-	-
64	Goldenrain Tree	989,092	1,153,941	2,472,730	2,884,851	4,945,459	5,769,703

Note. TPI_i = Tree price increase ($1,577.58); NS_i = Number of species; PRF = Park reduction factor (0.5); $SPIRA_i$ = Species price increase for reduced area

[a] Equation 45: $TPI_i \times NS_i \times PRF = SPIRA_i$

Table 20: *Reduced Area Benefits for One Million British Thermal Units*

		Equation					
		(52) [a]					
		Reduced area one million British thermal units value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
1	Siberian Elm	-	-	-	-	-	-
2	White Mulberry	-	-	-	-	-	-
3	Cottonwood	-3,656.39	-4,265.79	-9,140.98	-10,664.48	-18,281.97	-21,328.96
4	Desert Olive	-	-	-	-	-	-
5	Desert Willow	-38,845.65	-45,319.93	-97,114.13	-113,299.82	-194,228.27	-226,599.65
6	Firethorn Spp	-	-	-	-	-	-
7	Velvet Ash	-	-	-	-	-	-
8	Honey Locust	-11,293.68	-13,175.96	-28,234.20	-32,939.90	-56,468.41	-65,879.81
9	Pinyon Pine	-	-	-	-	-	-
10	Austrian Pine	-50,572.64	-59,001.42	-126,431.61	-147,503.54	-252,863.22	-29,5007.09
11	Tree of Heaven	-	-	-	-	-	-
12	Purpleleaf Plum	-27,362.98	-31,923.47	-68,407.44	-79,808.68	-136,814.88	-159,617.36
13	Callery Pear	-	-	-	-	-	-
14	Oriental Arborvitae	-107,741.72	-125,698.67	-269,354.30	-314,246.68	-538,708.59	-628,493.36
15	Other Species	-	-	-	-	-	-
16	Mimosa	-29,643.22	-34,583.76	-74,108.06	-86,459.40	-148,216.12	-172,918.81
17	Raywood Ash	-	-	-	-	-	-
18	Arizona Cypress	-	-	-	-	-	-
19	Ponderosa Pine	-57,169.08	-66,697.25	-142,922.69	-166,743.14	-285,845.38	-333,486.27
20	London Plane	-	-	-	-	-	-
21	White Ash	-	-	-	-	-	-

Tree description		Equation					
		(52) [a]					
		Reduced area one million British thermal units value ($)					
		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
22	Common Crape Myrtle	-	-	-	-	-	-
23	Chinese Pistache	-41,478.03	-48,391.04	-103,695.08	-120,977.59	-207,390.16	-241,955.19
24	Chitalpa	-	-	-	-	-	-
25	Almond	-24,279.82	-28,326.46	-60,699.56	-70,816.15	-121,399.12	-141,632.31
26	Yucca Spp	-	-	-	-	-	-
27	Aleppo Pine	-	-	-	-	-	-
28	Chaste Tree	-61,566.70	-71,827.81	-153,916.74	-179,569.53	-307,833.48	-359,139.06
29	Crabapple	-38,479.19	-44,892.38	-96,197.96	-112,230.96	-192,395.93	-224,461.91
30	Texas Red Oak	-13,681.49	-15,961.74	-34,203.72	-39,904.34	-68,407.44	-79,808.68
31	Cherry Plum	-16,491.08	-19,239.59	-41,227.70	-48,098.98	-82,455.40	-96,197.96
32	Live Oak	-22,659.96	-26,436.63	-56,649.91	-66,091.56	-113,299.82	-132,183.13
33	Boxelder	-26,303.14	-30,687.00	-65,757.86	-76,717.50	-131,515.71	-153,435.00
34	Evergreen Ash	-	-	-	-	-	-
35	Apple Spp	-38,479.19	-44,892.38	-96,197.96	-112,230.96	-192,395.93	-224,461.91
36	Plum Spp	-36,280.37	-42,327.10	-90,700.94	-105,817.76	-181,401.87	-211,635.52
37	Sweet Cherry	-11,381.17	-13,278.03	-28,452.92	-33,195.07	-56,905.84	-66,390.14
38	Common Pear	-104,748.89	-122,207.04	-261,872.23	-305,517.60	-523,744.47	-611,035.21
39	Soapberry Spp	-25,797.31	-30,096.87	-64,493.28	-75,242.16	-128,986.56	-150,484.33
40	Pine Spp	-11,971.30	-13,966.52	-29,928.26	-34,916.30	-59,856.51	-69,832.60
41	Chir Pine	-10,261.12	-11,971.30	-25,652.79	-29,928.26	-51,305.58	-59,856.51
42	Soaptree Yucca	-	-	-	-	-	-

		Equation					
		(52) [a]					
		Reduced area one million British thermal units value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
43	Leyland Cypress	-	-	-	-	-	-
44	Japanese Maple	-54,725.95	-63,846.94	-136,814.88	-159,617.36	-273,629.76	-319,234.72
45	Northern Red Oak	-13,742.57	-16,032.99	-34,356.42	-40,082.48	-68,712.83	-80,164.97
46	Chinese Elm	-	-	-	-	-	-
47	Freeman Maple	-	-	-	-	-	-
48	Northern Catalpa	-	-	-	-	-	-
49	Eastern Redbud	-	-	-	-	-	-
50	Hawthorn Spp	-61,566.70	-71,827.81	-153,916.74	-179,569.53	-307,833.48	-359,139.06
51	Russian Olive	-	-	-	-	-	-
52	Spindle Tree Spp	-58,146.32	-67,837.38	-145,365.81	-169,593.45	-290,731.62	-339,186.89
53	Swamp Privet Spp	-	-	-	-	-	-
54	Locust Spp	-9,161.71	-10,688.66	-22,904.28	-26,721.66	-45,808.55	-53,443.31
55	Chokeberry Spp	-	-	-	-	-	-
56	Blue Spruce	-	-	-	-	-	-
57	Scotch Pine	-	-	-	-	-	-
58	Texas Pistache	-25,797.31	-30,096.87	-64,493.28	-75,242.16	-128,986.56	-150,484.33
59	Black Cottonwood	-	-	-	-	-	-
60	Black Locust	-38,112.72	-44,464.84	-95,281.79	-111,162.09	-190,563.58	-222,324.18
61	Ash Spp	-	-	-	-	-	-
62	Mexican Pinyon	-82,088.93	-95,770.42	-205,222.32	-239,426.04	-410,444.64	-478,852.08
63	Rocky Mountain Juniper	-	-	-	-	-	-

