THE EFFECT OF NATURAL GAS WELL SETBACK DISTANCE ON DRILLABLE LAND IN THE CITY OF DENTON, TEXAS

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Thesis Prepared for the Degree of

MASTER OF SCIENCE

UNIVERSITY OF NORTH TEXAS

May 2014

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Daniel, Michael. *The Effect of Natural Gas Well Setback Distance on Drillable Land in the City of Denton, Texas.* Master of Science (Environmental Science), May 2014, 113 pp., 10 tables, 108 figures, references, 80 titles.

Municipalities protect human health and environmental resources from impacts of urban natural gas drilling through setback distances; the regulation of distances between well sites and residences, freshwater wells, and other protected uses. Setback distances have increased over time, having the potential to alter the amount and geographical distribution of drillable land within a municipality, thereby having implications for future land use planning and increasing the potential for future incompatible land uses. This study geographically applies a range of setback distances to protected uses and freshwater wells in the city limits of Denton, Texas to investigate the effect on the amount of land remaining for future gas well development and production. Denton lies on the edge of a productive region of the Barnett Shale geological formation, coinciding with a large concentration of drillable land in the southwestern region of the study area. This region will have the greatest potential for impacts to future municipal development and land use planning as a result of future gas well development and higher setback standards. Given the relatively high acreage of drillable land in industrially zoned subcategory IC-G and the concern regarding gas well drilling in more populated areas, future drilling in IC-G, specifically in IC-G land cover classes mowed/grazed/agriculture and herbaceous, would have the least impact on residential uses and tree cover, as well as decreasing the potential for future incompatible land uses.

ACKNOWLEDGEMENTS

I would like to thank my committee members Dr. Sam Atkinson, Dr. Bruce Hunter, Dr. Joseph Oppong and Dr. Kenneth Banks for the their direction and input throughout this project. I would like to express my sincere gratitude to Dr. Kenneth Banks for his guidance and patience in the development of this study from the beginning. This study would not have been possible without the assistance of the City of Denton Watershed Protection Department, the City of Denton Gas Wells Inspection Division, the Denton Central Appraisal District and the University of North Texas Center for Spatial Analysis and Mapping.

Lastly, I would like to especially thank my family, both present and departed, for their unending support, love, encouragement and inspiration.

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CHAPTER 1

INTRODUCTION

1.1 Background

According to the U.S. Energy Information Administration (USEIA) (2012b), due to ever increasing energy demands, there is a need for more efficient, sustainable, and domestically produced sources of energy in the United States. Since 2002, natural gas exploration and production have dramatically increased throughout the United States, due especially to technological advances in horizontal drilling and hydraulic fracturing and their effect on shale gas recoverability (Durham, 2005). According to the United States Environmental Protection Agency (USEPA) (2012d), when compared to emissions from coal-fired electric power generation, emissions from natural gas power production generate “half as much carbon dioxide, less than a third as much nitrogen oxides, and one percent as much sulfur oxides,” making natural gas an increasingly desirable fuel alternative. Forecasts show that U.S. shale gas production is expected to increase fourfold throughout 2035 (USEIA, 2011) while per capita emissions of carbon dioxide are expected to decrease by 1% per year throughout the same period (USEIA, 2012a).

The 24-county Barnett Shale formation in north central Texas is the largest shale gas field in the U.S. (USEIA, 2010), and according to the Texas Commission on Environmental Quality (TCEQ), is one of the most productive with approximately 14,660 natural gas wells producing as of January 2012 (TCEQ, 2012) (*Fig. 1*). There are 284 wells currently producing (City of Denton, 2013b) and approximately 143 surface drilling sites within the city limits of Denton, Texas (*Fig. 2*).

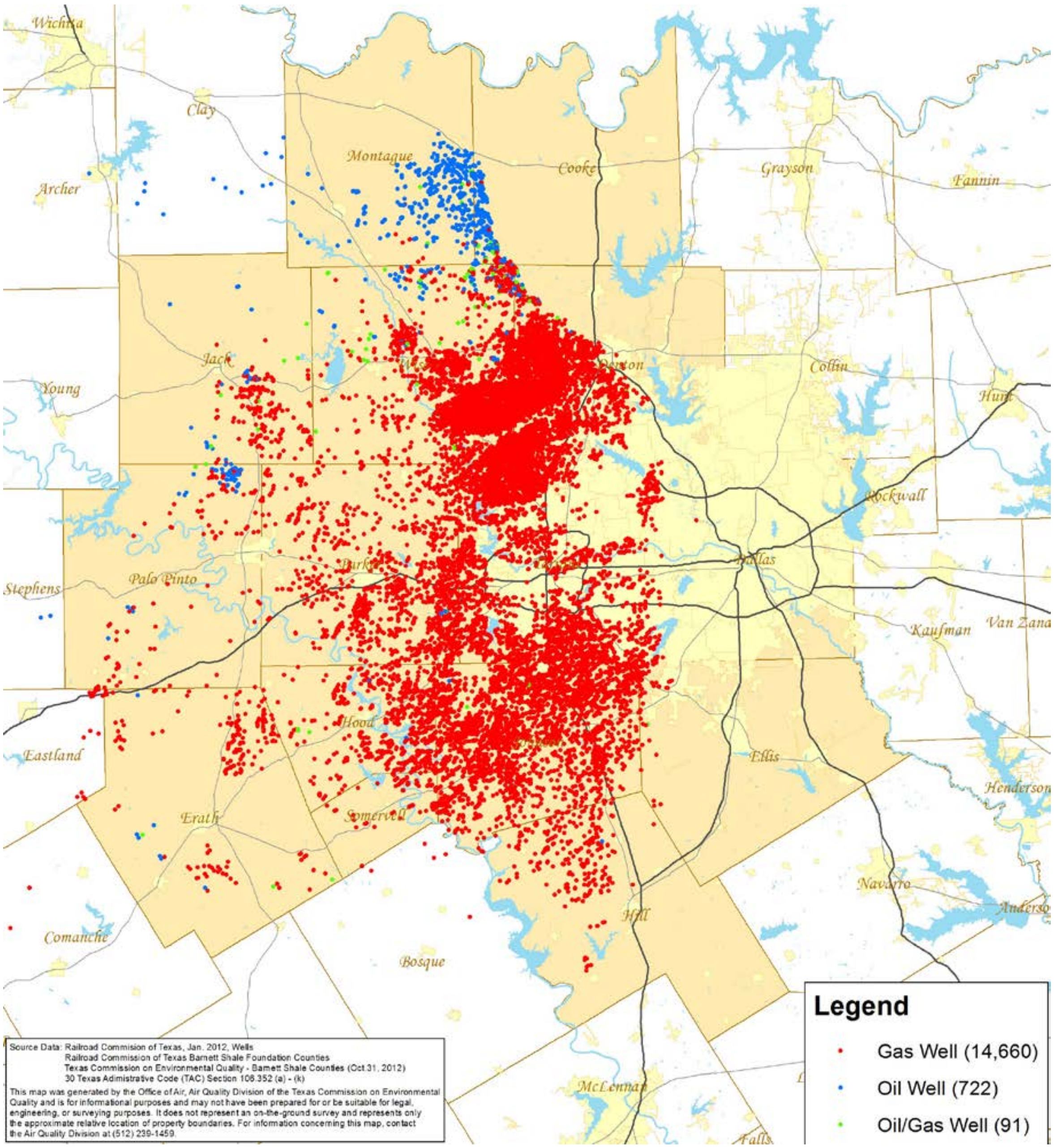

Fig. 1 Barnett Shale gas and oil wells (TCEQ, 2012)

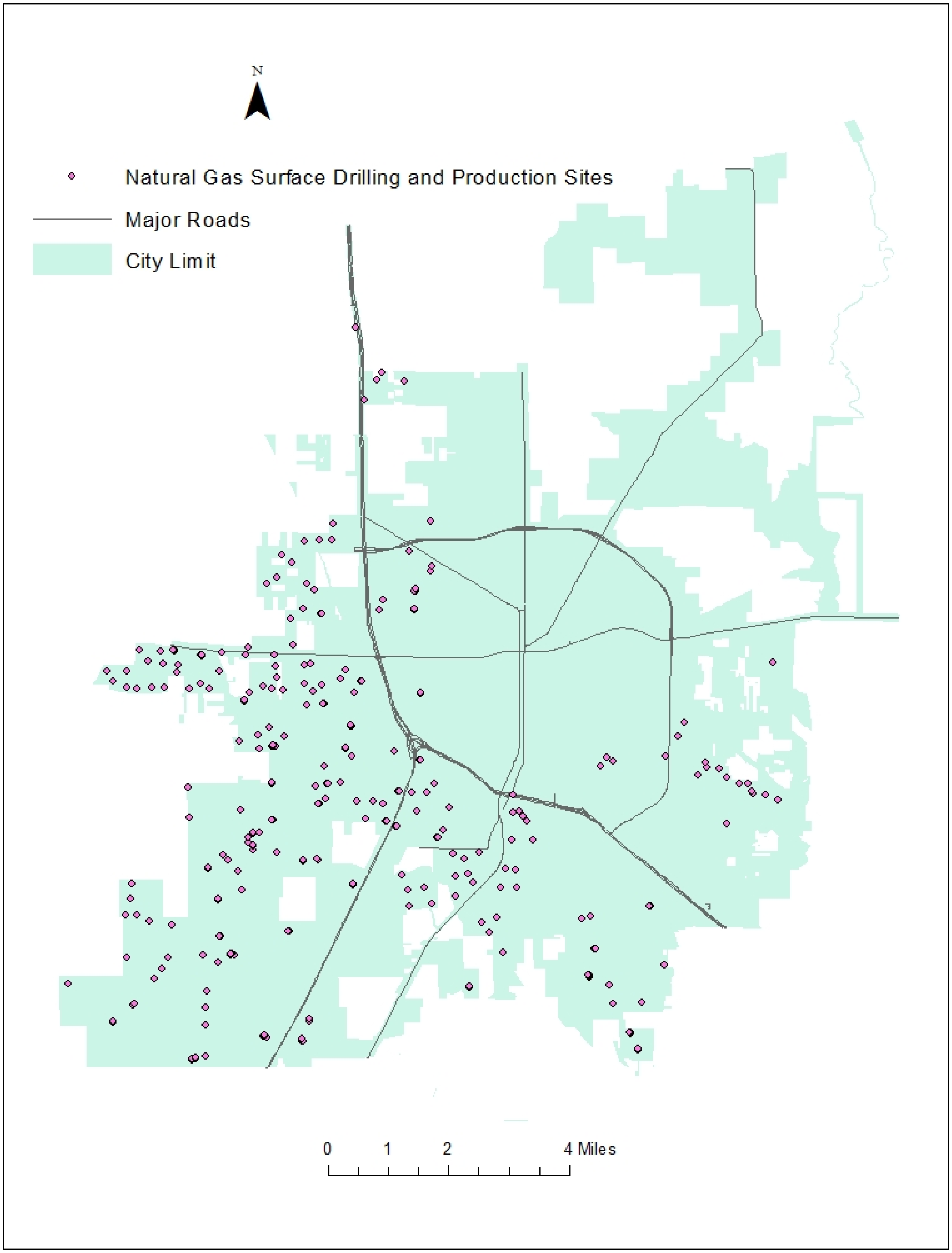

Fig. 2 Currently producing surface well sites within the study area

Natural gas well development has historically been limited to more rural, and therefore, less populated areas within some Barnett Shale area cities. However, urban areas have increasingly been experiencing the effects of natural gas exploration and production.

1.2 Study Premise

Minimum separation (setback) distances are a primary tool used by municipalities in the regulation of natural gas development to prevent natural gas well development within certain distances of structures, geographical boundaries or other geographical entities. These minimum setback distances are typically enforced to prevent development within certain distances of protected uses such as residential or commonly used public structures or geographical entities in the effort to protect human health and environmental resources while allowing for the economic development that accompanies such activity (Fry, 2013).

The natural gas industry estimates the average well pad size at approximately 3.5 acres during the drilling and completion phases and the long term production phase, after partial reclamation, at approximately 1.5 acres (Shale Gas Information Platform, 2014). Fry (2013) states that throughout the past several years, as natural gas well development in urban areas has increased, minimum setback distances, as set by local municipal ordinances, have tended to increase. Due to the fact that setback distances effectively reserve an area of land around a geographical border or point, these increases in setback distances have the effect of designating increasing areas of urban land as undevelopable for drilling and production operations, having the potential to bring about landowner regulatory takings claims. Though over time these setback standards employed by municipalities have evolved, Fry (2013) also states that setback distances as set forth in municipal ordinances are typically the result of “political compromises” rather than empirical study (p. 1).

Another commonly used tool in the municipal regulation of shale gas development involves the control of land use through the exercise of zoning authority. This type of regulation may be accomplished through the permission or prohibition of gas well development in certain zoning districts. Activity may be permitted in other zoning districts through the use of special use permits or other special review processes.

It is hypothesized that the findings of this study will show an inverse linear relationship between the range of setback distances applied to the study area (independent variable) and the associated range of the amount of drillable or developable land remaining for additional gas well development and production within the study area (dependent variable). As setback distance increases it is expected that drillable land will decrease. This effect has the potential to significantly alter the amount and geographical distribution of land available for additional gas well development and production within a city limit boundary, thereby having implications for future residential and commercial development and infrastructure. As drillable land within a city boundary decreases, especially in the case of more heavily populated parts of a city, gas well development may move to less populated, more rural areas. Gas well development requires not only a surface drilling site, but also other auxiliary structures, equipment and infrastructure such as pipelines and compressors. Gas well drilling and production facilities such as these in more undeveloped areas can impact future land development within a municipality by altering future land use plans and increasing the potential for future incompatible land uses. Additionally, as setback distances increase and land available for drilling and production decreases within city boundaries, drilling and production operations may be forced into extraterritorial jurisdictions or other un-annexed areas in which there are limited regulatory powers, resulting in the potential for the future annexation of lands with legally non-conforming land uses. It is the objective of city planning officials to weigh all of these potential outcomes of development activity when drafting or amending municipal ordinances in accordance with a city's unique requirements and concerns.

1.3 Study Objectives

One objective of this study is to investigate the effect of the current minimum natural gas well setback distance, as set by the current City of Denton Development Code, on the amount of land remaining for potential additional gas well development, or drillable land, within the city limits of Denton, Texas. Another objective of this study is to contribute to stakeholder understanding of the relationship between minimum natural gas well setback standards and drillable land, zoning, and land cover. The ultimate objective of this study is to investigate the relationship between a range of common and proposed minimum setback distances and the associated range of the amount of land remaining for potential additional gas well development, or drillable land, within the city limits of Denton, Texas. The findings of this research could be used by the City of

Denton Planning and Zoning Commission, other concerned governmental agencies, and other stakeholders in future gas well development policy decisions.

1.4 Scope of Study

The study is based on a geographical analysis of the amount of land within the study area available for future and additional natural gas drilling and production (drillable land) after a range of setback distances, or spatial buffers, are geographically applied to protected uses, as defined in the Denton Development Code Section 35.22.2, and freshwater wells “currently in use at the time a complete application for a Gas Well Development Site Plan is filed” (City of Denton, 2012) as of December 4, 2012. Additionally, no surface gas well development is allowed within the 100-year floodway (City of Denton, 2012) designated by Federal Emergency Management Agency (FEMA). This land area is not included in the range of setback distances.

This study employs geographic information system (GIS) technology using data obtained from the City of Denton, the Denton Central Appraisal District, and the Texas Natural Resources Information System to spatially analyze the effect of natural gas well separation standards on drillable land within the city limits of Denton, Texas.

The remainder of this study proposal is divided into five sections. The second chapter consists of a review of the scientific and regulatory literature relating to the shale gas development process, its potential environmental, health and economic impacts, and the regulation of its use at the federal, state, and municipal level. The third chapter includes a description of the study area and a presentation of the current municipal regulation relevant to the study. The fourth chapter is a discussion of the methods and procedures used to accomplish the stated objectives of the study. The fifth chapter is a presentation of the results of the analyses and discussion. The final chapter includes a summary of the findings in accordance with the stated study objectives.

CHAPTER 2

LITERATURE REVIEW

Based on the objectives of this research, a review of literature covers the following subjects: (1) a general description of the shale gas development and production process, (2) the potential environmental, health and economic impacts of shale gas production and (2) regulation at federal, state, and local levels.

2.1 Development and Production of Shale Gas

The process of shale gas exploration and production involves five general stages. The exploratory phase involves the use of 3D seismic imaging of the subsurface to assess the location of natural gas deposits in the various subsurface geological formations. Once deposits of natural gas are located, the construction phase begins with the transport and construction of the drilling equipment and required fencing, screening or acoustical barriers (*Fig. 3*). In the study area, this phase may only be conducted during daytime hours and typically spans from 14 to 21 days. Following construction, the drilling phase, a 24-hour per day, seven day per week process lasts approximately 30 days. The completion phase consists of the installation of well casing followed by the fracturing of the geological formation with a sand, water and chemical additive mixture in order to stimulate the release of natural gas. This process occurs over approximately three to five days per stage, with approximately eight to as many as 40 stages per well and may be conducted only during daytime hours throughout the study area. Finally, the production phase consists of the removal of the rig equipment and installation of the four to six foot wellhead and other processing equipment. The site then enters a long term phase in which there is little or no noise beyond the site boundary and may produce natural gas for up to 20 to 30 years (City of Denton, 2013a; Montgomery et al., 2010; University of Texas at Arlington, 2013) (*Fig. 4*).

Fig. 3 Constructed drilling site in the study area with acoustical barriers and accessory structures

Fig. 4 Well site in the study area in long-term production phase with required aesthetic fencing

2.2 Potential Environmental and Health Impacts

With increased natural gas production, especially in urban areas, a number of potential environmental and human health impacts have become a source of public concern. Potential impacts to water and air, as well as noise and light pollution will be discussed in the following section.

2.2.1 Water

Because hydraulic fracturing requires water and is typically conducted near sensitive sources of water, potential impacts to water resources such as water requirements, wastewater management, and contamination of water resources are of particular concern. Due to the fact that hydraulic fracturing has only recently begun to be used on a large scale, scientific consensus regarding its effects on water resources is still evolving.

2.2.1.1 Water Requirements

In an area subject to continued development and water demand (City of Denton Public Utilities Board, 2009), water use is an ongoing concern. Water usage per MMBTU of produced energy involved in shale gas production is up to 3.5 times less than that of conventional natural gas and up to 23 times less than that of conventional oil (Mantell, 2010). Between 1.2 and 3.5 million gallons of water may be used throughout the completion process of a single well (Andrews et al., 2009). Though these figures vary considerably among wells depending upon the physical characteristics of the particular geological formation, the average per well amount of water usage for Barnett Shale development is 2.7 million. This estimate includes 400,000 gallons used in the drilling phase of an operation and 2.3 million gallons used in the completion phase (Groundwater Protection Council and ALL Consulting, 2009). Bene et al. (2007) stated that although subject to fluctuations in natural gas prices and the use of water recycling technology, both surface water and groundwater are used, and estimates show that groundwater from the Trinity and Woodbine aquifers is used in approximately 60% of the fracturing operations in Denton County. The same study stated that overall Barnett Shale development accounted for less than one percent of total water usage in the area. According to the Railroad Commission of Texas (RRC), due to the fact that, unlike in urban areas, the primary water source for rural areas is groundwater, “increased groundwater use for any purpose will have a greater impact on rural areas in the study area” (RRC, 2011).

2.2.1.2 Wastewater Management

Wastewater from the hydraulic fracturing process is composed of flowback water used in the fracturing process and produced water or naturally occurring water from within the geological formation. This wastewater is typically managed through three primary processes: underground injection, treatment and discharge, and recycling (Groundwater Protection Council and ALL Consulting, 2009). Though underground injection is typically preferred by the industry, disposal of wastewaters in this manner is prohibited within city limits under Section 35.22.5(A)6n of the Denton Development Code (City of Denton, 2012). Disposal of wastewater through underground injection is therefore typically transported to disposal wells outside Denton city limits.

Treatment and discharge of shale gas wastewaters directly to surface waters is federally prohibited under the Clean Water Act; however, the discharge of treated wastewaters may be permitted through individual states. The treatment of shale gas wastewaters by wastewater treatment facilities maintains the water within the hydrologic cycle (RRC, 2011). Though this treatment process may be inadequate and costly (Gregory et al., 2011), these technologies are constantly changing and improving.

The use of water recycling technologies in the fracturing process is becoming an increasingly common practice. It is estimated that although recycling technology and use is increasing nationwide, the overall recycling rate as of 2011 in the Barnett Shale was 5 to 10% (Nicot et al., 2011).

Wastewater may also be managed through the use of impoundment pits in which drilling muds and wastewaters are impounded within lined pits and allowed to dewater through evaporation. The solid materials can then be disposed of properly. Denton Development Code Section 35.22.5(A) addresses requirements for impoundment pits relating to maintenance, setback requirements, contents and removal (City of Denton, 2012).

2.2.1.3 Contamination of Water Resources

The recovery of natural gas involves the use of potentially toxic chemicals in the drilling and extraction process as well as the production of natural contaminants from the geological formation. These chemicals and contaminants are found in the wastewater produced throughout the drilling, extraction and production phases (Colborn et al., 2011). These wastewaters must be transported, stored in pits or injected into underground disposal wells, posing potential risk to environmental resources and human health. A comprehensive study by USEPA of the impact of hydraulic fracturing on water resources is currently being conducted, and is scheduled for release in 2014 (USEPA, 2012b).

In a Denton area study, stormwater from natural gas well sites was found to contain elevated concentrations of total suspended solids (TSS) similar to concentrations associated with construction activities and concentrations of heavy metals similar to that of urban stormwater runoff (Wachal, 2008). Another Denton area study found increases in erosion and sediment runoff due to the disturbance of gas well pad sites resulting in increased sediment loading into nearby stream channels (Williams et al., 2008). Sediment, the primary cause of water quality degradation in the US (Office of Water, 2000) can significantly impair surface water quality (Davies- Colley and Smith, 2001).

The shale gas extraction process may potentially cause contamination of groundwater as well as surface water. Increased levels of methane have been noted in freshwater wells in close proximity to hydraulic fracturing operations (Osborn et al., 2011). The same study, through isotopic fingerprinting, indicated that the methane found in these wells originated from deeper sources consistent with depths associated with hydraulic fracturing. No evidence of contamination from saline brines or fracturing chemicals was found. A study conducted in the Barnett Shale found levels of arsenic, selenium, strontium and total dissolved solids (TDS) exceeding the EPA Maximum Drinking Water Contaminant Load (MCL) in wells within three kilometers of gas well operations (Fontenot et al., 2013). Another study in Garfield County, Colorado found elevated levels of endocrine disrupting chemicals in both surface and groundwater (Kassotis et al., 2013). Denton Development Code Section 35.22.5(A) establishes standards for drilling and production relating to erosion control, spills and setback requirements that address this issue (City of Denton, 2012).

2.2.2 Atmospheric Emissions

Due to increased shale gas production, especially in urban and suburban areas, atmospheric pollution and its effect on the environment and human health from this activity has become a source of public concern.

Several atmospheric pollutants have been associated with shale gas production at all phases of the development process(Katzenstein et al., 2003; USEPA, 2012e) and elevated concentrations of air pollutants have been reported in the vicinity of natural gas operations (Weinhold, 2012) in Texas(Eastern Research Group, 2011) New Mexico, Colorado (USEPA, 2013a), Wyoming (Wyoming Department of Environmental Quality, 2012) and Utah (Utah Department of Environmental Quality, 2013).

2.2.2.1 Methane

Methane, the principal component of natural gas and a powerful greenhouse gas, has over twenty times the heat trapping capacity of carbon dioxide (USEPA, 2011) and is a precursor to the synthesis of tropospheric ozone (USEPA, 2006). The oil and gas industry overall is estimated to be the source of almost 40% of the total anthropogenic methane emissions in the United States(USEPA, 2012e). Fugitive emissions, emissions of methane due to venting and leaks from shale gas production equipment are the primary source of concern, and over the lifetime of a shale gas well, 3.6% to 7.9% of the produced methane can be lost as fugitive emissions. These emissions are estimated to be at least 30% to 200% greater than those of conventional gas operations (Howarth et al., 2011). Adverse health effects of methane, as well as visibility impairment and effects on vegetation and climate, have been noted (USEPA, 2012e).

2.2.2.2 Air Toxics

Air toxics, an EPA class of air pollutants linked to health effects such as cancer, immune system, neurological, reproductive, developmental, and respiratory impairment are also of concern as potential emissions of shale gas development and are regulated through specific control technologies (USEPA, 2012a). Air toxics such as hydrogen sulfide, volatile organic compounds (VOCs) such as benzene, xylenes and naphthalene, and carbon disulfide have been noted as being associated with shale gas production (Kargbo et al., 2010; Schmidt, 2011; USEPA, 2012e; Weinhold, 2012). Oil and gas production in the U.S. is the leading industrial source of VOC emissions second to gasoline-powered automobiles (USEPA, 2013b).

2.2.2.3 Criteria Air Pollutants

Criteria air pollutants, another EPA class of pollutants found harmful to human health and the environment, are regulated through the use of local air quality standards and are aimed at protecting sensitive segments of the population such as children and the elderly (USEPA, 2008). Since the early 1990's, Denton County has been classified as a nonattainment area according to National Ambient Air Quality Standards (NAAQS) due to elevated concentrations of ground level ozone. Several other U.S. areas, also with large concentrations of gas well operations, have a history of this nonattainment status for ground level ozone, creating difficulty in identifying the causative agent (Weinhold, 2012). Though controversial, in a study for 2009, ozone and NOx emissions from natural gas operations in the Barnett Shale were predicted to be greater than those from major airport facilities and automobiles combined(Alvarez, R. and Environmental Defense Fund, 2009). However, since 2009, monitoring of air quality at gas well locations such as DISH, Texas by TCEQ "are showing no levels of concern for any chemicals" (TCEQ, 2013a).

Hydraulic fracturing, however, has only recently begun to be used on a large scale, and the effect of shale gas development on air quality is still a very controversial issue. Therefore, scientific consensus regarding its effects on air quality is still evolving.

2.2.3 Noise, Vibrational and Light Disturbances

Increased natural gas development in populated urban areas can cause disruptions from noise, vibration (National Institute for Occupational Safety and Health, 2013) and light (Davis and Mirick, 2006; Pauley, 2004) and has the potential to impact the quality of life for those living in close proximity.

2.2.3.1 Noise Disturbances

Due to the effect elevated noise levels can have upon the human population and environment, noise impacts from gas well operations within municipalities have become a source of public concern and study (Negro, 2012). Increased truck traffic, construction machinery, diesel engines, and drilling rig brakes have been identified as sources of noise (Witter et al., 2010). Estimates show that the oil and gas industry in Denton County was responsible for approximately 12,500 vehicle miles traveled in 2012 (Clark et al., 2012). Construction equipment has been shown to generate noise levels up to 89 dB at 50 feet and 69 dB at 500 feet (Crocker and Kessler, 1982). In accordance with federal guidelines for noise and land-use-compatibility (Federal Interagency Committee on Urban Noise, 1980) the City of Denton prohibits any gas well operation from operating in a manner causing noise levels to exceed 65 decibels (City of Denton, 2012). Behrens and Associates (2006) found that drilling noise level increases may be mitigated from 3 to 5 dBA above ambient levels by employing mitigation procedures such as brake noise control and acoustical barrier systems. In cases of ambient noise levels above 75 decibels, the City of Denton allows for a maximum exceedance of 5 decibels during daytime hours and 3 decibels during nighttime hours with intermittent allowances as stated in 35.22.5(C)5 of the Denton Development Code (City of Denton, 2012).

2.2.3.2 Vibrational Disturbances

Vibrational disturbances from natural gas production sites have been associated with the construction, drilling, and completion phases, as well as the associated increased heavy truck traffic required for equipment and water transport (Witter et al., 2010). Construction equipment has been shown to generate vibrational disturbances up to 85 VdB at a 50 foot distance (Hanson et al., 2006).

To address issues of noise and vibration, the City of Denton requires that well fracturing be performed only during daytime hours unless safety procedures require otherwise, and subject to notification of the Fire Marshall. Approved mitigation measures must also be employed and electric motors must be used in well pumping. Denton Development Code Section 35.22.5(C) addresses noise management standards relating to gas well operations (City of Denton, 2012).

2.2.3.3 Light Disturbances

Disturbances due to light pollution have been noted as a possible effect of natural gas operations in populated areas (Witter et al., 2010). Section 35.22.5(A)3b of the City of Denton Development Code requires directional lighting at drilling and production sites “so as not to disturb or adversely affect adjacent developments” (City of Denton, 2012).

2.2.4 Economic Impact of Shale Development

Natural gas well development in urban areas has the potential to impact both the local and regional economy. Development activities, investments, royalty and lease bonuses, revenue from ad valorem taxes and job growth in the Barnett Shale contributed an estimated $11.1 billion dollars to regional economy in 2011 in addition to an estimated 100,268 jobs (The Perryman Group and The Fort Worth Chamber of Commerce, 2011). However, negative impacts on residential property values as a result of proximity to gas well sites have been noted in a study performed for the Town of Flower Mound, a Barnett Shale city located approximately 20 miles south of the study area (Integra Realty Resources, 2010).

2.3 Regulatory Framework

Shale gas regulation is built upon existing oil and gas regulations and is performed through a system of federal, state and local agencies, though the primary regulatory agencies responsible for regulation throughout the U.S. are at the state level.

2.3.1 Federal Regulation

Shale gas development is regulated at least partly at the federal level through the Clean Water Act (CWA), Clean Air Act (CAA), Endangered Species Act (ESA), Migratory Bird Treaty Act (MBTA), Emergency Planning and Community Right-to-Know

Act (EPCRA) and the Comprehensive Environmental Responsibility Compensation and Liability Act (CERCLA) (Groat and Grimshaw, 2012). Specifically, though the CWA (U.S. Congress, 1972) prohibits the direct discharge of pollutants to surface waters, and through the National Pollutant Discharge Elimination System (NPDES) establishes a permitting process for discharging pollutants to surface waters, oil and gas sites are exempted from the stormwater permitting process (Lim, 2009). Oil and gas operations are exempt from the CAA (U.S. Congress, 1970) through their exemption from the aggregation rule. The Safe Drinking Water Act (SDWA) addresses subsurface water pollution, and requires natural gas operators to obtain a permit for disposal of wastewater in injection wells (U.S. Congress, 1996), but through the Energy Policy Act (U.S. Congress, 2005) exempts the fracturing phase of the operation. EPA recently announced the first federal shale gas regulations designed to address air pollution from natural gas operations. These regulations requiring equipment designed to capture emissions are expected to result in reductions of VOCs, methane, and hazardous air pollutants(USEPA, 2012e). Additionally, a comprehensive study by USEPA of the impact of hydraulic fracturing on water resources is currently being conducted, and is scheduled for release in 2014, and is expected to inform future policy decisions (USEPA, 2012b).

2.3.2 State and Local Regulation

Currently, the majority of shale gas regulation is the responsibility of the state in respect to enforcing federal law, developing and implementing state regulations, and oversight of local regulation (Groat and Grimshaw, 2012). Within the state of Texas, the

Texas Railroad Commission is the agency responsible for regulation of the oil and gas industry overall, while TCEQ, the state's environmental agency, is responsible for oil and gas activities such as air emissions, drinking water supply issues, spill response, certain oil and gas related wastes, and water rights (Texas Administrative Code, Title 16 §3.30). Through the use of zoning and permitting, Texas municipalities may further regulate operations (Negro, 2012). Chapter 3 addresses municipal regulation relating to zoning and separation distances within the study area.

CHAPTER 3

STUDY AREA

This chapter includes a description of the study area, a description of average climatic conditions and geology, a discussion of the study area's nonattainment status according to NAAQS, a brief analysis of the population and demographics of the study area, an inventory of zoning districts, and regulation relating to separation distances in the study area.

The study area includes all land within the city limits of Denton, Texas (*Fig. 5*). Denton was incorporated in 1866 and serves as the county seat of Denton County, Texas. The city is located approximately 39 miles north of Dallas, Texas along the Interstate 35 corridor and covers 87.95 square miles or 56,288 acres, 16th among Texas cities in land area (World Media Group, 2013). The City of Denton is located just west of the Elm Fork of the Trinity River and approximately equidistant from its two main water sources, Lewisville Lake and Ray Roberts Lake. Four watersheds, Pecan Creek, Hickory Creek, Cooper Creek, and Clear Creek drain the study area into Lewisville Lake (*Fig. 6*).

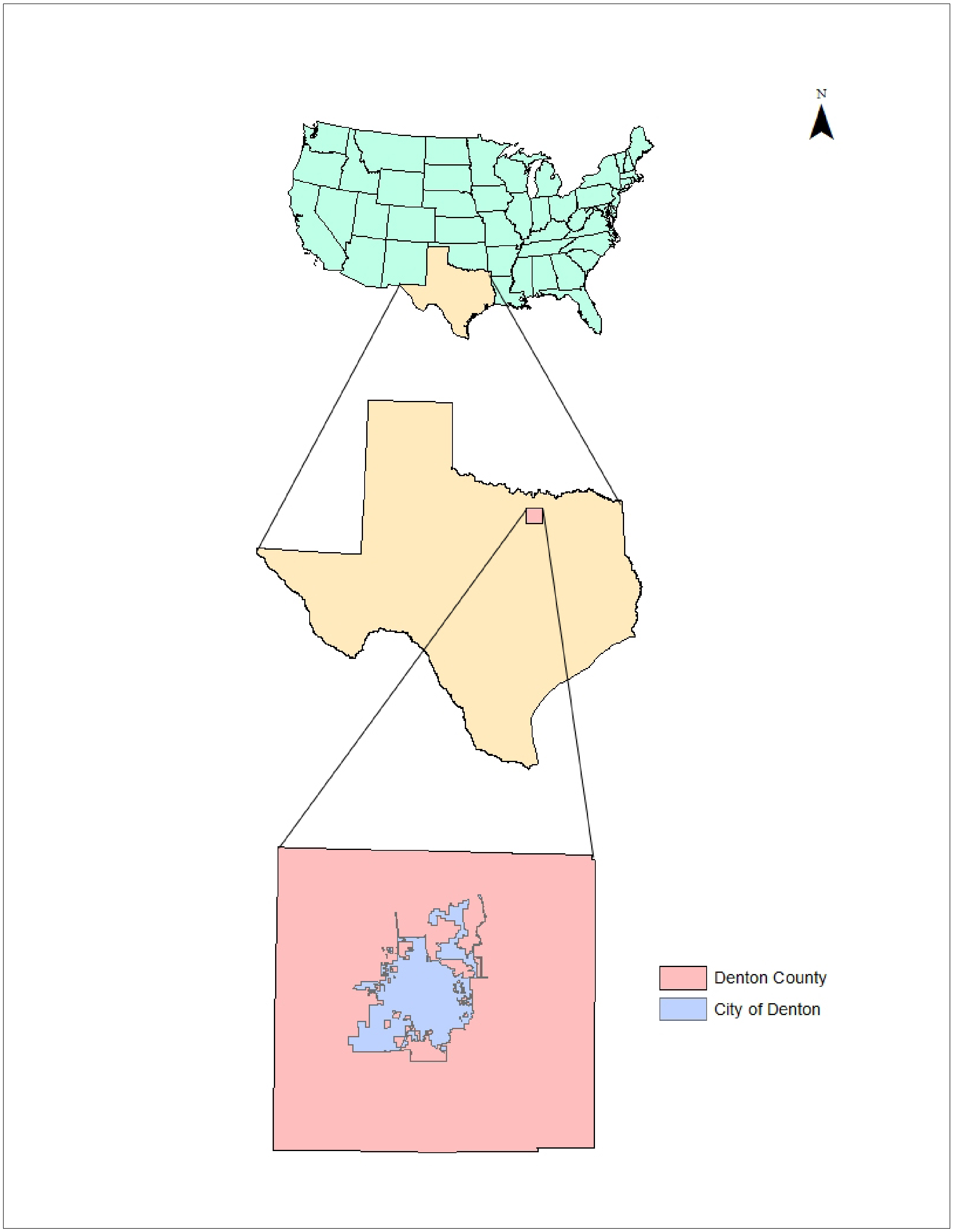

Fig. 5 Location of Study Area

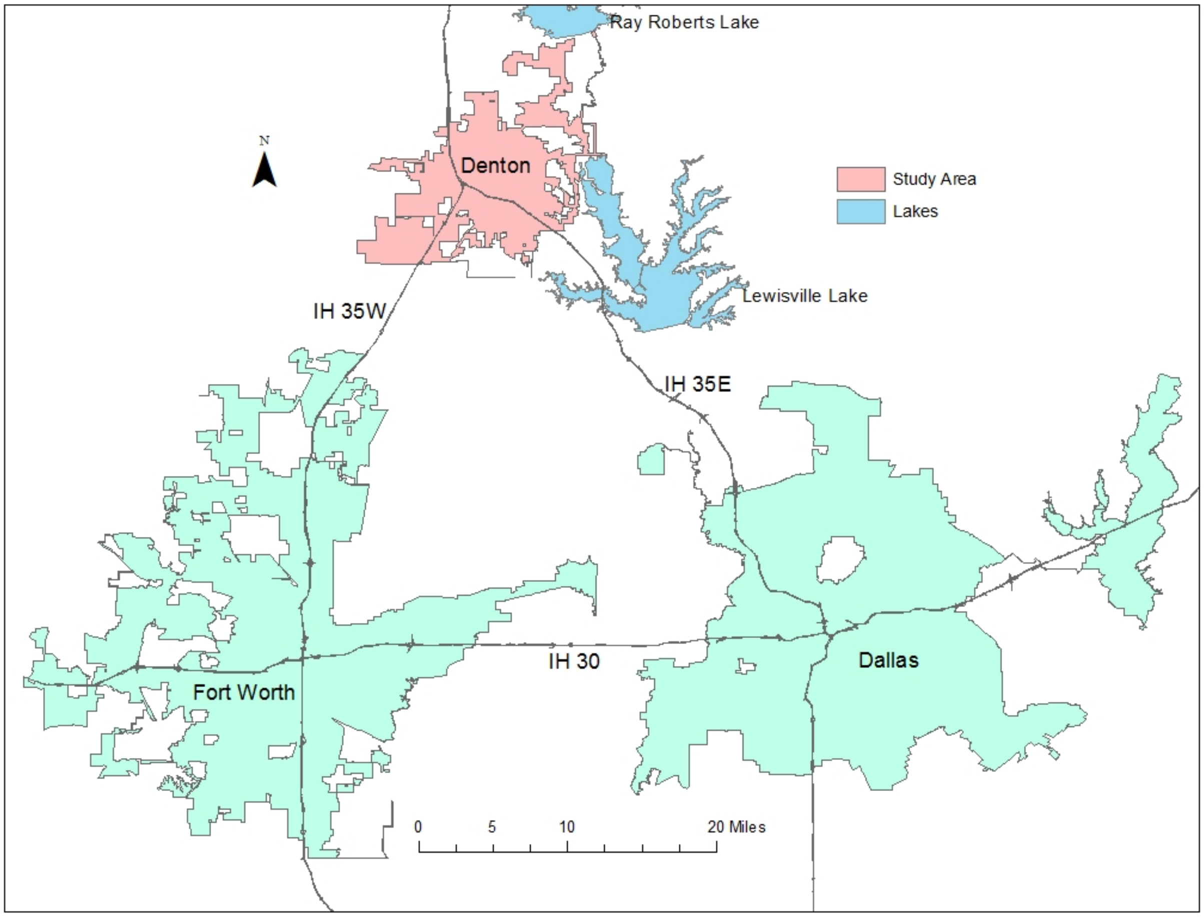

Fig. 6 Study area in relation to Dallas/Fort Worth metropolitan area and major lakes

Denton typically experiences hot, humid summer temperatures and mild to cool winter temperatures with yearly long term average temperatures ranging from 34.6º F to 93.9ºF and average annual rainfall of 38.09" (National Oceanic and Atmospheric Administration, 2012). As in recent years, the area is currently experiencing moderate to severe drought conditions (TCEQ, 2013b). Denton lies at the edge of the Blackland Prairie and Grand Prairie physiographic regions where soils range from heavily organic black clay to sandy soils (U.S. Department of Agriculture and National Resources Conservation Service, 2013).

Due to continued growth in the Denton area and the Dallas/Fort Worth area as a whole, air quality conditions have been of concern in recent years. As noted in Section 2.2.2.3, since the early 1990's EPA has designated Denton County as a nonattainment area according to NAAQS standards for ground level ozone (USEPA, 2012c).

As of 2011, the City of Denton was estimated to have a population of 117,187 with a population density of 1,289.1 persons per square mile or 2.014 persons per acre (U.S. Census Bureau, 2013). The city's population grew an estimated 40.8% during the period between 2000 and 2010 (U.S. Census Bureau, 2011a) and is estimated to increase to 229,964 by 2030 (Texas Water Development Board, 2011), a 96.2% increase over 2011 estimates. Denton ranks 27th in population among 1,212 incorporated areas of Texas (U.S. Census Bureau, 2011c). Two universities are located in Denton, the University of North Texas with a Spring 2013 enrollment of 33,715 (University of North Texas, 2013) and Texas Woman's University with a Spring 2013 enrollment of 14,221 (Texas Woman's University, 2013). Estimates show that approximately 19.8% of individuals in the study area live below the poverty level (U.S. Census Bureau, 2011b).

Denton Development Code Section 35.5 addresses the designated zoning districts within the study area and their associated subcategories as follows (Figure 3.3):

a. Rural districts - the purpose of a Rural District is to maintain an area of rural use within the City of Denton. Application of this district will ensure that the farming, forest, environmental and scenic values of these areas are protected from incompatible development that may result in a degradation of their values. Land Use categories within a Rural District include:

RD-5 Rural Residential
RC Rural Commercial

b. Neighborhood/Residential - the purpose of the Neighborhood Residential land use is to preserve and protect existing neighborhoods and to ensure that any new development is compatible with existing land uses, patterns, and design standards. Land Use within the Neighborhood Residential areas include:

NR-1	Neighborhood Residential 1
NR-2	Neighborhood Residential 2
NR-3	Neighborhood Residential 3
NR-4	Neighborhood Residential 4
NR-6	Neighborhood Residential 6
NRMU-12	Neighborhood Residential Mixed Use 12
NRMU	Neighborhood Residential Mixed Use

c. Downtown University Core - the purpose of the Downtown University Core District is to encourage mixed use developments within specified commercial areas of the district. This district is a pedestrian friendly district. Land Use categories within this district include:

DR-1	Downtown Residential 1
DR-2	Downtown Residential 2
DC-N	Downtown Commercial Neighborhood
DC-G	Downtown Commercial General

d. Community Mixed Use Centers - the purpose of the Community Mixed Use Centers is to provide the necessary shopping, services, recreation, employment and institutional facilities that are required and supported by the surrounding community. Land Use categories within the Community Mixed Use Centers include:

CM-G	Community Mixed Use General
CM-E	Community Mixed Use Employment

e. Regional Mixed Use Centers - the purpose of Regional Mixed Use Centers is to create centers of activity including shopping, services, recreation, employment and institutional facilities supported by and serving an entire region. Land Use categories within Regional Mixed Use Centers include:

RCR-1	Regional Center Residential 1
RCR-2	Regional Center Residential 2
RCC-N	Regional Center Commercial Neighborhood
RCC-D	Regional Center Commercial Downtown

f. Employment Centers - the purpose of the Employment Centers is to provide locations for a variety of workplaces and complimentary uses. Land Use categories within Employment Centers include:

EC-C	Employment Center Commercial
EC-I	Employment Center Industrial

g. Industrial Centers - the purpose of Industrial Centers is to provide locations for a variety of work processes and employment such as manufacturing, warehousing and distributing, indoor and outdoor storage, and a wide range of commercial and industrial operations. Land Use categories within Industrial Centers include:

IC-E	Industrial Center Employment
IC-G	Industrial Center General

(City of Denton, 2012)

An additional five zoning categories are not listed in the Development Code of the City of Denton and are as follows (Figure 3.3):

RD-5X A default zoning district for all property annexed into the City of Denton. It is not an official zoning district of the Denton Development Code, but rather a placeholder until the property owner or city proactively rezones the property.
PD A Planned Development is a unique zoning ordinance approved for a specific property. PD's are required to have a Concept Plan and Detail Plan approved by the City Council. The City of Denton no longer approves new PD's. Any PD's on the zoning map are pre-2002 and have been "grandfathered" in.
MPC The Master Planned Community District is intended to accommodate large-scale, unified, comprehensively planned development that conforms with and enhances the goals and policies contained within the Denton Plan. MPC's have a minimum size requirement of 300 contiguous acres or 150 acres under single ownership.
MF-1 Multi-family 1 is a zoning district from the 1991 code "grandfathered" for an individually designated property.
A (Agriculture): A zoning district from the 1991 code "grandfathered" for individually designated properties.