		Equation					
		(52) [a]					
		Reduced area one million British thermal units value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
64	Goldenrain Tree	-32,982.16	-38,479.19	-82,455.40	-96,197.96	-164,910.79	-192,395.93

Note. VMBTUPT = Value of one million British thermal units per tree; NS_i = Number of species; $SYDMH_i$ = Species years during mature height; $RAMBTUV_i$ = Reduced area one million British thermal units value

[a] Equation 52: $(VMBTUPT \times NS_i) \times SYDMH_i = RAMBTUV_i$

Table 21: *Reduced Areas Benefits for Megawatt Hours*

		Equation					
		(53) [a]					
		Reduced area megawatt hour value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
1	Siberian Elm	-	-	-	-	-	-
2	White Mulberry	-	-	-	-	-	-
3	Cottonwood	26,614.45	31,050.19	66,536.13	77,625.49	133,072.26	155,250.97
4	Desert Olive	-	-	-	-	-	-
5	Desert Willow	282,752.91	329,878.39	706,882.26	824,695.97	1,413,764.53	1,649,391.95
6	Firethorn Spp	-	-	-	-	-	-
7	Velvet Ash	-	-	-	-	-	-
8	Honey Locust	82,205.37	95,906.26	205,513.41	239,765.65	411,026.83	479,531.30
9	Pinyon Pine	-	-	-	-	-	-
10	Austrian Pine	368,112.27	429,464.32	920,280.68	1,073,660.80	1,840,561.37	2,147,321.59
11	Tree of Heaven	-	-	-	-	-	-
12	Purpleleaf Plum	199,171.86	232,367.17	497,929.64	580,917.92	995,859.29	1,161,835.84
13	Callery Pear	-	-	-	-	-	-
14	Oriental Arborvitae	784,239.19	914,945.72	1,960,597.98	2,287,364.31	3,921,195.95	4,574,728.61
15	Other Species	-	-	-	-	-	-

		Equation					
		(53) [a]					
		Reduced area megawatt hour value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
16	Mimosa	215,769.51	251,731.10	539,423.78	629,327.75	1,078,847.56	1,258,655.49
17	Raywood Ash	-	-	-	-	-	-
18	Arizona Cypress	-	-	-	-	-	-
19	Ponderosa Pine	416,126.92	485,481.40	1,040,317.29	1,213,703.51	2,080,634.59	2,427,407.02
20	London Plane	-	-	-	-	-	-
21	White Ash	-	-	-	-	-	-
22	Common Crape Myrtle	-	-	-	-	-	-
23	Chinese Pistache	301,913.68	352,232.63	754,784.20	880,581.56	1,509,568.40	1,761,163.13
24	Chitalpa	-	-	-	-	-	-
25	Almond	176,729.96	206,184.95	441,824.90	515,462.38	883,649.79	1,030,924.76
26	Yucca Spp	-	-	-	-	-	-
27	Aleppo Pine	-	-	-	-	-	-
28	Chaste Tree	448,136.68	522,826.13	1,120,341.70	1,307,065.32	2,240,683.40	2,614,130.64
29	Crabapple	280,085.43	326,766.33	700,213.56	816,915.82	1,400,427.13	1,633,831.65
30	Texas Red Oak	99,585.93	116,183.58	248,964.82	290,458.96	497,929.64	580,917.92
31	Cherry Plum	120,036.61	140,042.71	300,091.53	350,106.78	600,183.05	700,213.56

		Equation					
		(53) [a]					
		Reduced area megawatt hour value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
32	Live Oak	164,939.19	192,429.06	412,347.99	481,072.65	824,695.97	962,145.30
33	Boxelder	191,457.46	223,367.03	478,643.64	558,417.58	957,287.28	1,116,835.15
34	Evergreen Ash	-	-	-	-	-	-
35	Apple Spp	280,085.43	326,766.33	700,213.56	816,915.82	1,400,427.13	1,633,831.65
36	Plum Spp	264,080.54	308,093.97	660,201.36	770,234.92	1,320,402.72	1,540,469.84
37	Sweet Cherry	82,842.17	96,649.20	207,105.42	241,622.99	414,210.84	483,245.98
38	Common Pear	762,454.77	889,530.56	1,906,136.92	2,223,826.41	3,812,273.84	4,447,652.82
39	Soapberry Spp	187,775.58	219,071.51	469,438.95	547,678.78	938,877.90	1,095,357.56
40	Pine Spp	87,137.69	101,660.64	217,844.22	254,151.59	435,688.44	508,303.18
41	Chir Pine	74,689.45	87,137.69	186,723.62	217,844.22	373,447.23	435,688.44
42	Soaptree Yucca	-	-	-	-	-	-
43	Leyland Cypress	-	-	-	-	-	-
44	Japanese Maple	398,343.72	464,734.34	995,859.29	1,161,835.84	1,991,718.58	2,323,671.68
45	Northern Red Oak	100,030.51	116,702.26	250,076.27	291,755.65	500,152.55	583,511.30
46	Chinese Elm	-	-	-	-	-	-
47	Freeman Maple	-	-	-	-	-	-

		Equation					
		(53) [a]					
		Reduced area megawatt hour value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
48	Northern Catalpa	-	-	-	-	-	-
49	Eastern Redbud	-	-	-	-	-	-
50	Hawthorn Spp	448,136.68	522,826.13	1,120,341.70	1,307,065.32	2,240,683.40	2,614,130.64
51	Russian Olive	-	-	-	-	-	-
52	Spindle Tree Spp	423,240.20	493,780.23	1,058,100.50	1,234,450.58	2,116,200.99	2,468,901.16
53	Swamp Privet Spp	-	-	-	-	-	-
54	Locust Spp	66,687.01	77,801.51	166,717.52	194,503.77	333,435.03	389,007.54
55	Chokeberry Spp	-	-	-	-	-	-
56	Blue Spruce	-	-	-	-	-	-
57	Scotch Pine	-	-	-	-	-	-
58	Texas Pistache	187,775.58	219,071.51	469,438.95	547,678.78	938,877.90	1,095,357.56
59	Black Cottonwood	-	-	-	-	-	-
60	Black Locust	277,417.95	323,654.27	693,544.86	809,135.67	1,387,089.73	1,618,271.35
61	Ash Spp	-	-	-	-	-	-

Tree description		Equation (53) [a] Reduced area megawatt hour value ($) 10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
62	Mexican Pinyon	597,515.57	697,101.50	1,493,788.93	1,742,753.76	2,987,577.87	3,485,507.51
63	Rocky Mountain Juniper	-	-	-	-	-	-
64	Goldenrain Tree	240,073.22	280,085.43	600,183.05	700,213.56	1,200,366.11	1,400,427.13

Note. VMWHPT = Value of megawatt hour per tree; NS_i = Number of species; $SYDMH_i$ = Species years during mature height; $RAMWHV_i$ = Reduced area megawatt hour value

[a] Equation 53: $(VMWHPT \times NS_i) \times SYDMH_i = RAMWHV_i$

Table 22: *Reduced Areas Benefits for Carbon Avoided*

		Equation					
		(54) [a]					
		Reduced area carbon avoided value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
1	Siberian Elm	-	-	-	-	-	-
2	White Mulberry	-	-	-	-	-	-
3	Cottonwood	3,103.64	3,620.91	7,759.10	9,052.28	15,518.19	18,104.56
4	Desert Olive	-	-	-	-	-	-
5	Desert Willow	32,973.16	38,468.69	82,432.91	96,171.73	164,865.82	192,343.45
6	Firethorn Spp	-	-	-	-	-	-
7	Velvet Ash	-	-	-	-	-	-
8	Honey Locust	9,586.36	11,184.09	23,965.90	27,960.21	47,931.80	55,920.43
9	Pinyon Pine	-	-	-	-	-	-
10	Austrian Pine	42,927.33	50,081.88	107,318.31	125,204.70	214,636.63	250,409.40
11	Tree of Heaven	-	-	-	-	-	-
12	Purpleleaf Plum	23,226.38	27,097.44	58,065.95	67,743.61	116,131.90	135,487.21
13	Callery Pear	-	-	-	-	-	-
14	Oriental Arborvitae	91,453.87	106,696.18	228,634.67	266,740.45	457,269.34	533,480.90
15	Other Species	-	-	-	-	-	-
16	Mimosa	25,161.91	29,355.56	62,904.78	73,388.91	125,809.55	146,777.81
17	Raywood Ash	-	-	-	-	-	-
18	Arizona Cypress	-	-	-	-	-	-
19	Ponderosa Pine	48,526.54	56,614.30	121,316.36	141,535.75	242,632.71	283,071.50

Tree description		Equation (54) [a] Reduced area carbon avoided value ($)					
		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
20	London Plane	-	-	-	-	-	-
21	White Ash	-	-	-	-	-	-
22	Common Crape Myrtle	-	-	-	-	-	-
23	Chinese Pistache	35,207.59	41,075.52	88,018.98	102,688.81	176,037.96	205,377.62
24	Chitalpa	-	-	-	-	-	-
25	Almond	20,609.32	24,044.21	51,523.31	60,110.52	103,046.61	120,221.05
26	Yucca Spp	-	-	-	-	-	-
27	Aleppo Pine	-	-	-	-	-	-
28	Chaste Tree	52,259.35	60,969.25	130,648.38	152,423.11	261,296.77	304,846.23
29	Crabapple	32,662.10	38,105.78	81,655.24	95,264.45	163,310.48	190,528.89
30	Texas Red Oak	11,613.19	13,548.72	29,032.97	33,871.80	58,065.95	67,743.61
31	Cherry Plum	13,998.04	16,331.05	34,995.10	40,827.62	69,990.20	81,655.24
32	Live Oak	19,234.35	22,440.07	48,085.86	56,100.17	96,171.73	112,200.35
33	Boxelder	22,326.77	26,047.89	55,816.91	65,119.73	111,633.83	130,239.47
34	Evergreen Ash	-	-	-	-	-	-
35	Apple Spp	32,662.10	38,105.78	81,655.24	95,264.45	163,310.48	190,528.89
36	Plum Spp	30,795.69	35,928.31	76,989.23	89,820.76	153,978.45	179,641.53
37	Sweet Cherry	9,660.62	11,270.72	24,151.55	28,176.81	483,03.10	56,353.62
38	Common Pear	88,913.48	103,732.40	222,283.71	259,330.99	444,567.41	518,661.98
39	Soapberry Spp	21,897.40	25,546.97	54,743.51	63,867.43	109,487.02	127,734.86
40	Pine Spp	10,161.54	11,855.13	25,403.85	29,637.83	50,807.70	59,275.66