(Bell, M., personal communication December 2, 2013)

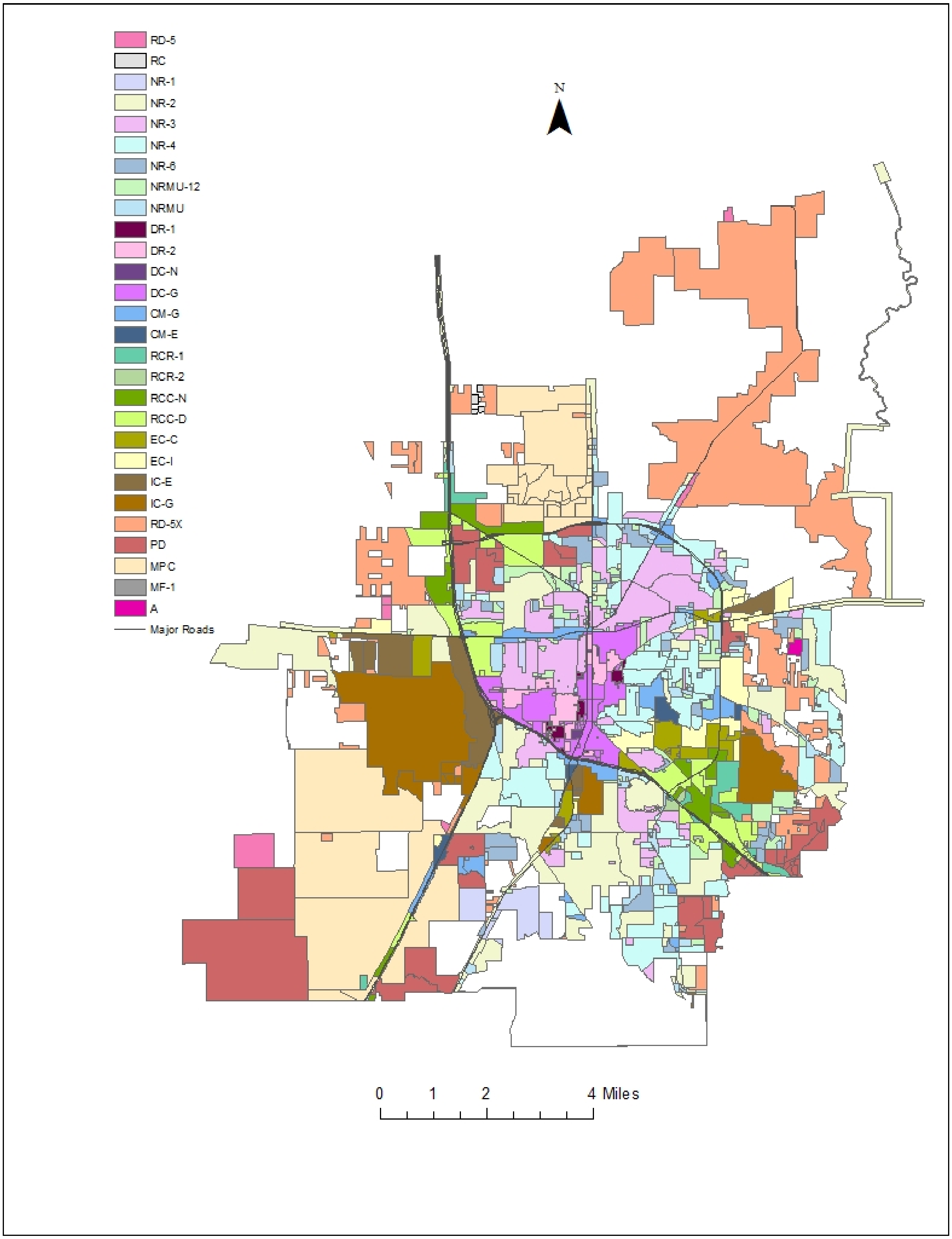

Fig. 7 28 zoning subcategories used in the study area

For the purposes of this study, a total of 28 zoning subcategories will be used in the analysis; the 23 zoning subcategories mentioned in the Denton Development Code, as well as the additional five zoning categories (*Fig. 7*).

Denton Development Code Section 35.22.3 addresses municipal regulation of gas well drilling and production by zoning classification in the study area as follows:

> A. The drilling and production of gas within the corporate limits of the City shall be permitted by right within the Rural Residential (RD-5) or within any unzoned area of the City that is subject to the use regulations of the RD-5 District, Rural Commercial (RC), Neighborhood Residential 1 (NR-1), Neighborhood Residential 2 (NR-2), Regional Center Commercial Neighborhood (RCC-N), Regional Center Commercial Downtown (RCC-D), Employment Center Commercial (EC-C), Employment Center Industrial (EC-I), Industrial Center Employment (IC-E) and Industrial Center General (IC-G) Zoning Districts, except as provided in subsection B, and subject to compliance with the requirements of this Subchapter.
> B. The drilling and production of gas within the corporate limits of the City in all other zoning districts shall be permitted only by Specific Use Permit pursuant to Subchapter 35.6, or through approval of a Detailed Plan in a Planned Development (PD) district, or site-specific authorization in Master Planned Community (MPC) district. Notwithstanding the provisions of Subsection A., approval of a Specific Use Permit also shall be required for gas well drilling and production on any land located within the 100-year flood fringe or within one thousand, two hundred (1,200) feet of the flood pool elevation of Lake Ray Roberts or Lake Lewisville. (City of Denton, 2012)

Denton Development Code Section 35.22.5(A) addresses municipal regulation of gas well drilling and production relating to separation standards in the study area as follows:

> a. No Drilling and Production Site may be located within twelve hundred (1,200) feet of any Protected Use, or freshwater well currently in use at the time a complete application for a Gas Well Development Site Plan is filed, or within twelve hundred (1,200) feet of any lot within a previously platted residential subdivision where one (1) or more lots have one (1) or more habitable structures.
> b. Except where more stringent separation distances are specified, the minimum separation distance between a Drilling and Production Site and all other habitable structures other than those listed in 35.22.5.A.1.a, shall be five hundred (500) feet.

c. The minimum separation requirement established in 35.22.5.A.1.a above may be reduced via the granting of a variance by the Zoning Board of Adjustment. Except that the Zoning Board of Adjustment shall not reduce the minimum separation distance any less than five hundred (500) feet.
d. Notwithstanding any other provision of this subsection, a Protected Use or lot within a previously platted residential subdivision where one (1) or more lots have one (1) or more habitable structures may be located as close as two hundred fifty (250) feet of a pre-existing Drilling and Production Site, provided that the lots or Protected Use is not served by a freshwater well that is located within twelve hundred (1,200) feet of the drilling and production area.
e. Separation distances shall be measured from the boundary of the Drilling and Production Site identified on the Gas Well Development Site Plan, in a straight line, without regard to intervening structures or objects, to the closest exterior point of any structure occupied by a Protected Use, or freshwater well currently in use at the time a complete application for a gas well development site plan is filed, or the closest lot line of any undeveloped lot within a previously platted residential subdivision where one (1) or more lots have one (1) or more structures.
f. The separation standards of this section apply to a site containing a compressor station. (City of Denton, 2012)

CHAPTER 4

METHODS AND PROCEDURES

This chapter includes a discussion of the study design, methods of data preparation and analyses, assumptions, data sources employed in the study and a summary of the search terms and databases used in the literature review.

4.1 Study Design

The study is based on a geographical analysis of the amount of land within the study area available for natural gas drilling (drillable land) after a range of setback distances, or spatial buffers, are geographically applied to the following entities that represent land area on which gas well surface development is prohibited. These entities are defined under the Denton Development Code Section 35.22.5.A.1.a as: “any Protected Use, or freshwater well currently in use at the time a complete application for a Gas Well Development Site Plan is filed,” or “any lot within a previously platted residential subdivision where one (1) or more lots have one (1) or more habitable structures.” According to the Denton Development Code Section 35.22.2, a protected use is defined as “any dwelling, church, public park, public library, hospital, pre-kindergarten, kindergarten or elementary, middle or high school, public pool, public transit center, senior center, public recreation center, hotel or motel” (City of Denton, 2012). These entities were geographically identified using the methods outlined in Section 4.2 (*Fig. 8*).

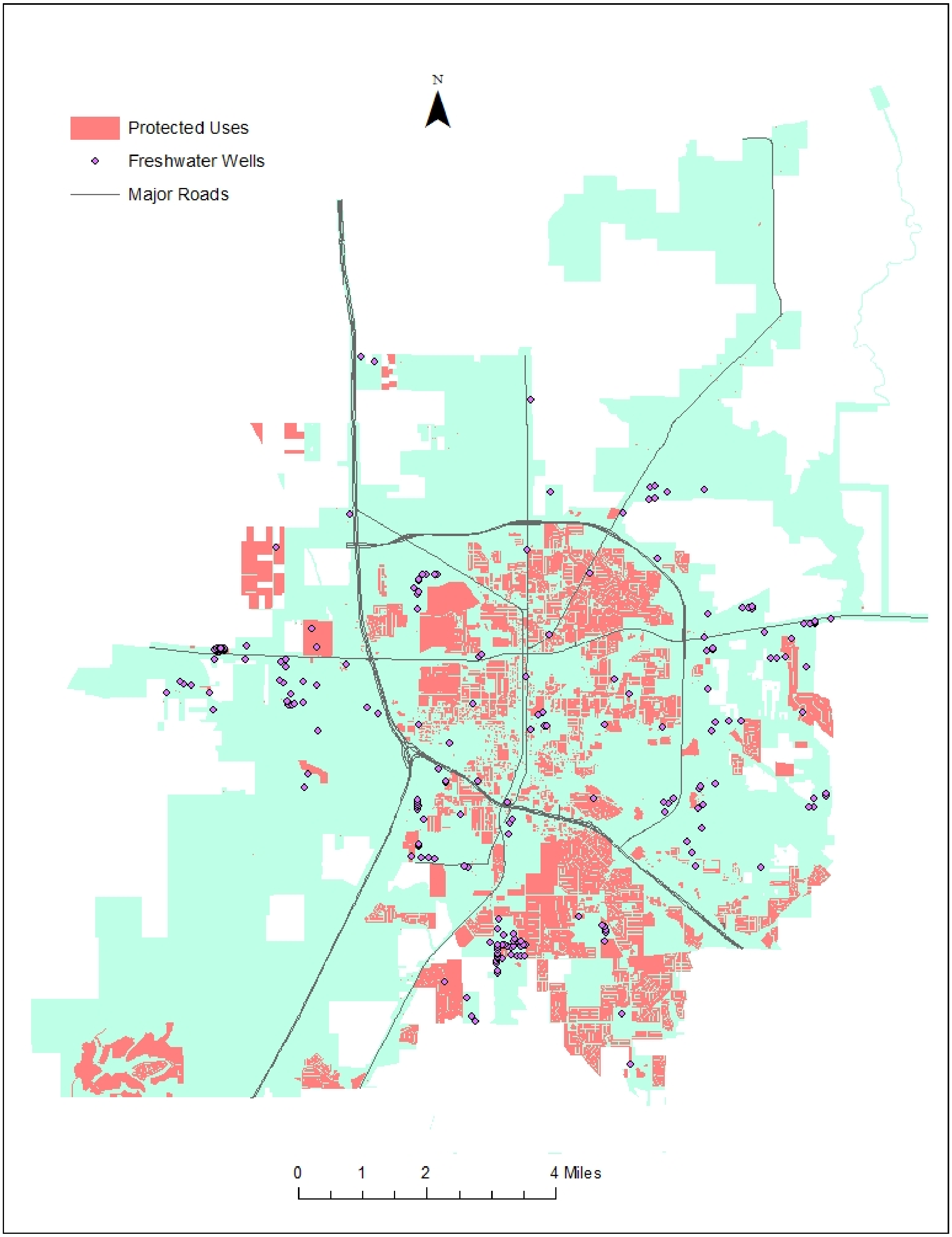

Fig. 8 Protected uses and freshwater wells in the study area

According to Fry (2013), setback distances from residences vary widely throughout the Barnett Shale in Texas, from 300 feet in Krum to 1500 feet in Flower Mound, while the state of Texas has set minimum distances from residences at 200 feet. Other common setback distances within the Denton County region of the Barnett Shale are 600, 1,000, 1,200 and 1,500 feet. For the purposes of this study, the common setback distances used for comparison in Chapter 5 will be 300, 600, 1,000, 1,200 and 1,500 feet. The entire range of setback distance analyzed (200 feet to 2,000 feet in increments of 100 feet) versus drillable land can be seen in Appendices B and C.

Additionally, no surface gas well development is allowed within the FEMA 100-year floodway (City of Denton, 2012) (*Fig. 9*). This land area was geographically excluded from drillable land, but not included in the range of setback distances. Three land cover classes (water, buildings and transportation) were also excluded from drillable land, but not included in the range of setback distances (*Fig. 9*). These land cover classes were identified in the City Green land cover analysis performed by the City of Denton and the Center for Spatial Analysis and Mapping at the University of North Texas performed in 2010 (*Fig. 10*). The remaining three land cover classes identified in the City Green analysis, mowed/grazed/agriculture, trees, and herbaceous, are classified as drillable land and are analyzed separately for drillable land as discussed below.

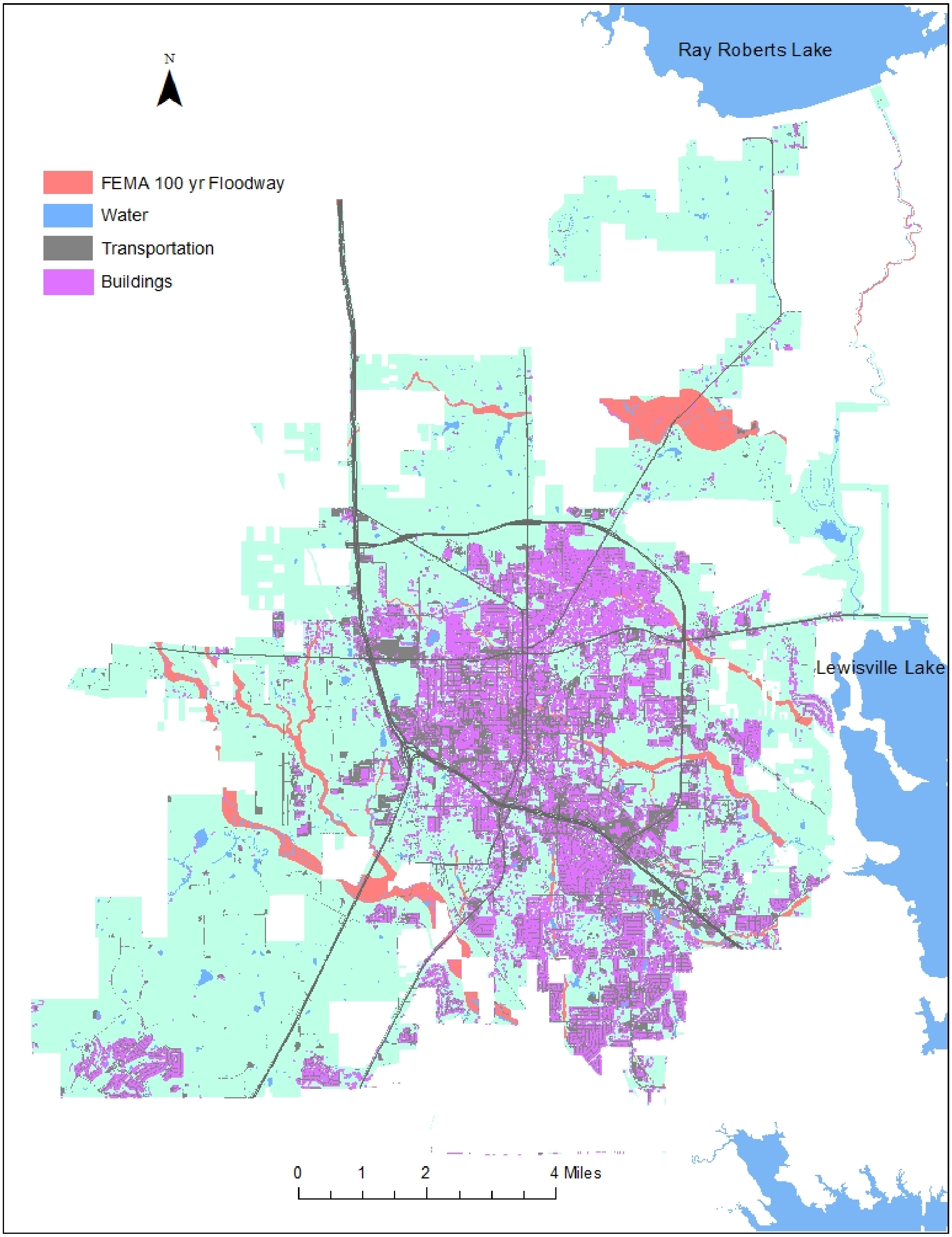

Fig. 9 Land area extracted from drillable land

The study consists of three levels of analysis. The first level consists of an analysis of drillable land within the study area as a whole. The second level consists of an analysis of drillable land within the study area as subdivided into the 28 zoning subcategories discussed in Chapter 3 (*Fig. 7*). The final level will consist of an analysis of drillable land in the three land cover classes (mowed/grazed/agriculture, trees and herbaceous) in each of the 28 zoning subcategories. Some land area included in the current city limit boundary has been annexed since the completion of the City Green land cover analysis, and is therefore not included in this third level of analysis (*Fig. 10*).

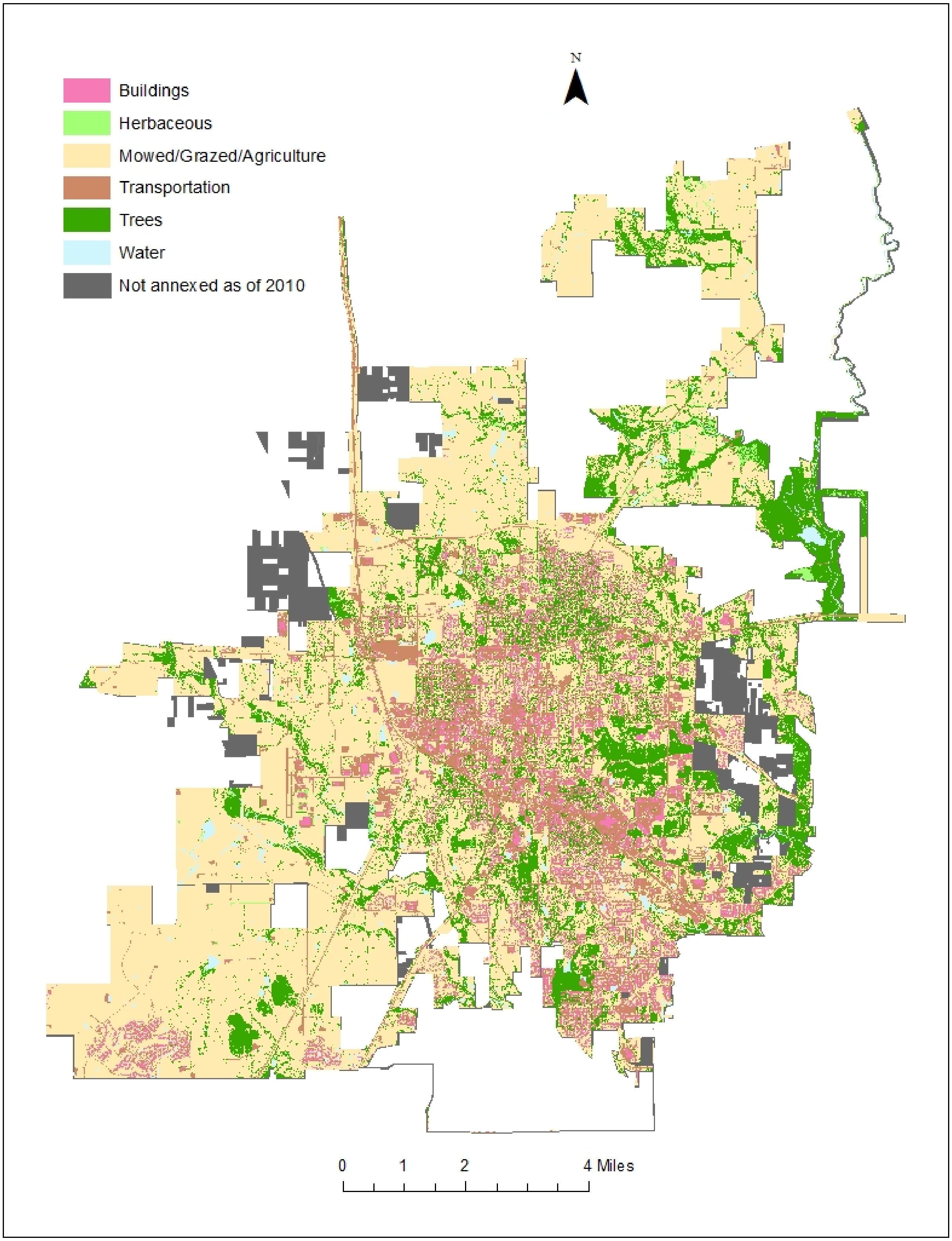

Fig. 10 City Green land cover analysis of 2010 (City of Denton, Texas and Center for Spatial Analysis and Mapping, University of North Texas, 2010)

The geographical analyses were performed using the ArcInfo version of ArcMap 10 produced by the Environmental Systems Research Institute (ESRI), or ArcGIS. Units are reported in U.S. customary units of feet and acres.

4.2 Data Preparation and Analyses

Protected uses were identified geographically utilizing a parcel shapefile for Denton County provided by the Denton Central Appraisal District along with an accompanying database of all properties within Denton County. The Denton County shapefile was first clipped to the boundary of the study area, and the resulting shapefile was joined to the accompanying database of properties using the like field “prop_id.” The data was then parsed using the legal description field. All properties for which the legal description began with “A####A” were identified as unplatted, and all other properties were identified as platted. Each of these property categories were then parsed using the “state_codes” field to determine the property type as identified by an accompanying state code database, allowing for identification of protected uses.

The first entities identified as protected uses were platted residential properties within a subdivision. All remaining platted and unplatted parcels with state codes signifying a protected use were then used to identify the structure of interest as described in Denton Development Code Section 35.22.5.A.1.e:

> Separation distances shall be measured from the boundary of the Drilling and Production Site identified on the Gas Well Development Site Plan, in a straight line, without regard to intervening structures or objects, to the closest exterior point of any structure occupied by a Protected Use, or freshwater well currently in use at the time a complete application for a gas well development site plan is filed, or the closest lot line of any undeveloped lot within a previously platted residential subdivision where one (1) or more lots have one (1) or more structures. (City of Denton, 2012)

This portion of the analysis was performed using satellite imagery from the National Agriculture Imagery Program (NAIP) obtained from the Texas Natural Resources Information System (TNRIS) website along with Google Earth and the property search portion of the Denton Central Appraisal District website.