		Equation					
		(54) [a]					
		Reduced area carbon avoided value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
41	Chir Pine	8,709.89	10,161.54	21,774.73	25,403.85	43,549.46	50,807.70
42	Soaptree Yucca	-	-	-	-	-	-
43	Leyland Cypress	-	-	-	-	-	-
44	Japanese Maple	46,452.76	54,194.88	116,131.90	135,487.21	232,263.79	270,974.42
45	Northern Red Oak	11,665.03	13,609.21	29,162.59	34,023.02	58,325.17	68,046.03
46	Chinese Elm	-	-	-	-	-	-
47	Freeman Maple	-	-	-	-	-	-
48	Northern Catalpa	-	-	-	-	-	-
49	Eastern Redbud	-	-	-	-	-	-
50	Hawthorn Spp	52,259.35	60,969.25	130,648.38	152,423.11	261,296.77	304,846.23
51	Russian Olive	-	-	-	-	-	-
52	Spindle Tree Spp	49,356.06	57,582.06	123,390.14	143,955.16	246,780.28	287,910.32
53	Swamp Privet Spp	-	-	-	-	-	-
54	Locust Spp	7,776.69	9,072.80	194,41.72	22,682.01	38,883.45	45,364.02
55	Chokeberry Spp	-	-	-	-	-	-
56	Blue Spruce	-	-	-	-	-	-
57	Scotch Pine	-	-	-	-	-	-
58	Texas Pistache	21,897.40	25,546.97	54,743.51	63,867.43	109,487.02	127,734.86

Tree description		Equation					
		(54) [a] Reduced area carbon avoided value ($)					
		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
59	Black Cottonwood	-	-	-	-	-	-
60	Black Locust	32,351.03	37,742.87	80,877.57	94,357.17	161,755.14	188,714.33
61	Ash Spp	-	-	-	-	-	-
62	Mexican Pinyon	69,679.14	81,292.33	174,197.84	203,230.82	348,395.69	406,461.63
63	Rocky Mountain Juniper	-	-	-	-	-	-
64	Goldenrain Tree	27,996.08	32,662.10	69,990.20	81,655.24	139,980.41	163,310.48

Note. VCAPT = Value of carbon avoided per tree; NS_i = Number of species; $SYDMH_i$ = Species years during mature height; $RACAV_i$ = Reduced area carbon avoided value.

[a] Equation 54: $(VCAPT \times NS_i) \times SYDMH_i = RACAV_i$

Table 23: *Reduced Areas Benefits for Energy Use*

		Equation					
		(55) [a]					
		Total reduced area energy value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
1	Siberian Elm	-	-	-	-	-	-
2	White Mulberry	-	-	-	-	-	-
3	Cottonwood	26,061.70	30,405.31	65,154.24	76,013.28	130,308.49	152,026.57
4	Desert Olive	-	-	-	-	-	-
5	Desert Willow	276,880.42	323,027.15	692,201.04	807,567.88	1,384,402.08	1,615,135.75
6	Firethorn Spp	-	-	-	-	-	-
7	Velvet Ash	-	-	-	-	-	-
8	Honey Locust	80,498.04	93,914.38	201,245.11	234,785.96	402,490.22	469,571.92
9	Pinyon Pine	-	-	-	-	-	-
10	Austrian Pine	360,466.96	420,544.78	901,167.39	1,051,361.95	1,802,334.78	2,102,723.91
11	Tree of Heaven	-	-	-	-	-	-
12	Purpleleaf Plum	195,035.26	227,541.14	487,588.15	568,852.84	975,176.30	1,137,705.69
13	Callery Pear	-	-	-	-	-	-
14	Oriental Arborvitae	767,951.34	895,943.23	1,919,878.35	2,239,858.07	3,839,756.70	4,479,716.15
15	Other Species	-	-	-	-	-	-
16	Mimosa	211,288.20	246,502.90	528,220.50	616,257.25	1,056,441.00	1,232,514.50
17	Raywood Ash	-	-	-	-	-	-
18	Arizona Cypress	-	-	-	-	-	-
19	Ponderosa Pine	407,484.38	475,398.45	1,018,710.96	1,188,496.12	2,037,421.92	2,376,992.24
20	London Plane	-	-	-	-	-	-
21	White Ash	-	-	-	-	-	-

		Equation					
		(55) [a]					
		Total reduced area energy value ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
22	Common Crape Myrtle	-	-	-	-	-	-
23	Chinese Pistache	295,643.24	344,917.11	739,108.10	862,292.78	1,478,216.19	1,724,585.56
24	Chitalpa	-	-	-	-	-	-
25	Almond	173,059.46	201,902.70	432,648.64	504,756.75	865,297.28	1,009,513.50
26	Yucca Spp	-	-	-	-	-	-
27	Aleppo Pine	-	-	-	-	-	-
28	Chaste Tree	438,829.34	511,967.56	1,097,073.34	1,279,918.90	2,194,146.69	2,559,837.80
29	Crabapple	274,268.34	319,979.72	685,670.84	799,949.31	1,371,341.68	1,599,898.62
30	Texas Red Oak	97,517.63	113,770.57	243,794.08	284,426.42	487,588.15	568,852.84
31	Cherry Plum	117,543.57	137,134.17	293,858.93	342,835.42	587,717.86	685,670.84
32	Live Oak	161,513.58	188,432.50	403,783.94	471,081.26	807,567.88	942,162.52
33	Boxelder	187,481.08	218,727.92	468,702.70	546,819.81	937,405.39	1,093,639.62
34	Evergreen Ash	-	-	-	-	-	-
35	Apple Spp	274,268.34	319,979.72	685,670.84	799,949.31	1,371,341.68	1,599,898.62
36	Plum Spp	258,595.86	301,695.17	646,489.65	754,237.92	1,292,979.30	1,508,475.85
37	Sweet Cherry	81,121.62	94,641.89	202,804.05	236,604.73	405,608.10	473,209.45
38	Common Pear	746,619.36	871,055.92	1,866,548.40	2,177,639.80	3,733,096.79	4,355,279.59
39	Soapberry Spp	183,875.67	214,521.62	459,689.18	536,304.05	919,378.36	1,072,608.09
40	Pine Spp	85,327.93	99,549.25	213,319.82	248,873.12	426,639.63	497,746.24
41	Chir Pine	73,138.22	85,327.93	182,845.56	213,319.82	365,691.11	426,639.63
42	Soaptree Yucca	-	-	-	-	-	-
43	Leyland Cypress	-	-	-	-	-	-

Tree description		Equation (55) [a] Total reduced area energy value ($)					
		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
44	Japanese Maple	390,070.52	455,082.28	975,176.30	1,137,705.69	1,950,352.61	2,275,411.38
45	Northern Red Oak	97,952.98	114,278.47	244,882.44	285,696.18	489,764.89	571,392.37
46	Chinese Elm	-	-	-	-	-	-
47	Freeman Maple	-	-	-	-	-	-
48	Northern Catalpa	-	-	-	-	-	-
49	Eastern Redbud	-	-	-	-	-	-
50	Hawthorn Spp	438,829.34	511,967.56	1,097,073.34	1,279,918.90	2,194,146.69	2,559,837.80
51	Russian Olive	-	-	-	-	-	-
52	Spindle Tree Spp	414,449.93	483,524.92	1,036,124.82	1,208,812.29	2,072,249.65	2,417,624.59
53	Swamp Privet Spp	-	-	-	-	-	-
54	Locust Spp	65,301.98	76,185.65	163,254.96	190,464.12	326,509.92	380,928.24
55	Chokeberry Spp	-	-	-	-	-	-
56	Blue Spruce	-	-	-	-	-	-
57	Scotch Pine	-	-	-	-	-	-
58	Texas Pistache	183,875.67	214,521.62	459,689.18	536,304.05	919,378.36	1,072,608.09
59	Black Cottonwood	-	-	-	-	-	-
60	Black Locust	271,656.26	316,932.30	679,140.64	792,330.75	1,358,281.28	1,584,661.50
61	Ash Spp	-	-	-	-	-	-
62	Mexican Pinyon	585,105.78	682,623.41	1,462,764.46	1,706,558.53	2,925,528.91	3,413,117.07
63	Rocky Mountain Juniper	-	-	-	-	-	-
64	Goldenrain Tree	235,087.14	274,268.34	587,717.86	685,670.84	1,175,435.72	1,371,341.68

Note. $RAMBTUV_i$ = Reduced area one million British thermal units value; $RAMWHV_i$ = Reduced area megawatt hour value; $RACAV_i$ = Reduced area carbon avoided value; $TRAEV_i$ = Total reduced area energy value.

[a] Equation 55: $RAMBTUV_i + RAMWHV_i + RACAV_i = TRAEV_i$

Table 24: *Reduced Areas Maintenance Cost*

		Equation					
		(56) [a]					
		Maintenance cost for area reduced ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
1	Siberian Elm	-	-	-	-	-	-
2	White Mulberry	-	-	-	-	-	-
3	Cottonwood	270,237.43	315,277.01	675,593.58	788,192.51	1,351,187.17	1,576,385.03
4	Desert Olive	-	-	-	-	-	-
5	Desert Willow	2,412,795.98	2,814,928.65	6,031,989.96	7,037,321.62	12,063,979.92	14,074,643.24
6	Firethorn Spp	-	-	-	-	-	-
7	Velvet Ash	-	-	-	-	-	-
8	Honey Locust	777,953.02	907,611.85	1,944,882.54	2,269,029.63	3,889,765.09	4,538,059.27
9	Pinyon Pine	-	-	-	-	-	-
10	Austrian Pine	3,694,075.49	4,309,754.74	9,235,188.73	10,774,386.85	18,470,377.46	21,548,773.71
11	Tree of Heaven	-	-	-	-	-	-
12	Purpleleaf Plum	1,855,575.15	2,164,837.68	4,638,937.88	5,412,094.20	9,277,875.77	10,824,188.39
13	Callery Pear	-	-	-	-	-	-
14	Oriental Arborvitae	6,976,050.65	8,138,725.76	17,440,126.63	20,346,814.40	34,880,253.25	40,693,628.79
15	Other Species	-	-	-	-	-	-
16	Mimosa	1,918,449.72	2,238,191.34	4,796,124.30	5,595,478.35	9,592,248.61	11,190,956.71
17	Raywood Ash	-	-	-	-	-	-
18	Arizona Cypress	-	-	-	-	-	-
19	Ponderosa Pine	3,859,650.92	4,502,926.07	9,649,127.29	11,257,315.18	19,298,254.59	22,514,630.35
20	London Plane	-	-	-	-	-	-