Existing drilling and production sites were geographically identified utilizing a point shapefile of current drilling and production sites provided by the City of Denton Gas Well Inspections Division in conjunction with NAIP satellite imagery, Google Earth and ground verification. These existing sites were not used in the analysis, but are meant for visualization purposes.

For the three levels of analyses of drillable land, a sequence of buffers, extraction, generalization, overlay and iterator tools were used in ArcGIS ModelBuilder in order to determine the amount of drillable land that corresponds to each setback distance for each level of analysis (*Fig. A.1-A.3*).

4.3 Assumptions

The City of Denton Watershed Protection Department provided a GIS database of freshwater wells for use in the analysis. For the purposes of this research, only freshwater wells that were found to be “active” or “unplugged” have been defined as “currently in use” as set forth in the current city gas well ordinance.

Some land area included in the current city limit boundary has been annexed since the completion of the City Green land cover analysis in 2010 and is therefore not included in the third level of analysis (*Fig. 10*).

Subject to the approval of a Specific Use Permit, gas well drilling and production is allowed on land within the 100-year flood fringe and land within 1,200 feet of the flood pool elevation of Ray Roberts Lake or Lewisville Lake. For the purposes of this study, this land area was assumed to be drillable, and therefore, not excluded from developable land. A Watershed Protection Permit must be approved for any gas well drilling or production on land within a floodplain or environmentally sensitive area. For the purposes of this study, land within the 100-year flood fringe and land within environmentally sensitive areas were assumed to be drillable, and therefore, not excluded from developable land (City of Denton, 2012).

4.4 Data Sources

Data used in the study was provided by the City of Denton, Denton Central Appraisal District, Texas Natural Resources Information System (TNRIS), the University of North Texas Department of Geography and FEMA.

4.5 Search Terms and Databases

General web searches for source literature were conducted first using Google Scholar and the University of North Texas library research web portal. More refined searches were then conducted using Web of Knowledge and EBSCO. Search terms such as “hydraulic fracturing,” “Barnett Shale,” and “natural gas development” were used to conduct preliminary literature searches. More refined searches were then conducted using search terms such as “natural gas atmospheric emissions and air quality” and “natural gas development and water quality.” Additional sources were obtained from regulatory and planning agencies such as EPA, U.S. Department of Energy (DOE), TCEQ, RRC, TNRIS, North Central Texas Council of Governments (NCTCOG), Texas Water Development Board (TWDB) and the City of Denton.

CHAPTER 5

RESULTS AND DISCUSSION

This chapter includes a presentation and discussion of the results of the first, second and third levels of analysis. Results are presented for five common setback distances within the Barnett Shale region as discussed in section 4.1. The first section includes results of the analysis of drillable land (DL) throughout all land area within the study area. The second section includes results of the analysis of DL within the study area as subdivided into 28 zoning subcategories as discussed in Chapter 3. The third section includes results of the analysis of DL in land cover classes mowed/grazed/agriculture, trees and herbaceous for all 28 zoning subcategories.

5.1 Analysis Level I

DL decreases by a total of 14,077.2 acres from a setback of 300 feet to 1,500 feet. An increase in setback distance from the current 1,200 feet to 1,500 feet results in a loss of 2,352.1 acres (*Table 1*).

Table 1 Selected setback distance and corresponding drillable land throughout study area as a whole

Setback (ft)	300	600	1000	1200	1500
DL (acres)	32749.6	27879.9	22916.6	21024.6	18672.4

Maps showing the resulting geographical distribution of DL for the selected setbacks are seen in *Fig. 5.1* through *5.5*. As setback distance increases, drillable land becomes concentrated in rural areas in the northern, and to a larger degree, the southwestern regions of the study area. It is important to note that, given that the study area lies on the edge of a highly productive portion of the geological formation as seen in *Fig. 1* and *2*, the southwestern region of the study area is one of the most geologically favorable regions for drilling and production. Results of the first level of analysis indicate that as setback distances increase, drillable land decreases at a decreasing rate (*Fig. C.1*) with an R-squared value of 96.7% (*Table B.1*). These results indicate that although there is an inverse relationship between setback distance and drillable land in the study area as a whole, the relationship is not completely linear.

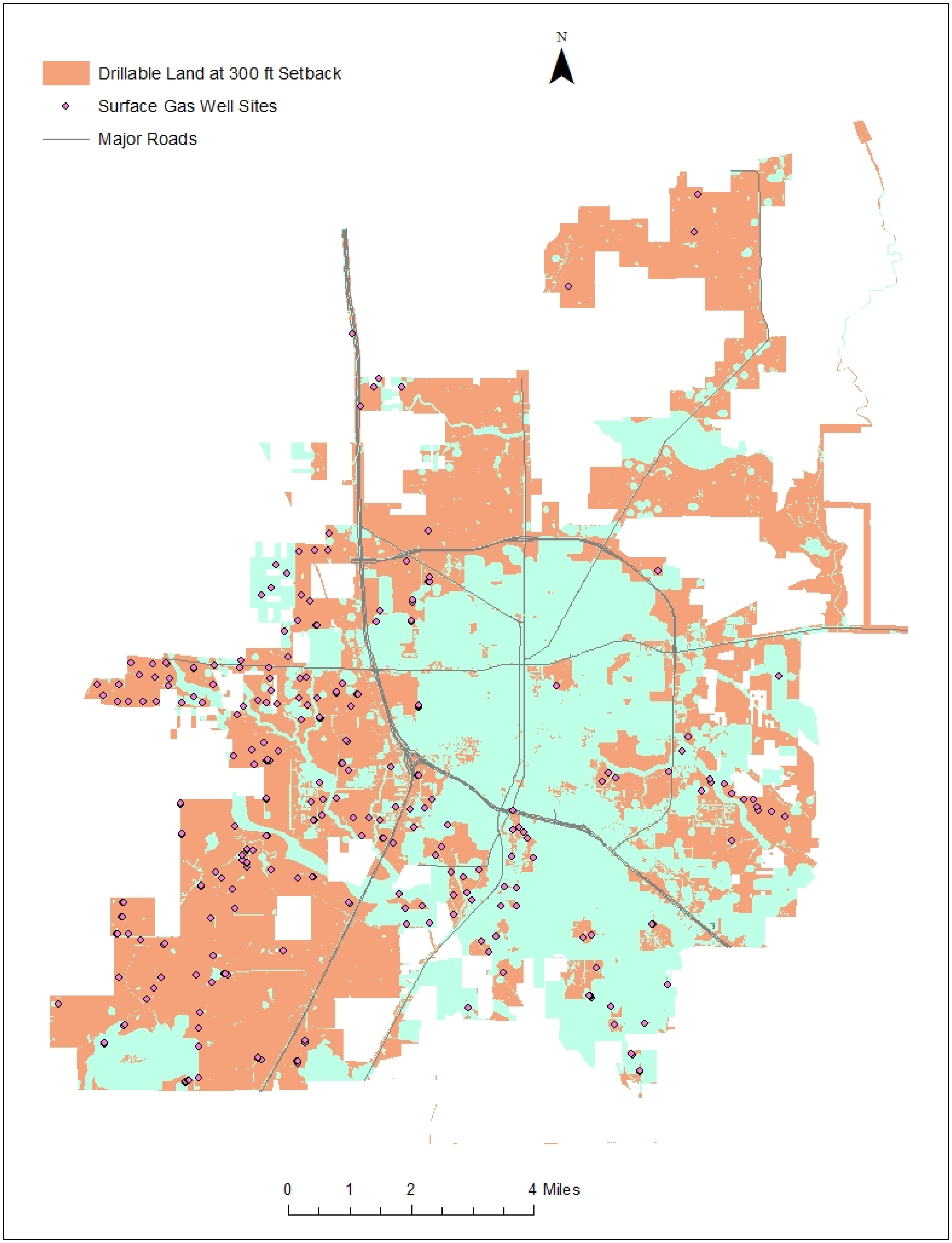

Fig. 11 Drillable land at 300 foot setback

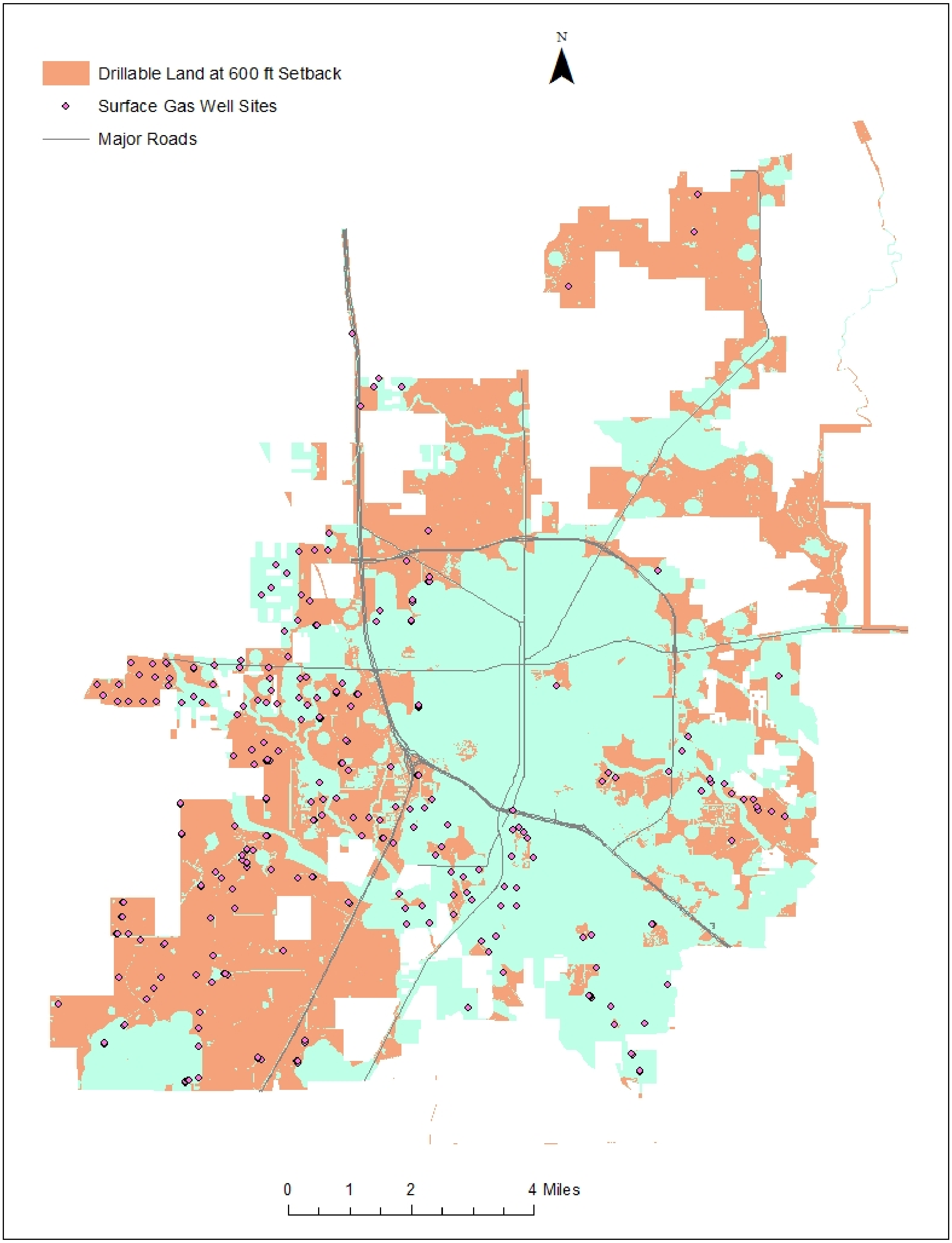

Fig. 12 Drillable land at 600 foot setback

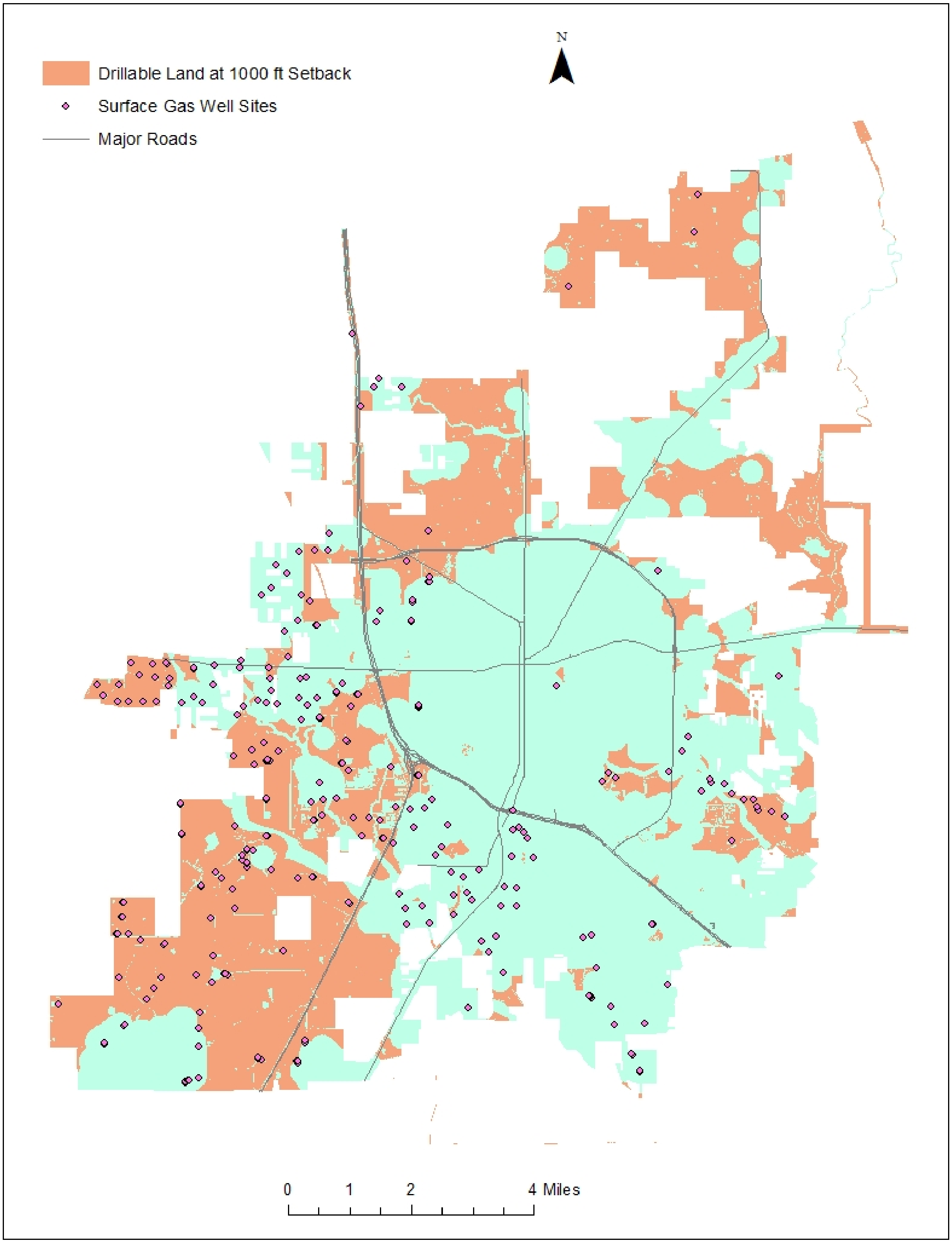

Fig. 13 Drillable land at 1,000 foot setback

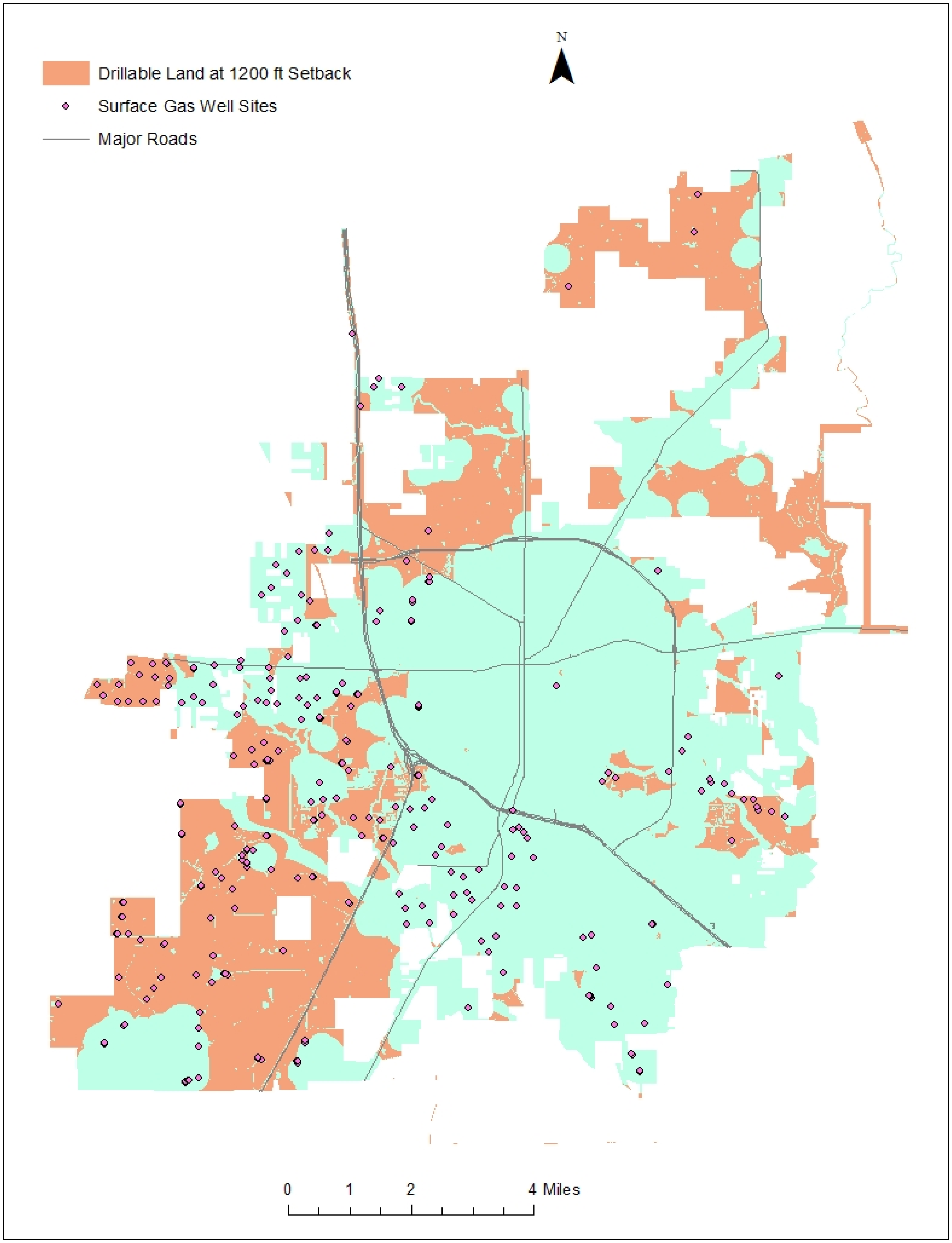

Fig. 14 Drillable land at 1,200 foot setback

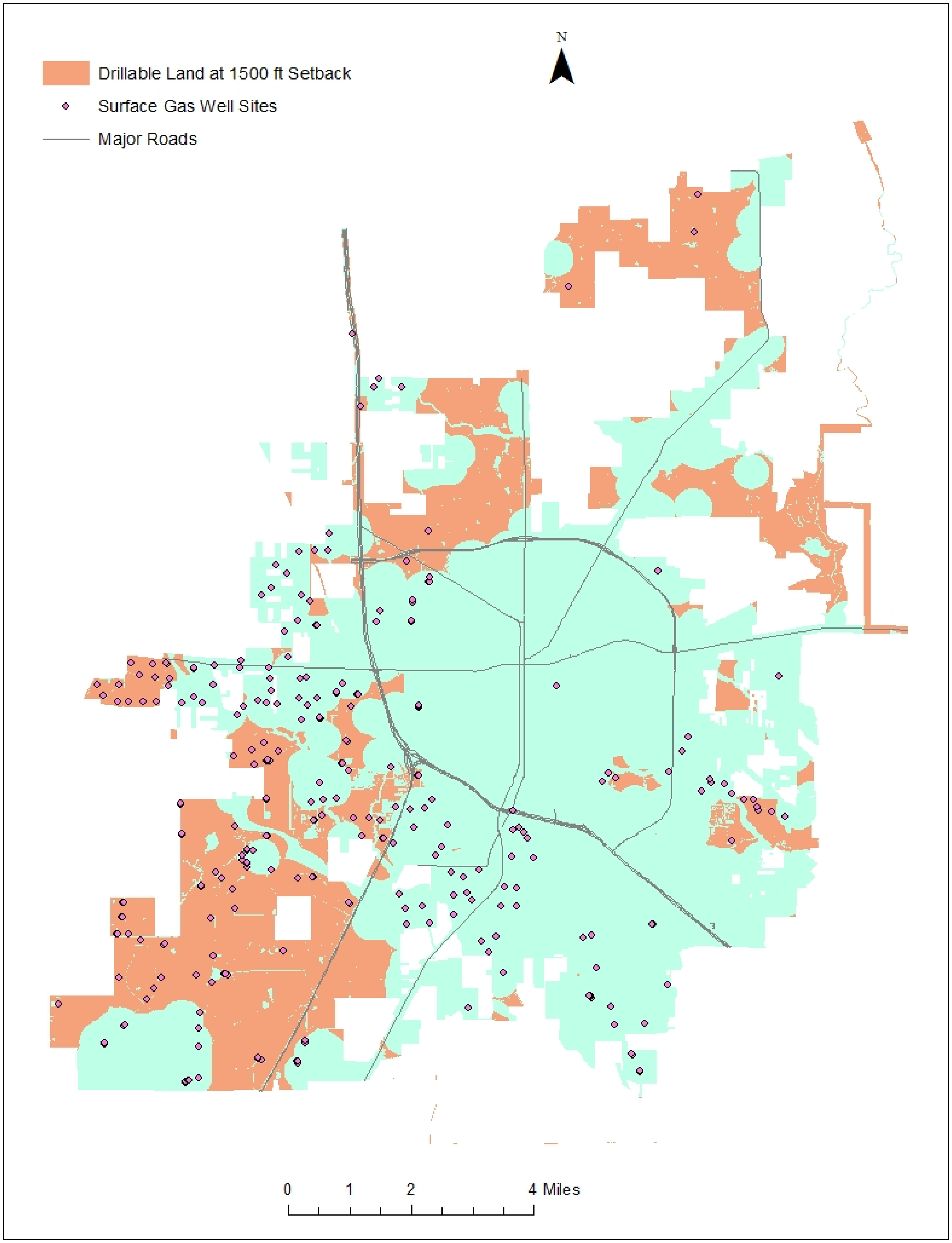

Fig. 15 Drillable land at 1,500 foot setback

5.2 Analysis Level II

The increase in setback distance from 300 feet to 1,500 feet has the greatest effect on DL in zoning subcategory RD-5X, followed by NR-2 and NR-4 with decreases in DL of 3,210.8, 1,332.9 and 1,215.5, respectively (*Table 2*). At the 1,500 foot setback, industrial zoning subcategory IC-G has the third highest acreage of DL at 1,589.9, a reduction of 1,096.7 acres from the 300 foot setback.