		Equation					
		(56) [a]					
		Maintenance cost for area reduced ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
21	White Ash	-	-	-	-	-	-
22	Common Crape Myrtle	-	-	-	-	-	-
23	Chinese Pistache	2,634,789.24	3,073,920.78	6,586,973.10	7,684,801.96	13,173,946.21	15,369,603.91
24	Chitalpa	-	-	-	-	-	-
25	Almond	1,639,488.10	1,912,736.11	4,098,720.24	4,781,840.28	8,197,440.49	9,563,680.57
26	Yucca Spp	-	-	-	-	-	-
27	Aleppo Pine	-	-	-	-	-	-
28	Chaste Tree	3,876,492.53	4,522,574.62	9,691,231.32	11,306,436.55	19,382,462.65	22,612,873.09
29	Crabapple	2,506,448.45	2,924,189.85	6,266,121.11	7,310,474.63	12,532,242.23	14,620,949.27
30	Texas Red Oak	961,963.61	1,122,290.87	2,404,909.01	2,805,727.18	4,809,818.03	5,611,454.36
31	Cherry Plum	1,192,869.74	1,391,681.36	2,982,174.35	3,479,203.41	5,964,348.71	6,958,406.82
32	Live Oak	1,471,923.02	1,717,243.52	3,679,807.54	4,293,108.80	7,359,615.08	8,586,217.60
33	Boxelder	1,741,711.80	2,031,997.10	4,354,279.50	5,079,992.75	8,708,559.00	10,159,985.50
34	Evergreen Ash	-	-	-	-	-	-
35	Apple Spp	2,506,448.45	2,924,189.85	6,266,121.11	7,310,474.63	12,532,242.23	14,620,949.27
36	Plum Spp	2,336,767.27	2,726,228.48	5,841,918.16	6,815,571.19	11,683,836.33	13,631,142.38
37	Sweet Cherry	796,458.57	929,201.66	1,991,146.42	2,323,004.16	3,982,292.85	4,646,008.32
38	Common Pear	6,736,575.73	7,859,338.35	16,841,439.31	19,648,345.87	33,682,878.63	39,296,691.73
39	Soapberry Spp	1,684,850.62	1,965,659.06	4,212,126.56	4,914,147.65	8,424,253.12	9,828,295.30
40	Pine Spp	989,925.64	1,154,913.25	2,474,814.11	2,887,283.12	4,949,628.21	5,774,566.25
41	Chir Pine	989,925.64	1,154,913.25	2,474,814.11	2,887,283.12	4,949,628.21	5,774,566.25

Tree description		Equation (56) [a] Maintenance cost for area reduced ($)					
		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
42	Soaptree Yucca	-	-	-	-	-	-
43	Leyland Cypress	-	-	-	-	-	-
44	Japanese Maple	3,600,493.89	4,200,576.20	9,001,234.72	10,501,440.50	18,002,469.43	21,002,881.00
45	Northern Red Oak	926,723.60	1,081,177.53	2,316,808.99	2,702,943.83	4,633,617.99	5,405,887.65
46	Chinese Elm	-	-	-	-	-	-
47	Freeman Maple	-	-	-	-	-	-
48	Northern Catalpa	-	-	-	-	-	-
49	Eastern Redbud	-	-	-	-	-	-
50	Hawthorn Spp	3,807,484.18	4,442,064.87	9,518,710.44	11,105,162.18	19,037,420.88	22,210,324.36
51	Russian Olive	-	-	-	-	-	-
52	Spindle Tree Spp	3,695,354.12	4,311,246.48	9,238,385.31	10,778,116.20	18,476,770.62	21,556,232.39
53	Swamp Privet Spp	-	-	-	-	-	-
54	Locust Spp	631,149.94	736,341.60	1,577,874.85	1,840,853.99	3,155,749.71	3,681,707.99
55	Chokeberry Spp	-	-	-	-	-	-
56	Blue Spruce	-	-	-	-	-	-
57	Scotch Pine	-	-	-	-	-	-
58	Texas Pistache	1,684,850.62	1,965,659.06	4,212,126.56	4,914,147.65	8,424,253.12	9,828,295.30
59	Black Cottonwood	-	-	-	-	-	-
60	Black Locust	2,524,378.16	2,945,107.85	6,310,945.39	7,362,769.63	12,621,890.79	14,725,539.25
61	Ash Spp	-	-	-	-	-	-
62	Mexican Pinyon	5,878,139.10	6,857,828.95	14,695,347.76	17,144,572.38	29,390,695.51	34,289,144.77

		Equation					
		(56) [a]					
		Maintenance cost for area reduced ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
63	Rocky Mountain Juniper	-	-	-	-	-	-
64	Goldenrain Tree	2,322,403.20	2,709,470.40	5,806,007.99	6,773,675.99	11,612,015.98	13,547,351.98

Note. MC = Maintenance cost per tree per year ($20.96); SLS_i = Species life span; $SYOP_i$ = Species years old at planting; NS_i = Number of species; $MCAR_i$ = Maintenance cost for area reduced.

[a] Equation 56: $MC \times (SLS_i - SYOP_i) \times NS_i = MCAR_i$

Table 25: *Reduced Areas Planting Cost*

Tree description		Equation (57) [a] Planting cost area reduced ($) 10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
1	Siberian Elm	-	-	-	-	-	-
2	White Mulberry	-	-	-	-	-	-
3	Cottonwood	34,405.30	40,139.52	86,013.25	100,348.79	172,026.50	200,697.58
4	Desert Olive	-	-	-	-	-	-
5	Desert Willow	310,349.85	362,074.82	775,874.62	905,187.05	1,551,749.23	1,810,374.11
6	Firethorn Spp	-	-	-	-	-	-
7	Velvet Ash	-	-	-	-	-	-
8	Honey Locust	95,642.41	111,582.81	239,106.01	278,957.02	478,212.03	557,914.03
9	Pinyon Pine	-	-	-	-	-	-
10	Austrian Pine	310,349.85	362,074.82	775,874.62	905,187.05	1,551,749.23	1,810,374.11
11	Tree of Heaven	-	-	-	-	-	-
12	Purpleleaf Plum	482,766.43	563,227.50	1,206,916.07	1,408,068.75	2,413,832.14	2,816,137.50
13	Callery Pear	-	-	-	-	-	-
14	Oriental Arborvitae	844,841.25	985,648.13	2,112,103.13	2,464,120.31	4,224,206.25	4,928,240.63
15	Other Species	-	-	-	-	-	-
16	Mimosa	482,766.43	563,227.50	1,206,916.07	1,408,068.75	2,413,832.14	2,816,137.50
17	Raywood Ash	-	-	-	-	-	-
18	Arizona Cypress	-	-	-	-	-	-
19	Ponderosa Pine	310,349.85	362,074.82	775,874.62	905,187.05	1,551,749.23	1,810,374.11
20	London Plane	-	-	-	-	-	-
21	White Ash	-	-	-	-	-	-

		Equation					
		(57) [a]					
		Planting cost area reduced ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
22	Common Crape Myrtle	-	-	-	-	-	-
23	Chinese Pistache	214,185.11	249,882.62	535,462.76	624,706.56	1,070,925.53	1,249,413.12
24	Chitalpa	-	-	-	-	-	-
25	Almond	214,185.11	249,882.62	535,462.76	624,706.56	1,070,925.53	1,249,413.12
26	Yucca Spp	-	-	-	-	-	-
27	Aleppo Pine	-	-	-	-	-	-
28	Chaste Tree	482,766.43	563,227.50	1,206,916.07	1,408,068.75	2,413,832.14	2,816,137.50
29	Crabapple	310,349.85	362,074.82	775,874.62	905,187.05	1,551,749.23	1,810,374.11
30	Texas Red Oak	120,691.61	140,806.88	301,729.02	352,017.19	603,458.04	704,034.38
31	Cherry Plum	310,349.85	362,074.82	775,874.62	905,187.05	1,551,749.23	1,810,374.11
32	Live Oak	120,691.61	140,806.88	301,729.02	352,017.19	603,458.04	704,034.38
33	Boxelder	214,185.11	249,882.62	535,462.76	624,706.56	1,070,925.53	1,249,413.12
34	Evergreen Ash	-	-	-	-	-	-
35	Apple Spp	310,349.85	362,074.82	775,874.62	905,187.05	1,551,749.23	1,810,374.11
36	Plum Spp	310,349.85	362,074.82	775,874.62	905,187.05	1,551,749.23	1,810,374.11
37	Sweet Cherry	214,185.11	249,882.62	535,462.76	624,706.56	1,070,925.53	1,249,413.12
38	Common Pear	844,841.25	985,648.13	2,112,103.13	2,464,120.31	4,224,206.25	4,928,240.63
39	Soapberry Spp	214,185.11	249,882.62	535,462.76	624,706.56	1,070,925.53	1,249,413.12
40	Pine Spp	120,691.61	140,806.88	301,729.02	352,017.19	603,458.04	704,034.38
41	Chir Pine	120,691.61	140,806.88	301,729.02	352,017.19	603,458.04	704,034.38
42	Soaptree Yucca	-	-	-	-	-	-
43	Leyland Cypress	-	-	-	-	-	-

Tree description		Equation (57) [a] Planting cost area reduced ($)					
		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
44	Japanese Maple	482,766.43	563,227.50	1,206,916.07	1,408,068.75	2,413,832.14	2,816,137.50
45	Northern Red Oak	77,587.46	90,518.71	193,968.65	226,296.76	387,937.31	452,593.53
46	Chinese Elm	-	-	-	-	-	-
47	Freeman Maple	-	-	-	-	-	-
48	Northern Catalpa	-	-	-	-	-	-
49	Eastern Redbud	-	-	-	-	-	-
50	Hawthorn Spp	482,766.43	563,227.50	1,206,916.07	1,408,068.75	2,413,832.14	2,816,137.50
51	Russian Olive	-	-	-	-	-	-
52	Spindle Tree Spp	482,766.43	563,227.50	1,206,916.07	1,408,068.75	2,413,832.14	2,816,137.50
53	Swamp Privet Spp	-	-	-	-	-	-
54	Locust Spp	77,587.46	90,518.71	193,968.65	226,296.76	387,937.31	452,593.53
55	Chokeberry Spp	-	-	-	-	-	-
56	Blue Spruce	-	-	-	-	-	-
57	Scotch Pine	-	-	-	-	-	-
58	Texas Pistache	214,185.11	249,882.62	535,462.76	624,706.56	1,070,925.53	1,249,413.12
59	Black Cottonwood	-	-	-	-	-	-
60	Black Locust	310,349.85	362,074.82	775,874.62	905,187.05	1,551,749.23	1,810,374.11
61	Ash Spp	-	-	-	-	-	-
62	Mexican Pinyon	482,766.43	563,227.50	1,206,916.07	1,408,068.75	2,413,832.14	2,816,137.50
63	Rocky Mountain Juniper	-	-	-	-	-	-
64	Goldenrain Tree	310,349.85	362,074.82	775,874.62	905,187.05	1,551,749.23	1,810,374.11

Note. PCT = Planting cost per tree ($247.50); NS_i = Number of species; $PCAD_i$ = Planting cost area reduced

[a] Equation 57: $PCT \times NS_i = PCAD_i$

Table 26: *Reduced Areas Total Benefits (Cost)*

		Equation					
		(58) [a]					
		Total net species benefits for reduced area ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
1	Siberian Elm	-	-	-	-	-	-
2	White Mulberry	-	-	-	-	-	-
3	Cottonwood	1,788,001	2,086,001	4,470,001	5,215,002	8,940,003	10,430,003
4	Desert Olive	-	-	-	-	-	-
5	Desert Willow	865,563	1,009,823	2,163,907	2,524,558	4,327,814	5,049,116
6	Firethorn Spp	-	-	-	-	-	-
7	Velvet Ash	-	-	-	-	-	-
8	Honey Locust	1,700,065	1,983,409	4,250,163	4,958,524	8,500,326	9,917,047
9	Pinyon Pine	-	-	-	-	-	-
10	Austrian Pine	441,442	515,016	1,103,606	1,287,540	2,207,212	2,575,080
11	Tree of Heaven	-	-	-	-	-	-
12	Purpleleaf Plum	501,728	585,349	1,254,320	1,463,374	2,508,640	2,926,747