Among all zoning subcategories in which drilling and production are allowed by right, IC-G has the highest amount of DL acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 1,896.9 and 1,589.9 acres respectively. NR-2 contains the second highest amount of DL acreage at the current 1,200 foot setback and 1,500 foot setback with 1,435.4 and 1,276.8 acres respectively. Among zoning subcategories in which drilling and production require a special use permit, RD-5X contains the most DL at all selected setback distances (*Table 2*).

Results of the second level of analysis indicate that for most zoning subcategories, as setback distances increase, drillable land decreases at a decreasing rate (Fig. C.2-C.25). Only in subcategories CM-E, IC-G and MPC does DL decrease at a slightly increasing rate. Subcategories RC, DR-1, DC-N and MF-1 contain no reportable DL. R-squared values range from 23.2% for subcategory RCR-2 to 99.7% for IC-G, indicating a wide range in linearity as seen in *Table B.2*.

Graphs of setback versus DL for zoning subcategories in which drilling and production are allowed by right are RD-5 (*Fig. C.2*), RC (no DL), NR-1 (*Fig. C.3*), NR-2 (*Fig. C.4*), RCC-N (*Fig. C.16*), RCC-D (*Fig. C.17*), EC-C (*Fig. C.18*), EC-I (*Fig. C.19*), IC-E (*Fig. C.20*) and IC-G (*Fig. C.21*). A graph of setback versus DL for zoning subcategory PD in which drilling and production require approval of a detailed plan can be seen in *Fig. C.23*. A graph of setback versus DL for zoning subcategory MPC in which drilling and production require site-specific authorization can be seen in *Fig. C.24*. Graphs of setback versus DL for zoning subcategories in which drilling and production require a special use permit are NR-3 (*Fig. C.5*), NR-4 (*Fig. C.6*), NR-6 (*Fig. C.7*), NRMU-12 (*Fig. C.8*), NRMU (*Fig. C.9*), DR-1 (no DL), DR-2 (*Fig. C.10*), DC-N (no DL), DC-G (*Fig. C.11*), CM-G (*Fig. C.12*), CM-E (*Fig. C.13*), RCR-1 (*Fig. C.14*), RCR-2 (*Fig. C.15*), RD-5X (*Fig. C.22*), MF-1 (no DL) and A (*Fig. C.25*).

Table 2 Selected setback distance and corresponding drillable land by zoning subcategory

	DL (acres)				
Setback (ft)	300	600	1000	1200	1500
Zoning Cat.					
RD-5	357.6	343.1	317.1	314.1	313.9
RC	0.0	0.0	0.0	0.0	0.0
NR-1	217.4	182.4	147.1	131.0	107.7
NR-2	2609.7	2012.1	1575.8	1435.4	1276.8
NR-3	115.9	31.9	0.4	0.0	0.0
NR-4	1401.1	890.7	435.0	301.4	185.6
NR-6	580.9	348.0	189.3	146.1	96.3
NRMU-12	325.6	161.9	65.9	45.9	28.6
NRMU	446.8	247.5	125.9	94.5	70.7
DR-1	0.0	0.0	0.0	0.0	0.0
DR-2	2.6	0.1	0.0	0.0	0.0
DC-N	0.0	0.0	0.0	0.0	0.0
DC-G	250.4	118.4	20.0	3.6	0.0
CM-G	436.8	295.2	170.1	121.0	86.2
CM-E	131.0	113.2	95.1	86.5	65.3
RCR-1	319.3	242.9	176.6	161.3	148.9
RCR-2	0.8	0.0	0.0	0.0	0.0
RCC-N	607.4	474.2	333.2	302.3	263.9
RCC-D	960.8	750.7	516.1	440.9	334.4
EC-C	461.0	331.3	169.0	111.1	59.2
EC-I	632.2	444.1	243.4	169.0	94.7
IC-E	848.8	610.8	328.6	236.4	145.2
IC-G	2686.6	2438.7	2086.3	1896.9	1589.9
RD-5X	8121.0	7212.7	6073.6	5561.8	4910.1
PD	2666.8	2243.1	1812.0	1636.7	1422.2
MPC	8338.8	8178.2	7866.2	7671.4	7331.1
MF-1	0.0	0.0	0.0	0.0	0.0
A	42.7	32.3	14.0	6.7	0.0

5.3 Analysis Level III

This section includes results of the third level of analysis in which DL is analyzed by the three land cover classes, mowed/grazed/agriculture, trees and herbaceous, for all 28 zoning subcategories.

5.3.1 Analysis Level III Mowed/Grazed/Agriculture Drillable Land

The increase in setback distance from 300 feet to 1,500 feet has the greatest effect on mowed/grazed/agriculture DL in zoning subcategory RD-5X, followed by PD, NR-2 and MPC with decreases in DL of 1,520.1, 1,069.8, 987.4 and 939.2, respectively (*Table 3*). At the 1,500 foot setback, MPC has the highest acreage of mowed/grazed/agriculture DL at 6,628.8, a reduction of 939.2 acres from the 300 foot setback. At the 1,500 foot setback, RD-5X has the second highest acreage of mowed/grazed/agriculture DL. At the 1,500 foot setback, industrial zoning subcategory IC-G has the third highest acreage of mowed/grazed/agriculture DL at 1,377.7 acres.

Among all zoning subcategories in which drilling and production are allowed by right, IC-G has the highest amount of mowed/grazed/agriculture DL acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 1,631.1 and 1,377.7 acres respectively. Among by right zoning subcategories, NR-2 contains the second highest amount of mowed/grazed/agriculture DL acreage at the current 1,200 foot setback and 1,500 foot setback with 965.7 and 855.1 acres respectively. Among zoning subcategories in which drilling and production require a special use permit, RD-5X contains the most mowed/grazed/agriculture DL at all selected setback distances (*Table 3*).

Results of this level of analysis indicate that for most zoning subcategories of mowed/grazed/agriculture land cover class, as setback distances increase, drillable land decreases at a decreasing rate (Fig. C.26-C.49). Only in subcategories CM-E, IC-G and MPC does DL decrease at a slightly increasing rate. Subcategories RC, DR-1, DC-N and MF-1 contain no reportable DL. R-squared values range from 25.1% for subcategory RCR-2 to 99.7% for NR-1, indicating a wide range in linearity as seen in *Table B.3*.

Graphs of setback versus DL for zoning subcategories in which drilling and production are allowed by right are RD-5 (*Fig. C.26*), RC (no DL), NR-1 (*Fig. C.27*), NR-2 (*Fig. C.28*), RCC-N (*Fig. C.40*), RCC-D (*Fig. C.41*), EC-C (*Fig. C.42*), EC-I (*Fig. C.43*), IC-E (*Fig. C.44*) and IC-G (*Fig. C.45*). A graph of setback versus DL for zoning subcategory PD in which drilling and production require approval of a detailed plan can be seen in *Fig. C.47*. A graph of setback versus DL for zoning subcategory MPC in which drilling and production require site-specific authorization can be seen in *Fig. C.48*. Graphs of setback versus DL for zoning subcategories in which drilling and production require a special use permit are NR-3 (*Fig. C.29*), NR-4 (*Fig. C.30*), NR-6 (*Fig. C.31*), NRMU-12 (*Fig. C.32*), NRMU (*Fig. C.33*), DR-1 (no DL), DR-2 (*Fig. C.34*), DC-N (no DL), DC-G (*Fig. C.35*), CM-G (*Fig. C.36*), CM-E (*Fig. C.37*), RCR-1 (*Fig. C.38*), RCR-2 (*Fig. C.39*), RD-5X (*Fig. C.46*), MF-1 (no DL) and A (*Fig. C.49*).

Table 3 Selected setback distance and corresponding drillable land by zoning subcategory for land cover class Mowed/Grazed/Agriculture

	DL (acres) Mowed/Grazed/Agriculture				
Setback (ft)	300	600	1000	1200	1500
Zoning Cat.					
RD-5	347.7	335.1	314.0	311.4	311.1
RC	0.0	0.0	0.0	0.0	0.0
NR-1	207.3	178.0	143.6	127.8	104.5
NR-2	1842.5	1393.0	1068.0	965.7	855.1
NR-3	86.2	23.5	0.4	0.0	0.0
NR-4	883.9	540.6	242.7	163.4	110.3
NR-6	382.8	222.3	116.7	91.7	64.1
NRMU-12	173.3	66.1	21.7	15.9	11.6
NRMU	351.0	214.7	113.9	84.7	65.4
DR-1	0.0	0.0	0.0	0.0	0.0
DR-2	2.5	0.1	0.0	0.0	0.0
DC-N	0.0	0.0	0.0	0.0	0.0
DC-G	196.3	90.5	12.9	2.9	0.0
CM-G	337.6	227.3	140.6	103.3	74.6
CM-E	58.1	51.5	46.4	44.6	34.9
RCR-1	220.3	191.3	159.2	147.9	139.5
RCR-2	0.8	0.0	0.0	0.0	0.0
RCC-N	441.6	359.4	280.4	260.4	227.5
RCC-D	768.4	600.6	416.3	353.3	261.3
EC-C	301.6	212.5	89.2	45.9	18.7
EC-I	398.3	277.8	142.5	90.3	46.2
IC-E	729.7	524.9	286.5	206.1	129.7
IC-G	2260.9	2075.1	1787.9	1631.1	1377.7
RD-5X	4067.9	3676.0	3135.3	2880.9	2547.8
PD	2434.9	2075.8	1707.1	1553.9	1365.0
MPC	7568.0	7413.9	7118.9	6939.6	6628.8
MF-1	0.0	0.0	0.0	0.0	0.0
A	41.4	31.2	14.0	6.7	0.0

5.3.2 Analysis Level III Trees Drillable Land

The increase in setback distance from 300 feet to 1,500 feet has the greatest effect on trees DL in zoning subcategory NR-4, followed by RD-5X and NR-2 with decreases in DL of 414.5, 343.4, and 330.9, respectively (*Table 4*). At the 1,500 foot setback, RD-5X has the highest acreage of trees DL at 1,524.0, a reduction of 343.4 acres from the 300 foot setback. At the 1,500 foot setback, MPC has the second highest acreage of trees DL at 630.2 acres. At the 1,500 foot setback, industrial zoning subcategory IC-G has the fourth highest acreage of trees DL at 139.2 acres.

Among all zoning subcategories in which drilling and production are allowed by right, NR-2 has the highest amount of trees DL acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 433.5 and 387.8 acres respectively. Among by right zoning subcategories, IC-G contains the second highest amount of trees DL acreage at the current 1,200 foot setback and 1,500 foot setback with 175.8 and 139.2 acres respectively. Among zoning subcategories in which drilling and production require a special use permit, RD-5X contains the most trees DL at all selected setback distances (*Table 4*).

Results of this level of analysis indicate that for most zoning subcategories of trees land cover class, as setback distances increase, drillable land decreases at a decreasing rate (Fig. C.50-C.73). Only in subcategories CM-E, IC-G and MPC does DL decrease at a slightly increasing rate. Subcategories RC, DR-1, DC-N and MF-1 contain no reportable DL. R-squared values range from 16.7% for subcategory RCR-2 to 99.7% for RD-5X, indicating a wide range in linearity as seen in *Table B.4*.

Graphs of setback versus DL for zoning subcategories in which drilling and production are allowed by right are RD-5 (*Fig. C.50*), RC (no data), NR-1 (*Fig. C.51*), NR-2 (*Fig. C.52*), RCC-N (*Fig. C.64*), RCC-D (*Fig. C.65*), EC-C (*Fig. C.66*), EC-I (*Fig. C.67*), IC-E (*Fig. C.68*) and IC-G (*Fig. C.69*). A graph of setback versus DL for zoning subcategory PD in which drilling and production require approval of a detailed plan can be seen in *Fig. C.71*. A graph of setback versus DL for zoning subcategory MPC in which drilling and production require site-specific authorization can be seen in *Fig. C.72*. Graphs of setback versus DL for zoning subcategories in which drilling and production require a special use permit are NR-3 (*Fig. C.53*), NR-4 (*Fig. C.54*), NR-6 (*Fig. C.55*), NRMU-12 (*Fig. C.56*), NRMU (*Fig. C.57*), DR-1 (no DL), DR-2 (*Fig. C.58*), DC-N (no DL), DC-G (*Fig. C.59*), CM-G (*Fig. C.60*), CM-E (*Fig. C.61*), RCR-1 (*Fig. C.62*), RCR-2 (*Fig. C.63*), RD-5X (*Fig. C.70*), MF-1 (no DL) and A (*Fig. C.73*).

Table 4 Selected setback distance and corresponding drillable land by zoning subcategory for land cover class Trees

	DL (acres) Trees				
Setback (ft)	300	600	1000	1200	1500
Zoning Cat.					
RD-5	5.3	4.8	2.1	2.1	2.1
RC	0.0	0.0	0.0	0.0	0.0
NR-1	9.4	4.1	3.4	3.2	3.2
NR-2	718.6	577.5	470.6	433.5	387.8
NR-3	29.7	8.4	0.0	0.0	0.0
NR-4	485.7	326.6	178.3	128.9	71.2
NR-6	192.3	121.7	69.1	51.0	29.2
NRMU-12	130.7	82.1	41.7	30.0	17.0
NRMU	94.3	32.3	11.8	9.6	5.1
DR-1	0.0	0.0	0.0	0.0	0.0
DR-2	0.1	0.0	0.0	0.0	0.0
DC-N	0.0	0.0	0.0	0.0	0.0
DC-G	54.1	27.9	7.1	0.7	0.0
CM-G	89.9	59.0	24.0	13.2	7.2
CM-E	66.7	55.6	43.5	37.0	27.3
RCR-1	98.8	51.3	17.2	13.1	9.2
RCR-2	0.1	0.0	0.0	0.0	0.0
RCC-N	156.8	106.0	45.8	36.9	32.2
RCC-D	169.6	128.2	79.4	68.0	54.5
EC-C	157.6	117.3	78.7	64.3	40.2
EC-I	227.9	160.8	96.0	74.5	45.9
IC-E	109.8	79.3	39.4	28.8	14.3
IC-G	306.2	251.4	198.8	175.8	139.2
RD-5X	1867.4	1783.4	1681.7	1624.5	1524.0
PD	207.0	145.7	87.6	67.4	44.1
MPC	694.1	688.1	672.3	658.1	630.2
MF-1	0.0	0.0	0.0	0.0	0.0
A	1.3	1.1	0.0	0.0	0.0

5.3.3 Analysis Level III Herbaceous Drillable Land

The increase in setback distance from 300 feet to 1,500 feet has the greatest effect on herbaceous DL in zoning subcategory RD-5X, followed by NR-4 and IC-G with decreases in DL of 65.3, 21.8, and 12.5, respectively (*Table 5*). At the 1,500 foot setback, RD-5X has the highest acreage of herbaceous DL at 142.4, a reduction of 65.3 acres from the 300 foot setback. At the 1,500 foot setback, industrial zoning subcategory IC-G has the fourth highest acreage of herbaceous DL at 20.9 acres.

Among all zoning subcategories in which drilling and production are allowed by right, NR-2 has the highest amount of herbaceous DL acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 29.0 and 27.1 acres respectively. Among by right zoning subcategories, IC-G contains the second highest amount of herbaceous DL acreage at the current 1,200 foot setback and 1,500 foot setback with 25.0 and 20.9 acres respectively. Among zoning subcategories in which drilling and production require a special use permit, RD-5X contains the most herbaceous DL at all selected setback distances (*Table 5*).

Results of this level of analysis indicate that for most zoning subcategories of herbaceous land cover class, as setback distances increase, drillable land decreases at a decreasing rate (*Fig. C.74-C.90*). Only in subcategories CM-E, RCC-D, IC-G and MPC does DL decrease at a slightly increasing rate. Subcategories RC, NR-1, NR-3, DR-1, DR-2, DC-N, DC-G, RCR-1, RCR-2, MF-1 and A contain no reportable herbaceous DL. R-squared values range from 32.9% for subcategory NRMU-12 to 99.3% for PD, indicating a wide range in linearity as seen in *Table B.5*.

Graphs of setback versus DL for zoning subcategories in which drilling and production are allowed by right are RD-5 (*Fig. C.74*), RC (no DL), NR-1 (no DL), NR-2 (*Fig. C.76*), RCC-N (*Fig. C.82*), RCC-D (*Fig. C.83*), EC-C (*Fig. C.84*), EC-I (*Fig. C.85*), IC-E (*Fig. C.86*) and IC-G (*Fig. C.87*). A graph of setback versus DL for zoning subcategory PD in which drilling and production require approval of a detailed plan can be seen in *Fig. C.89*. A graph of setback versus DL for zoning subcategory MPC in which drilling and production require site-specific authorization can be seen in *Fig. C.90*. Graphs of setback versus DL for zoning subcategories in which drilling and production require a special use permit are NR-3 (no DL), NR-4 (*Fig. C.76*), NR-6 (*Fig. C.77*), NRMU-12 (*Fig. C.78*), NRMU (*Fig. C.79*), DR-1 (no DL), DR-2 (no DL), DC-N (no DL), DC-G (no DL), CM-G (*Fig. C.80*), CM-E (*Fig. C.81*), RCR-1 (no DL), RCR-2 (no DL), RD-5X (*Fig. C.88*), MF-1 (no DL) and A (no DL).

Table 5 Selected setback distance and corresponding drillable land by zoning subcategory for land cover class Herbaceous

	DL (acres) Herbaceous				
Setback (ft)	300	600	1000	1200	1500
Zoning Cat.					
RD-5	4.6	3.2	1.0	0.6	0.6
RC	0.0	0.0	0.0	0.0	0.0
NR-1	0.0	0.0	0.0	0.0	0.0
NR-2	35.1	32.0	29.6	29.0	27.1
NR-3	0.0	0.0	0.0	0.0	0.0
NR-4	25.9	19.8	12.4	9.0	4.1
NR-6	4.7	3.8	3.5	3.4	3.1
NRMU-12	0.5	0.1	0.0	0.0	0.0
NRMU	1.3	0.3	0.1	0.1	0.1
DR-1	0.0	0.0	0.0	0.0	0.0
DR-2	0.0	0.0	0.0	0.0	0.0
DC-N	0.0	0.0	0.0	0.0	0.0
DC-G	0.0	0.0	0.0	0.0	0.0
CM-G	4.7	4.4	4.4	4.4	4.4
CM-E	6.2	6.0	5.2	4.9	3.1
RCR-1	0.2	0.2	0.2	0.2	0.2
RCR-2	0.0	0.0	0.0	0.0	0.0
RCC-N	8.3	8.2	6.5	4.5	3.7
RCC-D	15.9	15.0	13.5	12.9	11.6
EC-C	1.8	1.5	1.1	1.0	0.4
EC-I	5.9	5.6	4.9	4.2	2.6
IC-E	8.2	5.9	2.4	1.5	1.2
IC-G	33.3	31.8	28.6	25.0	20.9
RD-5X	207.8	186.3	161.4	152.2	142.4
PD	9.9	8.6	7.0	6.1	4.3
MPC	55.1	54.5	53.5	52.4	51.1
MF-1	0.0	0.0	0.0	0.0	0.0
A	0.0	0.0	0.0	0.0	0.0

CHAPTER 6

SUMMARY

This chapter includes a summary of the findings in accordance with the stated objectives of the study and recommendations for future study.

The current 1,200 foot setback as set by the current gas well ordinance is among the higher minimum setback distances within the Barnett Shale region and results in 21,024.6 acres of drillable land throughout the study area as a whole, down approximately 1,892 acres from the previous 1,000 foot setback as set by the Denton Development Code. Drillable land within the study area decreases as setback distances increase, mostly at a decreasing rate. Protected uses and freshwater wells are mostly concentrated within the central and southeastern regions of the study area (Fig. 8), and as setback distances increase, protected expanses of land area begin to overlap, resulting in a decrease in the rate of loss of drillable land. The largest concentrations of drillable land are located in the southwestern region of the study area, and to a lesser degree, the northern regions. The northern expanses of drillable land are less concentrated and more dispersed and lie mostly beyond the productive boundary of the geological formation. Since Denton lies on the edge of a productive region of the Barnett Shale geological formation (Fig. 2), which coincides with a large concentration of drillable land in the southwestern region of the study area (*Fig. 11- 15*), actual productive drillable land will be less than drillable land as reported in this study. Consequently, this region will have the greatest potential for impacts to future municipal development and land use planning as a result of additional gas well development and higher setback standards.

Among all zoning subcategories, MPC, RD-5X and IC-G contain the highest acreage of drillable land at all selected setback distances. MPC (Master Planned Community), in which drilling and production require site-specific authorization, contains the highest amount of drillable land acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 7,671.4 and 7,331.1 acres respectively. RD-5X, in which drilling and production require a special use permit, contains the second highest amount of drillable land acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 5,561.8 and 4,910.1 acres respectively. IC-G, in which drilling and production are allowed by right, contains the third highest amount of drillable land acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 1,896.9 and 1,589.9 acres respectively. Given relatively high acreage of drillable land in industrially zoned subcategory IC-G and the public concern regarding gas well drilling and development in more populated areas, further drilling and production in IC-G would have less of an impact on residential uses and population.

In land cover class mowed/grazed/agriculture among all zoning subcategories, MPC, RD-5X, IC-G and PD contain the highest acreage of mowed/grazed/agriculture-covered drillable land at all selected setback distances. MPC (Master Planned Community), in which drilling and production require site-specific authorization, contains the highest amount of mowed/grazed/agriculture-covered drillable land acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 6,939.6 and 6,628.8 acres respectively. RD-5X, in which drilling and production require a special use permit, contains the second highest amount of mowed/grazed/agriculture-covered drillable land acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 2,880.9

and 2547.8 acres respectively. IC-G, in which drilling and production are allowed by right, contains the third highest amount of mowed/grazed/agriculture-covered drillable land acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 1,631.1 and 1,377.7 acres respectively.