Tree description		Equation (58) [a] Total net species benefits for reduced area ($)					
		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
13	Callery Pear	-	-	-	-	-	-
14	Oriental Arborvitae	(-1,827,188)	(-2,131,719)	(-4,567,970)	(-5,329,298)	(-9,135,939)	(-10,658,596)
15	Other Species	-	-	-	-	-	-
16	Mimosa	559,995	653,328	1,399,988	1,633,320	2,799,977	3,266,640
17	Raywood Ash	-	-	-	-	-	-
18	Arizona Cypress	-	-	-	-	-	-
19	Ponderosa Pine	738,779	861,909	1,846,947	2,154,771	3,693,894	4,309,543
20	London Plane	-	-	-	-	-	-
21	White Ash	-	-	-	-	-	-
22	Common Crape Myrtle	-	-	-	-	-	-
23	Chinese Pistache	1,763,490	2,057,405	4,408,724	5,143,512	8,817,449	10287,023
24	Chitalpa	-	-	-	-	-	-

Tree description		Equation (58) [a] Total net species benefits for reduced area ($)					
		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
25	Almond	1,103,844	1,287,818	2,759,610	3,219,545	5,519,219	6,439,089
26	Yucca Spp	-	-	-	-	-	-
27	Aleppo Pine	-	-	-	-	-	-
28	Chaste Tree	96,069	112,081	240,173	280,201	480,345	560,403
29	Crabapple	785,936	916,925	1,964,840	2,292,313	3,929,680	4,584,626
30	Texas Red Oak	1,484,910	1,732,394	3,712,274	4,330,986	7,424,548	8,661,972
31	Cherry Plum	598,659	698,435	1,496,646	1,746,088	2,993,293	3,492,175
32	Live Oak	2,414,241	2,816,615	6,035,604	7,041,538	12,071,207	14,083,075
33	Boxelder	1,202,094	1,402,444	3,005,236	3,506,109	6,010,472	7,012,218
34	Evergreen Ash	-	-	-	-	-	-
35	Apple Spp	837,888	977,536	2,094,720	2,443,841	4,189,441	4,887,681
36	Plum Spp	789,938	921,595	1,974,846	2,303,987	3,949,691	4,607,973
37	Sweet Cherry	742,464	866,208	1,856,160	2,165,520	3,712,320	4,331,040

Tree description		Equation (58) [a] Total net species benefits for reduced area ($)					
		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
38	Common Pear	(-1,653,498)	(-1,929,081)	(-4,133,745)	(-4,822,703)	(-8,267,490)	(-9,645,405)
39	Soapberry Spp	1,212,477	1,414,556	3,031,191	3,536,390	6,062,383	7,072,780
40	Pine Spp	1,187,904	1,385,888	2,969,759	3,464,719	5,939,519	6,929,438
41	Chir Pine	930,000	1,085,000	2,325,000	2,712,499	4,649,999	5,424,999
42	Soaptree Yucca	-	-	-	-	-	-
43	Leyland Cypress	-	-	-	-	-	-
44	Japanese Maple	(-6,067)	(-7,078)	(-15,168)	(-17,696)	(-30,336)	(-35,392)
45	Northern Red Oak	2,583,028	3,013,532	6,457,569	7,533,831	12,915,139	15,067,662
46	Chinese Elm	-	-	-	-	-	-
47	Freeman Maple	-	-	-	-	-	-
48	Northern Catalpa	-	-	-	-	-	-
49	Eastern Redbud	-	-	-	-	-	-

		Equation					
		(58) [a]					
		Total net species benefits for reduced area ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
50	Hawthorn Spp	105,668	123,280	264,170	308,199	528,341	616,398
51	Russian Olive	-	-	-	-	-	-
52	Spindle Tree Spp	59,058	68,901	147,644	172,251	295,288	344,503
53	Swamp Privet Spp	-	-	-	-	-	-
54	Locust Spp	1,765,454	2,059,697	4,413,636	5,149,242	8,827,272	10,298,484
55	Chokeberry Spp	-	-	-	-	-	-
56	Blue Spruce	-	-	-	-	-	-
57	Scotch Pine	-	-	-	-	-	-
58	Texas Pistache	1,335,909	1,558,560	3,339,772	3,896,401	6,679,545	7,792,802
59	Black Cottonwood	-	-	-	-	-	-
60	Black Locust	901,098	1,051,281	2,252,745	2,628,202	4,505,489	5,256,404
61	Ash Spp	-	-	-	-	-	-

		Equation					
		(58) [a]					
		Total net species benefits for reduced area ($)					
Tree description		10%		25%		50%	
i	Common name	Low	High	Low	High	Low	High
62	Mexican Pinyon	(-1,002,432)	(-1,169,504)	(-2,506,080)	(-2,923,760)	(-5,012,160)	(-5,847,520)
63	Rocky Mountain Juniper	-	-	-	-	-	-
64	Goldenrain Tree	598,322	698,043	1,495,806	1,745,107	2,991,612	3,490,214

Note. $TSRRCS_i$ = Total species reduced runoff cost savings; $RACSV_i$ = Reduced area carbon sequestration value; $RAAPV_i$ = Reduced area air pollution value; $SPIRA_i$ = Species price increase for reduced area; $TRAEV_i$ = Total reduced area energy value; $MCAR_i$ = Maintenance cost for area reduced; $PCAD_i$ = Planting cost area reduced; $TNSBRA_i$ = Total net species benefits for reduced area

[a] $(TSRRCS_i + RACSV_i + RAAPV_i + SPIRA_i + TRAEV_i) - (MCAR_i + PCAD_i) = TNSBRA_i$