In land cover class trees among all zoning subcategories, RD-5X, MPC and NR-2 contain the highest acreage of drillable land at all selected setback distances. RD-5X, in which drilling and production require a special use permit, contains the highest amount of tree-covered drillable land acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 1,624.5 and 1,524.0 acres respectively. MPC, in which drilling and production require site-specific authorization, contains the second highest amount of tree-covered drillable land acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 658.1 and 630.1 acres respectively. Residential category NR-2 contains the third highest amount of tree-covered drillable land acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 433.5 and 387.8 acres respectively.

In land cover class herbaceous among all zoning subcategories, RD-5X, MPC and NR-2 contain the highest acreage of drillable land at all selected setback distances. RD-5X, in which drilling and production require a special use permit, contains the highest amount of herbaceous-covered drillable land acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 152.2 and 142.4 acres respectively. MPC (Master Planned Community), in which drilling and production require site-specific authorization, contains the second highest amount of herbaceous-covered drillable land acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 52.4

and 51.1 acres respectively. Residential zoning subcategory NR-2, in which drilling and production are allowed by right, contains the third highest amount of herbaceous-covered drillable land acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 29.0 and 27.1 acres respectively. Finally, industrially zoned IC-G, in which drilling and production are allowed by right, contains the fourth highest amount of herbaceous-covered drillable land acreage at the current 1,200 foot setback as well as the 1,500 foot setback with 25.0 and 20.9 acres respectively.

Given the relatively high acreage of drillable land in industrially zoned subcategory IC-G and the concern regarding gas well drilling in more populated areas, future drilling in IC-G, specifically in IC-G land cover classes mowed/grazed/agriculture and herbaceous, would have the least impact on residential uses and tree cover, as well as decreasing the potential for future incompatible land uses.

Recommendations for future study within this study area would include these analyses with updated land cover analysis data. Given that the land cover analysis used in this study was performed in 2010 and the fact that the study area is subject to rapid growth and change, updated land cover data could improve accuracy of results. Further study on the inventory of freshwater wells within the study area could also potentially improve the accuracy of these results.

As Fry (2013) states, setback standards throughout the Barnett Shale are neither uniform nor based on empirical evidence: therefore, municipalities with heavy gas well drilling and production could benefit from updating public policy with analyses of this nature in conjunction with empirically based environmental studies. Analyses using the methods outlined herein with unique data from each municipality, could be used by municipal zoning and planning commissions, other concerned governmental agencies, and other stakeholders to inform more comprehensive and evidence-based gas well ordinances and policy decisions.

APPENDIX A

MODELS USED FOR ANALYSIS IN ARCGIS MODELBUILDER

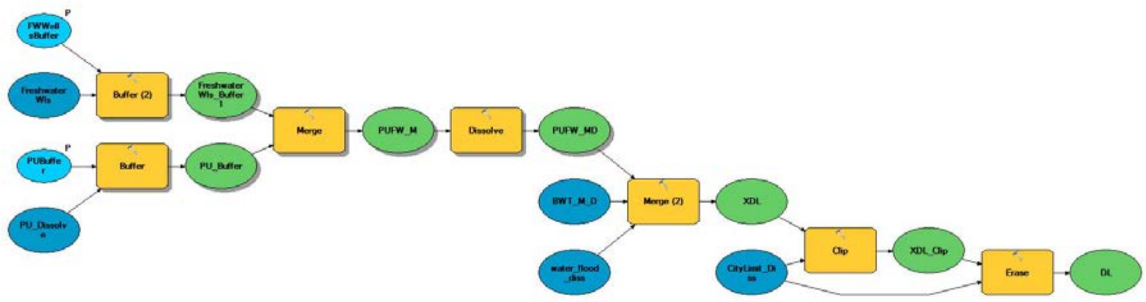

Fig. A.1 Model used for level one analysis

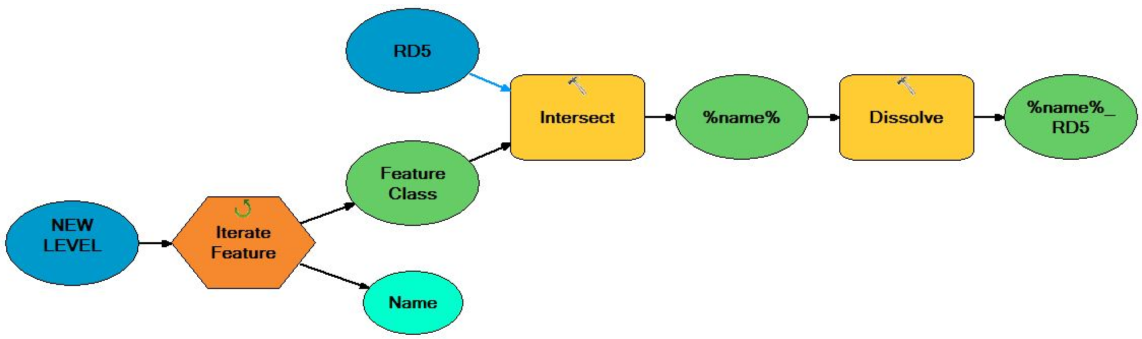

Fig. A.2 Example of model used for Analysis Level II

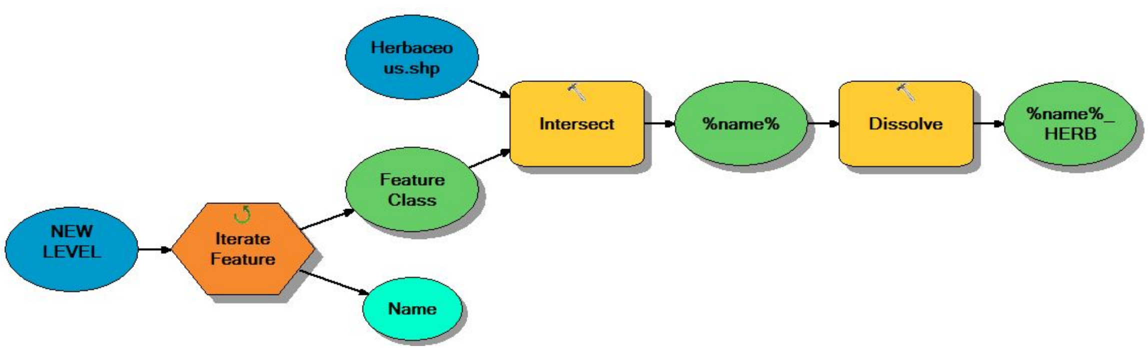

Fig. A.3 Example of model used for Analysis Level III

APPENDIX B

TABLES OF VARIABLES AND R-SQUARED OUTPUT

Table B.1 Variable and R-squared output from Analysis Level I

Setback (ft)	DL (acres)
200	34697.3
300	32749.6
400	30984.7
500	29373.1
600	27879.9
700	26476.3
800	25178.0
900	23990.8
1000	22916.6
1100	21929.5
1200	21024.6
1300	20184.2
1400	19407.0
1500	18672.4
1600	17975.0
1700	17309.6
1800	16664.9
1900	16040.9
2000	15437.3
RSQ	0.967

Table B.2 Variable and R-squared output from Analysis Level II

Setback (ft)	DL (acres)								
	RD-5	RC	NR-1	NR-2	NR-3	NR-4	NR-6	NRMU-12	NRMU
200	360.3	0.0	235.0	2918.7	165.4	1616.7	681.6	438.7	535.0
300	357.6	0.0	217.4	2609.7	115.9	1401.1	580.9	325.6	446.8
400	354.6	0.0	202.7	2360.7	79.2	1213.0	490.0	251.6	368.3
500	349.7	0.0	191.7	2169.0	51.3	1043.8	413.8	200.1	300.6
600	343.1	0.0	182.4	2012.1	31.9	890.7	348.0	161.9	247.5
700	335.1	0.0	172.8	1881.0	17.9	754.9	289.7	130.8	207.4
800	327.3	0.0	163.8	1766.5	8.7	632.7	249.1	105.5	175.7
900	321.5	0.0	155.7	1664.0	3.3	525.1	217.1	82.8	146.7
1000	317.1	0.0	147.1	1575.8	0.4	435.0	189.3	65.9	125.9
1100	315.2	0.0	138.9	1499.6	0.0	359.8	165.1	54.5	108.3
1200	314.1	0.0	131.0	1435.4	0.0	301.4	146.1	45.9	94.5
1300	314.0	0.0	123.2	1377.1	0.0	252.8	127.8	40.5	84.8
1400	314.0	0.0	115.4	1325.1	0.0	215.7	110.1	34.9	77.5
1500	313.9	0.0	107.7	1276.8	0.0	185.6	96.3	28.6	70.7
1600	313.8	0.0	99.9	1230.6	0.0	162.8	85.5	21.6	64.0
1700	313.8	0.0	92.3	1186.4	0.0	146.4	74.7	14.2	55.8
1800	313.8	0.0	84.9	1143.4	0.0	131.6	64.0	7.9	46.2
1900	313.7	0.0	77.5	1102.4	0.0	116.5	56.5	4.6	39.5
2000	313.5	0.0	69.9	1064.1	0.0	99.9	49.8	4.3	36.2
RSQ	0.784	no DL	0.990	0.899	0.560	0.870	0.855	0.770	0.815

Setback (ft)	DL (acres)									
	DR-1	DR-2	DC-N	DC-G	CM-G	CM-E	RCR-1	RCR-2	RCC-N	RCC-D
200	0.0	5.5	0.0	327.5	499.7	137.7	348.7	4.2	651.9	1023.4
300	0.0	2.6	0.0	250.4	436.8	131.0	319.3	0.8	607.4	960.8
400	0.0	1.1	0.0	195.9	379.9	125.0	291.3	0.4	560.9	890.2
500	0.0	0.4	0.0	153.9	335.7	119.3	266.5	0.0	516.5	819.3
600	0.0	0.1	0.0	118.4	295.2	113.2	242.9	0.0	474.2	750.7
700	0.0	0.0	0.0	86.4	256.6	108.3	220.0	0.0	429.0	680.5
800	0.0	0.0	0.0	57.8	224.5	103.6	201.2	0.0	386.9	614.0
900	0.0	0.0	0.0	34.6	196.5	99.3	187.6	0.0	356.4	560.8
1000	0.0	0.0	0.0	20.0	170.1	95.1	176.6	0.0	333.2	516.1
1100	0.0	0.0	0.0	10.0	144.0	91.3	167.9	0.0	316.6	476.1
1200	0.0	0.0	0.0	3.6	121.0	86.5	161.3	0.0	302.3	440.9
1300	0.0	0.0	0.0	0.7	105.6	79.8	155.8	0.0	289.2	404.2
1400	0.0	0.0	0.0	0.0	94.7	72.9	151.9	0.0	276.9	368.0
1500	0.0	0.0	0.0	0.0	86.2	65.3	148.9	0.0	263.9	334.4
1600	0.0	0.0	0.0	0.0	79.4	56.6	146.7	0.0	250.4	302.4
1700	0.0	0.0	0.0	0.0	74.0	47.8	144.1	0.0	238.4	270.4
1800	0.0	0.0	0.0	0.0	69.9	39.3	140.9	0.0	228.1	238.7
1900	0.0	0.0	0.0	0.0	68.4	31.4	137.4	0.0	217.8	208.0
2000	0.0	0.0	0.0	0.0	68.2	25.5	133.5	0.0	208.8	179.1
RSQ	no DL	0.346	no DL	0.714	0.880	0.986	0.845	0.232	0.913	0.970

Setback (ft)	DL (acres)								
	EC-C	EC-I	IC-E	IC-G	RD-5X	PD	MPC	MF-1	A
200	503.6	692.9	920.8	2756.0	8406.7	2857.3	8373.4	0.0	45.1
300	461.0	632.2	848.8	2686.6	8121.0	2666.8	8338.8	0.0	42.7
400	419.9	569.7	771.3	2609.5	7820.7	2511.8	8293.8	0.0	39.1
500	377.6	507.4	691.1	2527.1	7509.7	2372.5	8239.6	0.0	35.5
600	331.3	444.1	610.8	2438.7	7212.7	2243.1	8178.2	0.0	32.3
700	288.5	384.7	528.3	2351.0	6920.2	2122.7	8110.6	0.0	28.8
800	246.2	331.8	452.1	2263.1	6629.9	2011.6	8036.9	0.0	23.5
900	205.4	284.8	383.9	2175.6	6347.7	1909.0	7954.3	0.0	18.4
1000	169.0	243.4	328.6	2086.3	6073.6	1812.0	7866.2	0.0	14.0
1100	136.5	205.7	281.4	1993.9	5811.4	1719.0	7771.2	0.0	10.1
1200	111.1	169.0	236.4	1896.9	5561.8	1636.7	7671.4	0.0	6.7
1300	90.5	137.1	198.6	1798.3	5325.9	1562.3	7564.4	0.0	3.9
1400	73.5	113.2	168.0	1697.9	5109.8	1491.1	7450.3	0.0	1.6
1500	59.2	94.7	145.2	1589.9	4910.1	1422.2	7331.1	0.0	0.0
1600	47.8	77.7	127.2	1479.8	4724.6	1359.6	7205.6	0.0	0.0
1700	39.5	63.8	110.0	1370.2	4552.3	1305.3	7074.0	0.0	0.0
1800	32.1	51.9	95.5	1261.5	4386.2	1254.6	6940.1	0.0	0.0
1900	25.5	41.6	82.5	1155.1	4225.9	1202.4	6801.9	0.0	0.0
2000	19.6	31.6	71.1	1049.3	4074.1	1150.5	6658.1	0.0	0.0
RSQ	0.929	0.933	0.925	0.997	0.988	0.966	0.975	no DL	0.916

Table B.3 Variable and R-Squared output from Analysis Level III, zoning Subcategory and Land Cover Class Mowed/Grazed/Agriculture

Setback (ft)	DL (acres)								
	RD-5	RC	NR-1	NR-2	NR-3	NR-4	NR-6	NRMU-12	NRMU
200	350.2	0.0	219.9	2079.6	124.2	1022.8	455.0	253.6	411.1
300	347.7	0.0	207.3	1842.5	86.2	883.9	382.8	173.3	351.0
400	344.9	0.0	195.8	1655.2	58.1	755.7	319.5	121.2	296.8
500	340.6	0.0	186.6	1510.8	37.1	640.2	269.4	87.2	251.7
600	335.1	0.0	178.0	1393.0	23.5	540.6	222.3	66.1	214.7
700	328.6	0.0	168.9	1294.9	14.6	453.7	181.6	50.9	184.9
800	322.1	0.0	160.0	1209.6	7.7	372.3	154.6	38.4	159.0
900	317.2	0.0	151.9	1133.3	3.1	300.0	133.9	28.1	133.2
1000	314.0	0.0	143.6	1068.0	0.4	242.7	116.7	21.7	113.9
1100	312.2	0.0	135.6	1012.2	0.0	196.6	102.7	18.4	97.6
1200	311.4	0.0	127.8	965.7	0.0	163.4	91.7	15.9	84.7
1300	311.3	0.0	120.0	924.7	0.0	138.1	80.9	15.0	76.2
1400	311.2	0.0	112.2	888.1	0.0	121.2	71.1	13.6	71.0
1500	311.1	0.0	104.5	855.1	0.0	110.3	64.1	11.6	65.4
1600	311.1	0.0	96.7	823.3	0.0	102.8	57.7	9.7	59.8
1700	311.0	0.0	89.1	792.8	0.0	96.6	50.2	7.7	52.9
1800	311.0	0.0	81.8	763.8	0.0	90.4	43.0	5.8	43.9
1900	311.0	0.0	74.3	736.1	0.0	83.5	38.9	4.4	37.4
2000	310.8	0.0	66.8	709.7	0.0	74.9	35.2	4.3	34.1
RSQ	0.782	no DL	0.997	0.888	0.561	0.835	0.830	0.641	0.853

Setback (ft)	DL (acres)									
	DR-1	DR-2	DC-N	DC-G	CM-G	CM-E	RCR-1	RCR-2	RCC-N	RCC-D
200	0.0	5.3	0.0	253.6	385.4	61.2	233.8	3.2	475.5	821.5
300	0.0	2.5	0.0	196.3	337.6	58.1	220.3	0.8	441.6	768.4
400	0.0	1.1	0.0	154.1	293.1	56.1	208.9	0.4	410.3	709.9
500	0.0	0.4	0.0	119.9	257.6	54.2	200.2	0.0	382.3	653.5
600	0.0	0.1	0.0	90.5	227.3	51.5	191.3	0.0	359.4	600.6
700	0.0	0.0	0.0	64.6	198.6	49.3	180.7	0.0	334.2	545.4
800	0.0	0.0	0.0	42.7	175.9	47.9	172.2	0.0	311.0	494.1
900	0.0	0.0	0.0	24.2	157.3	47.1	165.5	0.0	293.8	452.3
1000	0.0	0.0	0.0	12.9	140.6	46.4	159.2	0.0	280.4	416.3
1100	0.0	0.0	0.0	6.2	121.9	45.8	153.0	0.0	270.6	383.0
1200	0.0	0.0	0.0	2.9	103.3	44.6	147.9	0.0	260.4	353.3
1300	0.0	0.0	0.0	0.7	91.0	41.4	144.4	0.0	250.8	321.8
1400	0.0	0.0	0.0	0.0	82.1	39.0	141.8	0.0	240.0	290.9
1500	0.0	0.0	0.0	0.0	74.6	34.9	139.5	0.0	227.5	261.3
1600	0.0	0.0	0.0	0.0	68.9	30.4	137.4	0.0	214.3	232.9
1700	0.0	0.0	0.0	0.0	65.0	26.2	134.8	0.0	202.7	205.4
1800	0.0	0.0	0.0	0.0	62.7	23.5	131.7	0.0	192.7	179.0
1900	0.0	0.0	0.0	0.0	62.2	20.8	128.3	0.0	182.6	153.2
2000	0.0	0.0	0.0	0.0	62.1	18.6	124.6	0.0	173.9	129.1
RSQ	no DL	0.345	no DL	0.706	0.879	0.958	0.926	0.251	0.951	0.976

Setback (ft)	DL (acres)								
	EC-C	EC-I	IC-E	IC-G	RD-5X	PD	MPC	MF-1	A
200	332.7	437.9	793.5	2309.0	4171.4	2594.8	7600.8	0.0	43.8
300	301.6	398.3	729.7	2260.9	4067.9	2434.9	7568.0	0.0	41.4
400	270.9	358.9	661.3	2206.2	3945.9	2303.6	7525.2	0.0	37.9
500	242.6	318.4	593.4	2143.8	3809.3	2185.1	7472.8	0.0	34.4
600	212.5	277.8	524.9	2075.1	3676.0	2075.8	7413.9	0.0	31.2
700	183.4	239.0	455.8	2004.8	3542.6	1973.4	7350.1	0.0	28.0
800	152.1	203.8	391.2	1934.2	3406.3	1878.6	7280.9	0.0	23.5
900	119.0	171.9	334.2	1862.5	3270.1	1790.3	7202.6	0.0	18.4
1000	89.2	142.5	286.5	1787.9	3135.3	1707.1	7118.9	0.0	14.0
1100	64.1	115.4	244.9	1710.9	3005.4	1626.6	7030.4	0.0	10.1
1200	45.9	90.3	206.1	1631.1	2880.9	1553.9	6939.6	0.0	6.7
1300	33.2	69.9	174.2	1549.0	2759.5	1488.3	6842.0	0.0	3.9
1400	25.3	56.2	148.7	1464.5	2648.3	1425.4	6738.5	0.0	1.6
1500	18.7	46.2	129.7	1377.7	2547.8	1365.0	6628.8	0.0	0.0
1600	12.6	36.8	113.8	1290.0	2452.4	1310.1	6512.8	0.0	0.0
1700	9.6	29.8	98.4	1202.0	2360.3	1261.0	6394.7	0.0	0.0
1800	7.0	23.9	84.4	1114.0	2272.6	1214.7	6273.5	0.0	0.0
1900	4.9	19.0	71.8	1026.3	2186.7	1168.2	6147.6	0.0	0.0
2000	2.8	15.9	60.9	939.7	2105.6	1122.5	6019.3	0.0	0.0
RSQ	0.904	0.922	0.928	0.996	0.994	0.970	0.978	no DL	0.920

Table B.4 Variable and R-Squared output from Analysis Level III, zoning Subcategory and Land Cover Class Trees

Setback (ft)	DL (acres)								
	RD-5	RC	NR-1	NR-2	NR-3	NR-4	NR-6	NRMU-12	NRMU
200	5.5	0.0	14.1	788.1	41.1	560.4	220.3	161.2	122.0
300	5.3	0.0	9.4	718.6	29.7	485.7	192.3	130.7	94.3
400	5.3	0.0	6.3	659.8	21.1	427.4	165.2	110.9	70.5
500	5.1	0.0	4.6	615.1	14.2	376.5	140.1	96.3	48.3
600	4.8	0.0	4.1	577.5	8.4	326.6	121.7	82.1	32.3
700	3.9	0.0	3.9	545.7	3.3	281.5	104.3	69.2	22.2
800	3.1	0.0	3.8	517.4	1.0	242.6	90.8	59.7	16.3
900	2.6	0.0	3.7	492.5	0.2	208.8	79.6	50.0	13.3
1000	2.1	0.0	3.4	470.6	0.0	178.3	69.1	41.7	11.8
1100	2.1	0.0	3.3	450.9	0.0	152.0	59.0	35.3	10.6
1200	2.1	0.0	3.2	433.5	0.0	128.9	51.0	30.0	9.6
1300	2.1	0.0	3.2	416.9	0.0	107.2	43.6	25.6	8.5
1400	2.1	0.0	3.2	402.5	0.0	88.7	35.7	21.3	6.4
1500	2.1	0.0	3.2	387.8	0.0	71.2	29.2	17.0	5.1
1600	2.1	0.0	3.2	373.9	0.0	56.8	25.0	11.9	4.0
1700	2.1	0.0	3.2	360.7	0.0	47.3	21.9	6.5	2.8
1800	2.1	0.0	3.2	347.3	0.0	39.5	18.8	2.1	2.1
1900	2.1	0.0	3.2	334.4	0.0	31.7	15.7	0.1	1.9
2000	2.1	0.0	3.1	322.9	0.0	24.2	12.8	0.0	1.9
RSQ	0.761	no DL	0.449	0.926	0.555	0.917	0.897	0.900	0.658

Setback (ft)	DL (acres)									
	DR-1	DR-2	DC-N	DC-G	CM-G	CM-E	RCR-1	RCR-2	RCC-N	RCC-D
200	0.0	0.2	0.0	73.8	104.6	70.1	114.7	1.0	167.3	178.9
300	0.0	0.1	0.0	54.1	89.9	66.7	98.8	0.1	156.8	169.6
400	0.0	0.0	0.0	41.8	77.7	62.8	82.2	0.0	141.7	157.8
500	0.0	0.0	0.0	34.0	69.0	59.0	66.1	0.0	125.4	143.7
600	0.0	0.0	0.0	27.9	59.0	55.6	51.3	0.0	106.0	128.2
700	0.0	0.0	0.0	21.8	49.1	53.0	39.1	0.0	86.0	113.6
800	0.0	0.0	0.0	15.1	40.2	49.8	28.8	0.0	67.6	98.9
900	0.0	0.0	0.0	10.3	32.3	46.7	21.8	0.0	54.5	87.7
1000	0.0	0.0	0.0	7.1	24.0	43.5	17.2	0.0	45.8	79.4
1100	0.0	0.0	0.0	3.8	17.4	40.2	14.6	0.0	40.4	73.1
1200	0.0	0.0	0.0	0.7	13.2	37.0	13.1	0.0	36.9	68.0
1300	0.0	0.0	0.0	0.0	10.1	33.6	11.2	0.0	34.0	63.0
1400	0.0	0.0	0.0	0.0	8.2	30.5	9.8	0.0	32.6	58.0
1500	0.0	0.0	0.0	0.0	7.2	27.3	9.2	0.0	32.2	54.5
1600	0.0	0.0	0.0	0.0	6.1	23.4	9.1	0.0	31.9	51.8
1700	0.0	0.0	0.0	0.0	4.6	19.0	9.0	0.0	31.6	48.0
1800	0.0	0.0	0.0	0.0	2.9	13.8	9.0	0.0	31.3	43.7
1900	0.0	0.0	0.0	0.0	1.9	8.9	8.9	0.0	31.1	39.9
2000	0.0	0.0	0.0	0.0	1.7	6.0	8.7	0.0	30.8	35.6
RSQ	no DL	0.369	no DL	0.740	0.876	0.996	0.741	0.167	0.794	0.923

Setback (ft)	DL (acres)								
	EC-C	EC-I	IC-E	IC-G	RD-5X	PD	MPC	MF-1	A
200	169.1	248.9	117.2	327.0	1889.1	236.0	695.7	0.0	1.4
300	157.6	227.9	109.8	306.2	1867.4	207.0	694.1	0.0	1.3
400	147.2	204.9	101.2	285.8	1838.8	184.4	692.1	0.0	1.2
500	133.3	183.2	90.0	268.4	1809.1	164.7	690.4	0.0	1.1
600	117.3	160.8	79.3	251.4	1783.4	145.7	688.1	0.0	1.1
700	103.6	140.2	66.9	236.7	1758.9	128.7	684.9	0.0	0.7
800	92.8	122.6	56.3	222.8	1733.8	113.5	680.7	0.0	0.0
900	85.2	107.8	46.3	210.1	1708.6	100.0	676.5	0.0	0.0
1000	78.7	96.0	39.4	198.8	1681.7	87.6	672.3	0.0	0.0
1100	71.3	85.5	34.6	187.2	1654.2	75.7	666.2	0.0	0.0
1200	64.3	74.5	28.8	175.8	1624.5	67.4	658.1	0.0	0.0
1300	56.6	63.5	22.9	165.1	1593.8	59.5	649.3	0.0	0.0
1400	47.5	53.8	17.9	154.5	1560.3	52.1	639.2	0.0	0.0
1500	40.2	45.9	14.3	139.2	1524.0	44.1	630.2	0.0	0.0
1600	35.0	38.7	12.2	123.7	1488.3	37.3	621.2	0.0	0.0
1700	29.7	32.0	10.6	108.6	1455.0	32.5	608.8	0.0	0.0
1800	24.9	26.1	10.2	94.5	1422.8	28.5	597.1	0.0	0.0
1900	20.5	20.8	10.1	83.1	1395.3	23.5	585.5	0.0	0.0
2000	16.6	14.3	9.7	71.3	1369.5	18.4	570.8	0.0	0.0
RSQ	0.968	0.946	0.913	0.994	0.997	0.933	0.927	no DL	0.674

Table B.5 Variable and R-Squared output from Analysis Level III, zoning Subcategory and Land Cover Class Herbaceous

Setback (ft)	DL (acres)								
	RD-5	RC	NR-1	NR-2	NR-3	NR-4	NR-6	NRMU-12	NRMU
200	4.7	0.0	0.0	36.8	0.0	28.0	5.0	1.3	1.7
300	4.6	0.0	0.0	35.1	0.0	25.9	4.7	0.5	1.3
400	4.4	0.0	0.0	33.8	0.0	24.3	4.3	0.2	0.9
500	4.0	0.0	0.0	32.6	0.0	22.2	4.2	0.1	0.6
600	3.2	0.0	0.0	32.0	0.0	19.8	3.8	0.1	0.3
700	2.6	0.0	0.0	31.4	0.0	16.9	3.7	0.0	0.3
800	2.1	0.0	0.0	31.1	0.0	15.4	3.6	0.0	0.3
900	1.7	0.0	0.0	30.3	0.0	14.4	3.5	0.0	0.2
1000	1.0	0.0	0.0	29.6	0.0	12.4	3.5	0.0	0.1
1100	0.8	0.0	0.0	29.2	0.0	10.4	3.5	0.0	0.1
1200	0.6	0.0	0.0	29.0	0.0	9.0	3.4	0.0	0.1
1300	0.6	0.0	0.0	28.4	0.0	7.3	3.3	0.0	0.1
1400	0.6	0.0	0.0	27.5	0.0	5.7	3.2	0.0	0.1
1500	0.6	0.0	0.0	27.1	0.0	4.1	3.1	0.0	0.1
1600	0.6	0.0	0.0	26.8	0.0	3.2	2.9	0.0	0.1
1700	0.6	0.0	0.0	26.4	0.0	2.4	2.5	0.0	0.1
1800	0.6	0.0	0.0	26.0	0.0	1.7	2.2	0.0	0.1
1900	0.6	0.0	0.0	25.7	0.0	1.3	2.0	0.0	0.1
2000	0.6	0.0	0.0	25.5	0.0	0.8	1.8	0.0	0.1
RSQ	0.808	no DL	no DL	0.957	no DL	0.974	0.942	0.329	0.574

Setback (ft)	DL (acres)									
	DR-1	DR-2	DC-N	DC-G	CM-G	CM-E	RCR-1	RCR-2	RCC-N	RCC-D
200	0.0	0.0	0.0	0.0	4.9	6.4	0.0	0.0	8.3	16.1
300	0.0	0.0	0.0	0.0	4.7	6.2	0.0	0.0	8.3	15.9
400	0.0	0.0	0.0	0.0	4.6	6.0	0.0	0.0	8.2	15.5
500	0.0	0.0	0.0	0.0	4.5	6.0	0.0	0.0	8.2	15.2
600	0.0	0.0	0.0	0.0	4.4	6.0	0.0	0.0	8.2	15.0
700	0.0	0.0	0.0	0.0	4.4	6.0	0.0	0.0	8.2	14.7
800	0.0	0.0	0.0	0.0	4.4	5.9	0.0	0.0	7.7	14.1
900	0.0	0.0	0.0	0.0	4.4	5.5	0.0	0.0	7.4	13.9
1000	0.0	0.0	0.0	0.0	4.4	5.2	0.0	0.0	6.5	13.5
1100	0.0	0.0	0.0	0.0	4.4	5.2	0.0	0.0	5.1	13.1
1200	0.0	0.0	0.0	0.0	4.4	4.9	0.0	0.0	4.5	12.9
1300	0.0	0.0	0.0	0.0	4.4	4.8	0.0	0.0	3.8	12.6
1400	0.0	0.0	0.0	0.0	4.4	3.5	0.0	0.0	3.7	12.3
1500	0.0	0.0	0.0	0.0	4.4	3.1	0.0	0.0	3.7	11.6
1600	0.0	0.0	0.0	0.0	4.4	2.9	0.0	0.0	3.6	10.9
1700	0.0	0.0	0.0	0.0	4.4	2.6	0.0	0.0	3.6	10.1
1800	0.0	0.0	0.0	0.0	4.3	2.0	0.0	0.0	3.6	9.2
1900	0.0	0.0	0.0	0.0	4.3	1.6	0.0	0.0	3.6	8.1
2000	0.0	0.0	0.0	0.0	4.3	0.9	0.0	0.0	3.6	7.7
RSQ	no DL	no DL	no DL	no DL	0.592	0.905	no DL	no DL	0.881	0.952

Setback (ft)	DL (acres)								
	EC-C	EC-I	IC-E	IC-G	RD-5X	PD	MPC	MF-1	A
200	1.8	6.0	8.9	33.6	213.7	11.0	55.2	0.0	0.0
300	1.8	5.9	8.2	33.3	207.8	9.9	55.1	0.0	0.0
400	1.8	5.9	7.6	32.8	200.3	9.3	54.8	0.0	0.0
500	1.7	5.8	6.7	32.2	193.4	8.9	54.8	0.0	0.0
600	1.5	5.6	5.9	31.8	186.3	8.6	54.5	0.0	0.0
700	1.4	5.5	5.1	31.3	178.9	8.1	54.1	0.0	0.0
800	1.3	5.3	4.0	30.2	172.2	7.6	53.8	0.0	0.0
900	1.2	5.1	3.0	29.3	166.6	7.4	53.6	0.0	0.0
1000	1.1	4.9	2.4	28.6	161.4	7.0	53.5	0.0	0.0
1100	1.0	4.7	1.8	27.6	156.5	6.6	53.2	0.0	0.0
1200	1.0	4.2	1.5	25.0	152.2	6.1	52.4	0.0	0.0
1300	0.7	3.7	1.5	23.0	148.8	5.4	51.9	0.0	0.0
1400	0.6	3.2	1.3	22.0	146.0	4.8	51.5	0.0	0.0
1500	0.4	2.6	1.2	20.9	142.4	4.3	51.1	0.0	0.0
1600	0.2	2.2	1.1	18.9	140.0	3.6	50.6	0.0	0.0
1700	0.2	2.0	1.0	17.8	137.8	3.3	49.6	0.0	0.0
1800	0.1	1.9	0.9	17.0	135.2	3.0	48.8	0.0	0.0
1900	0.1	1.8	0.7	15.7	132.1	2.5	48.2	0.0	0.0
2000	0.1	1.3	0.5	13.8	128.9	1.6	47.3	0.0	0.0
RSQ	0.977	0.949	0.874	0.968	0.960	0.993	0.941	no DL	no DL

APPENDIX C

GRAPHS OF SETBACK DISTANCE VERSUS DRILLABLE LAND

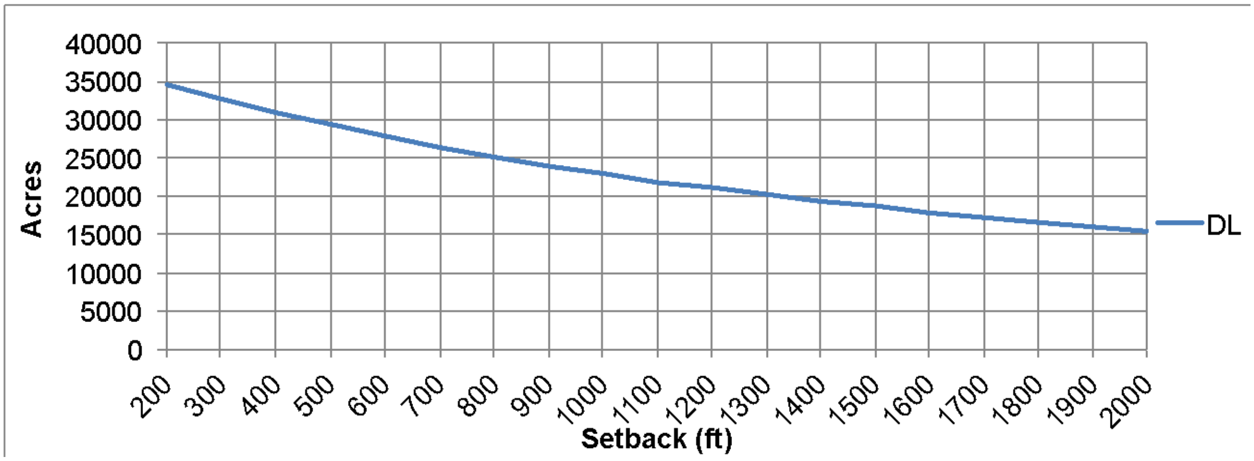

Fig. C.1 Setback distance versus drillable land for study area as a whole

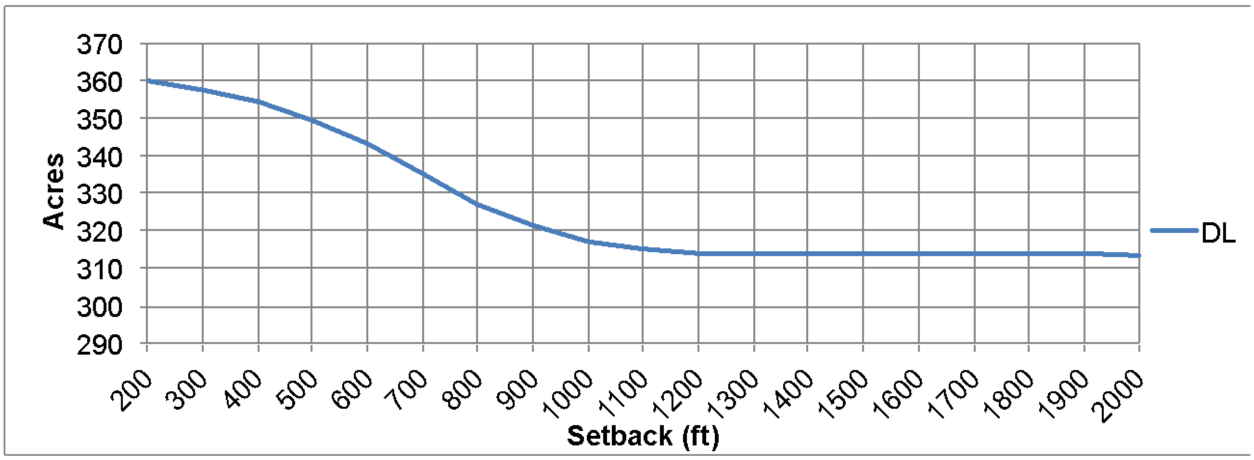

Fig. C.2 Setback distance versus drillable land for zoning subcategory RD-5

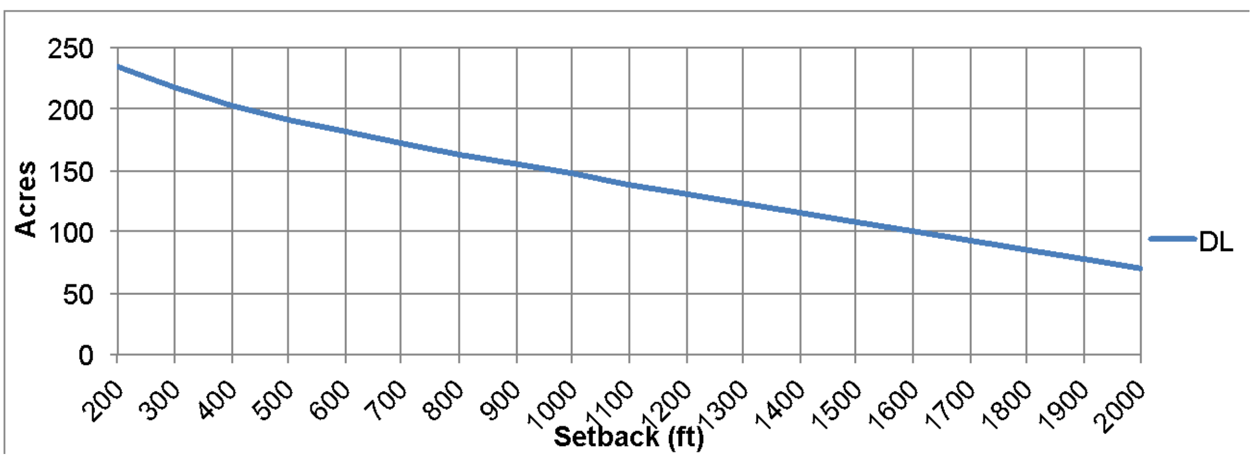

Fig. C.3 Setback distance versus drillable land for zoning subcategory NR-1

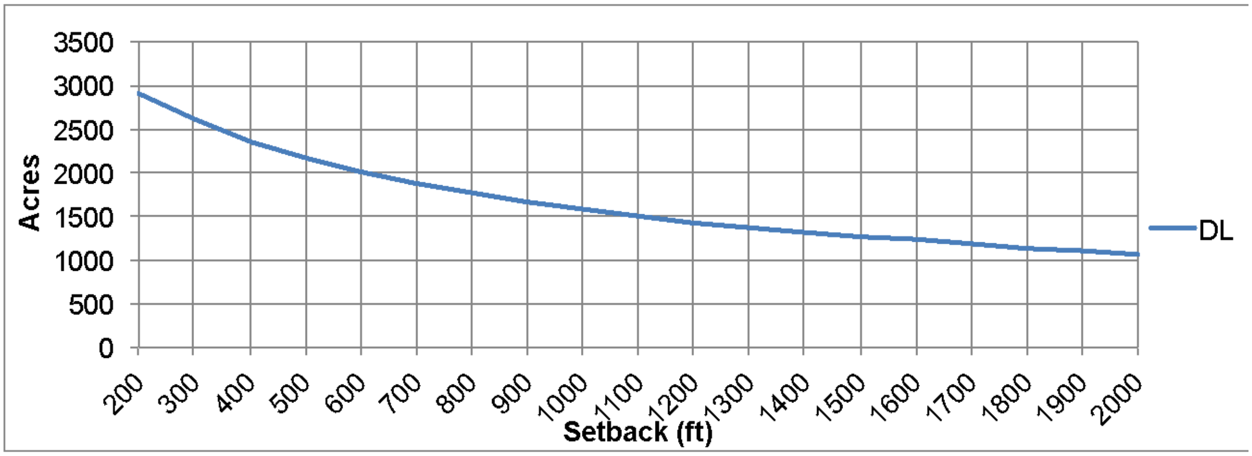

Fig. C.4 Setback distance versus drillable land for zoning subcategory NR-2

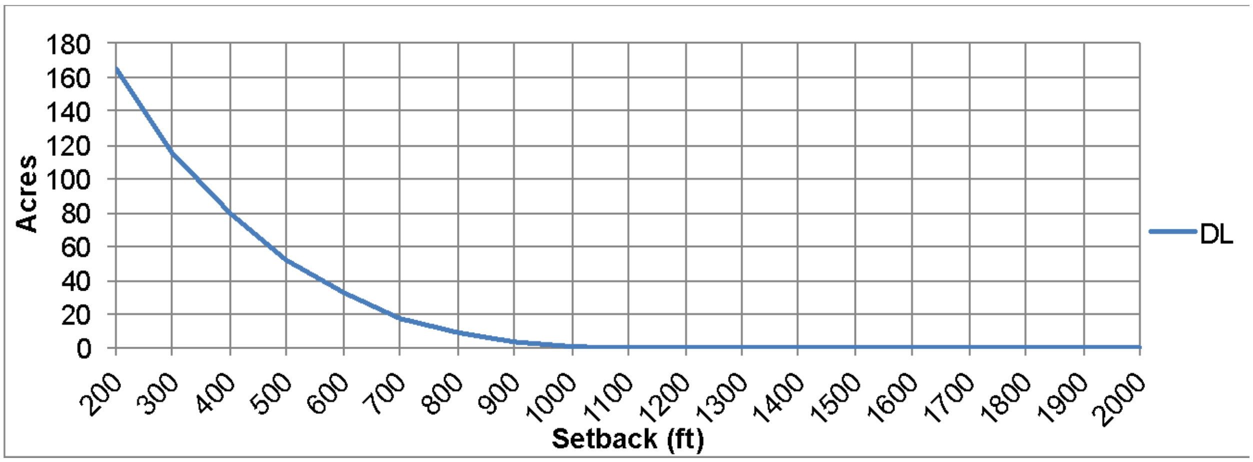

Fig. C.5 Setback distance versus drillable land for zoning subcategory NR-3

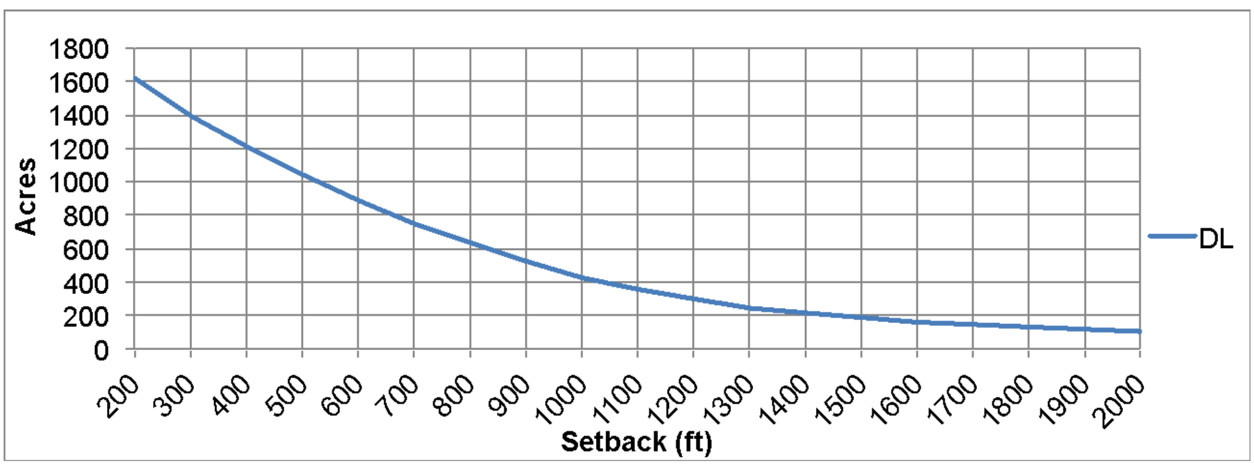

Fig. C.6 Setback distance versus drillable land for zoning subcategory NR-4

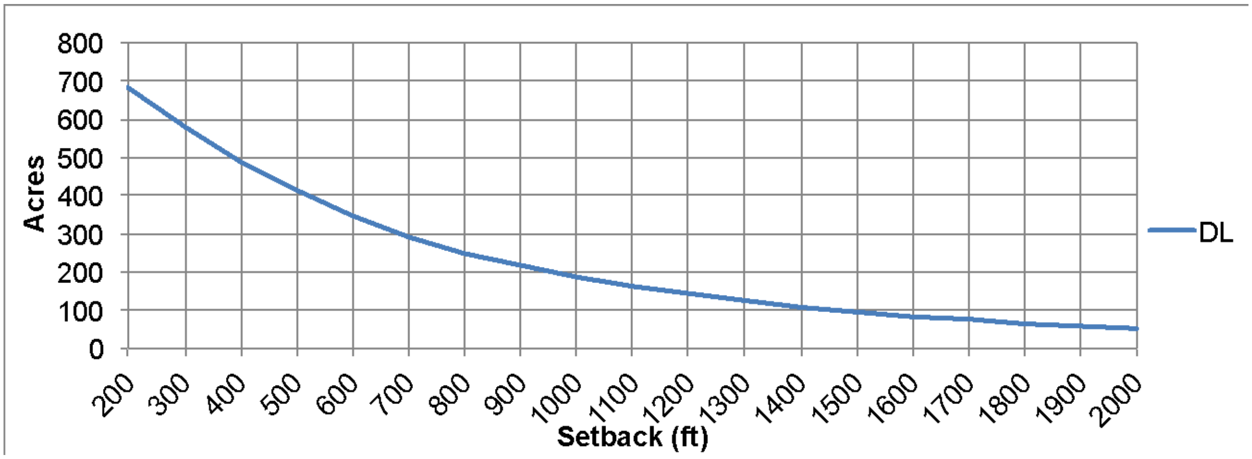

Fig. C.7 Setback distance versus drillable land for zoning subcategory NR-6

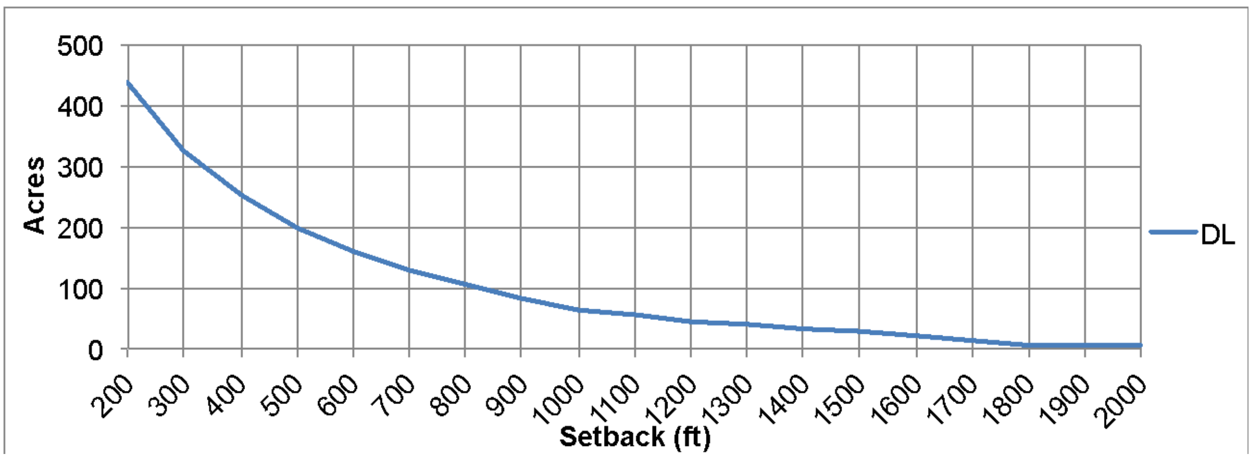

Fig. C.8 Setback distance versus drillable land for zoning subcategory NRMU-12

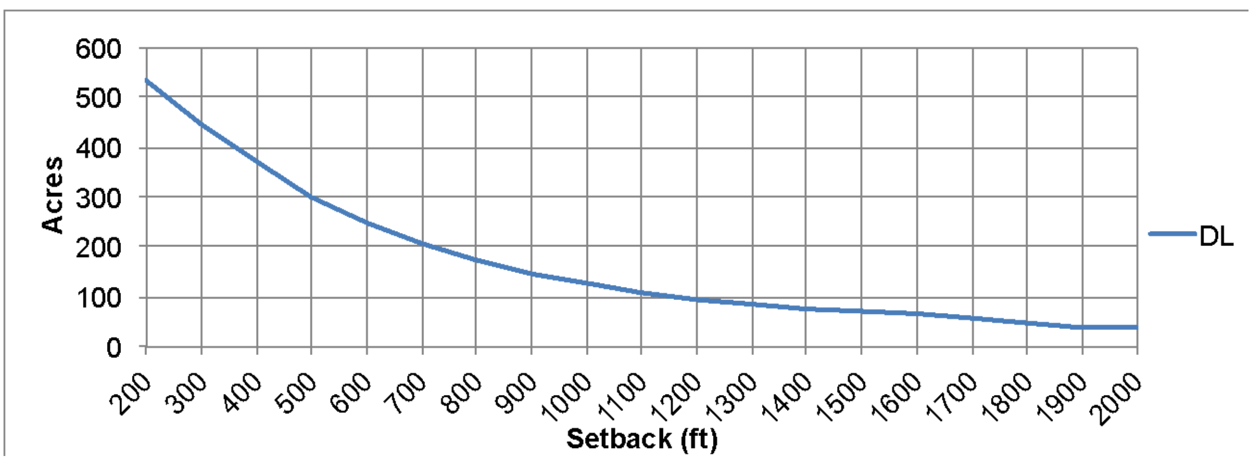

Fig. C.9 Setback distance versus drillable land for zoning subcategory NRMU

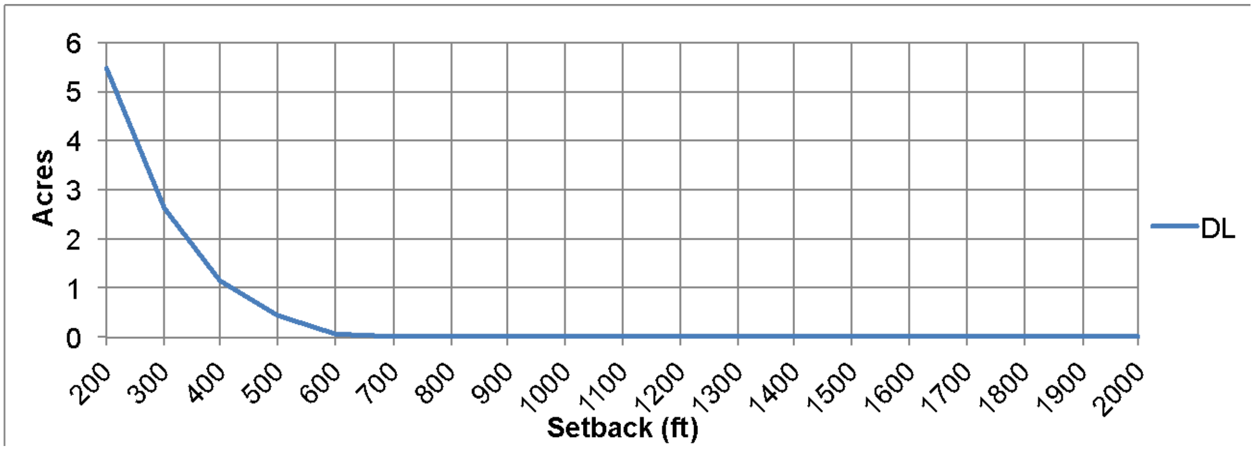

Fig. C.10 Setback distance versus drillable land for zoning subcategory DR-2

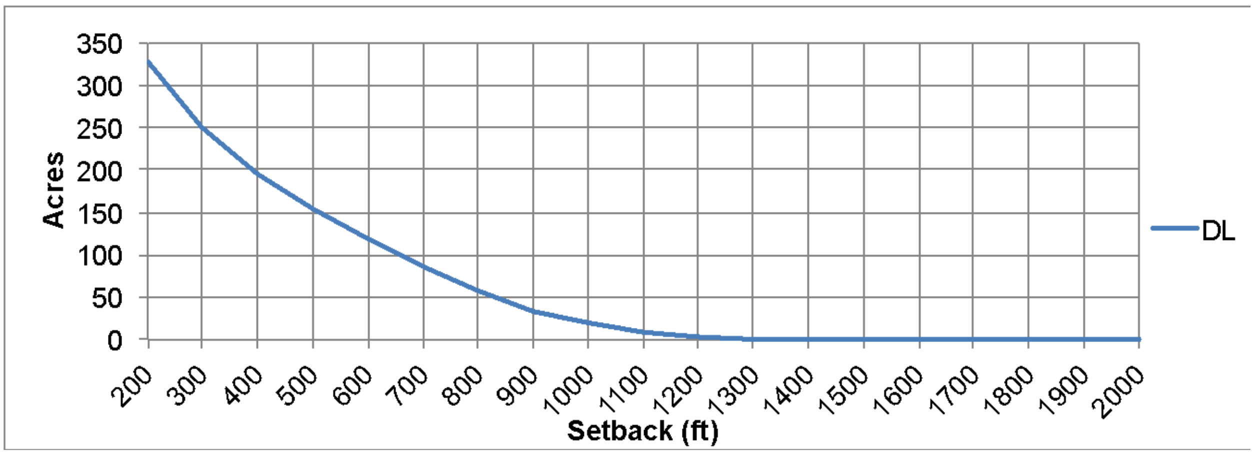

Fig. C.11 Setback distance versus drillable land for zoning subcategory DC-G

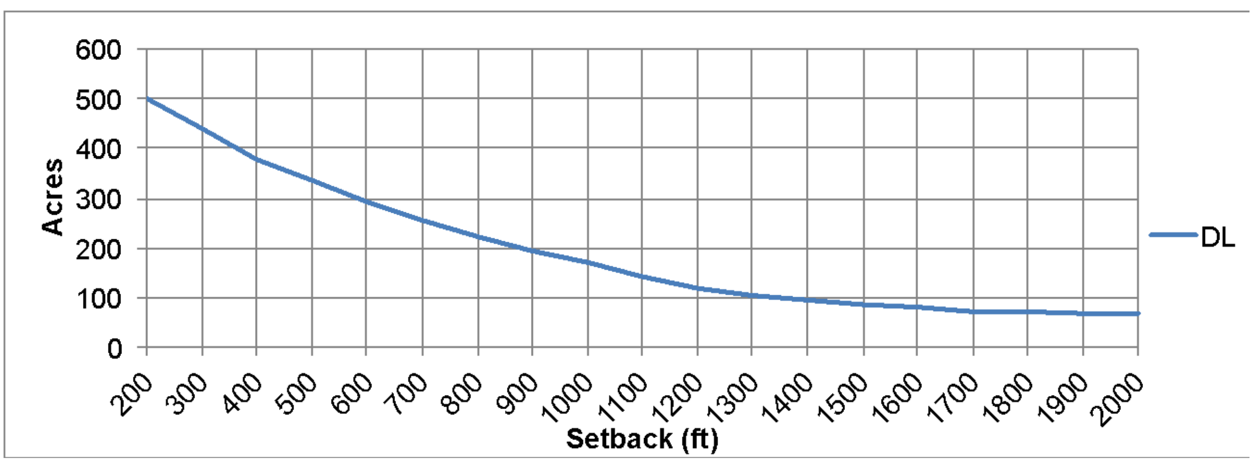

Fig. C.12 Setback distance versus drillable land for zoning subcategory CM-G

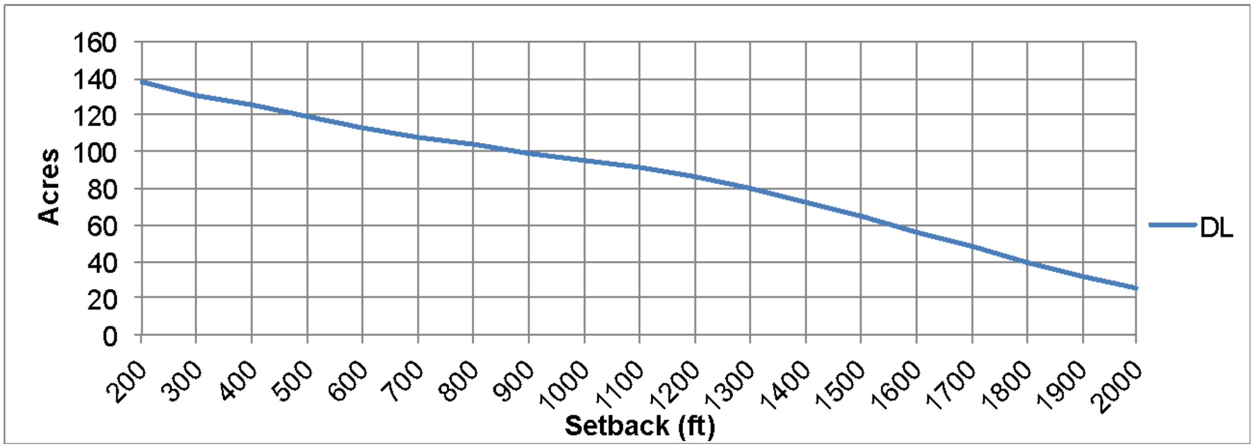

Fig. C.13 Setback distance versus drillable land for zoning subcategory CM-E

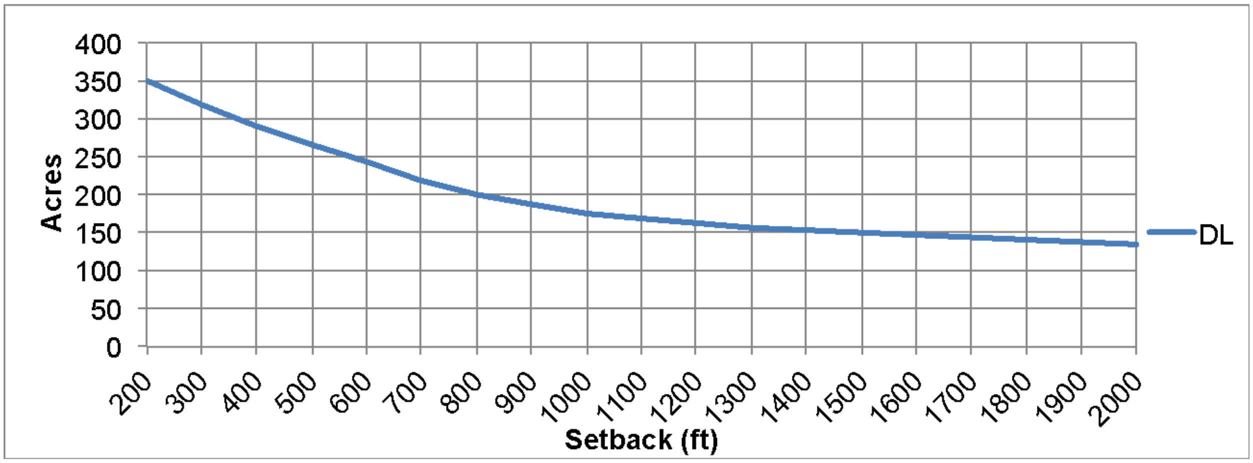

Fig. C.14 Setback distance versus drillable land for zoning subcategory RCR-1

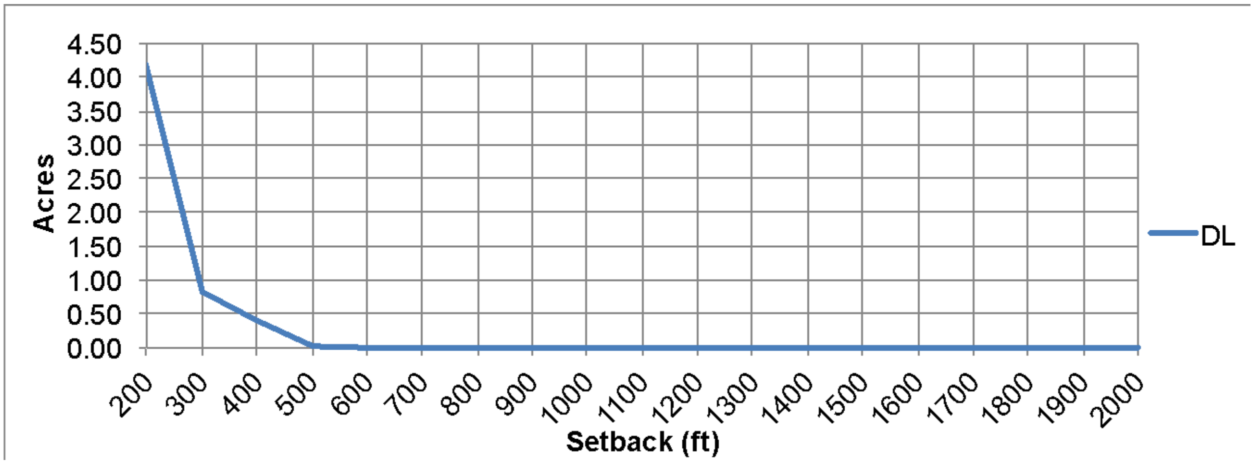

Fig. C.15 Setback distance versus drillable land for zoning subcategory RCR-2

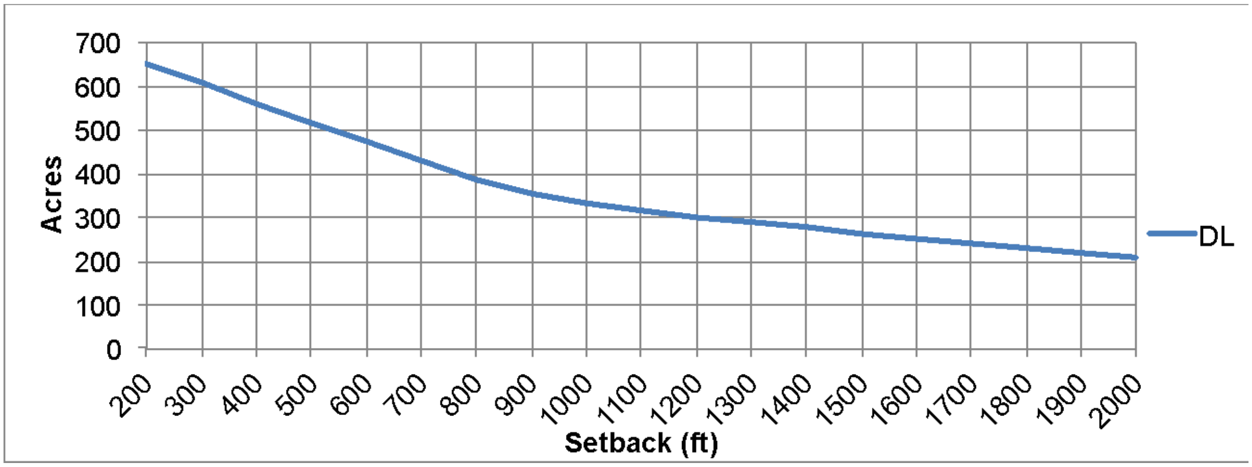

Fig. C.16 Setback distance versus drillable land for zoning subcategory RCC-N

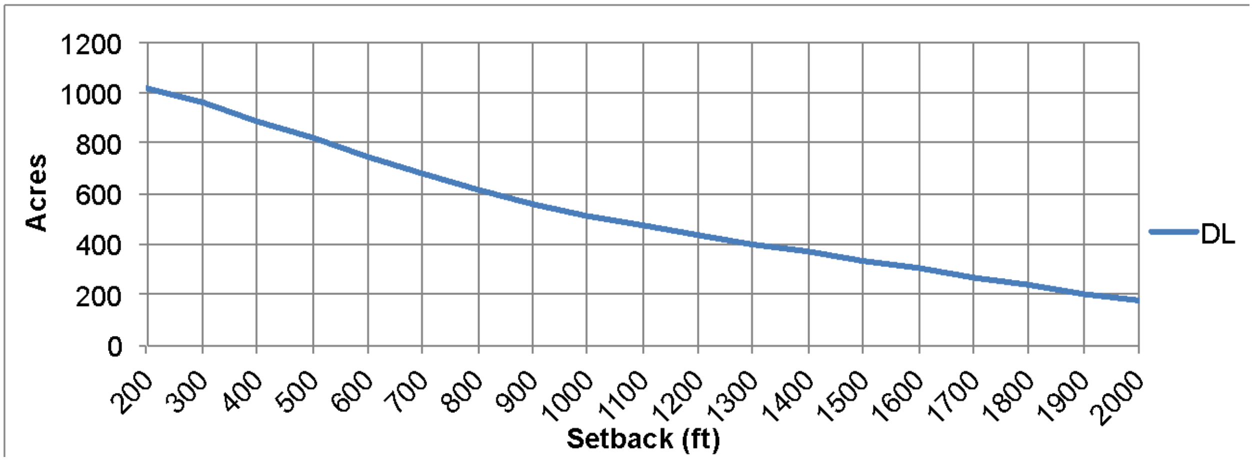

Fig. C.17 Setback distance versus drillable land for zoning subcategory RCC-D

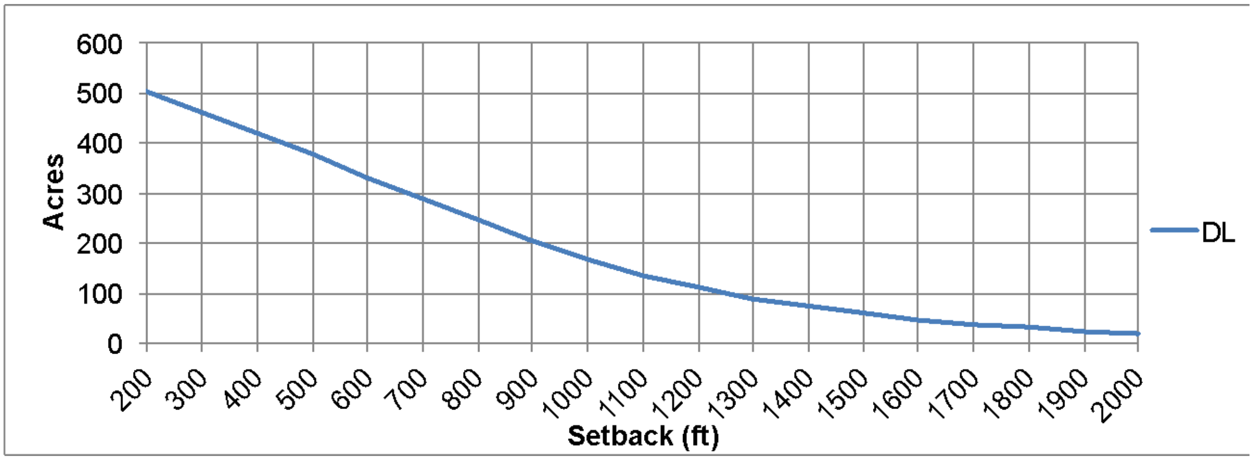

Fig. C.18 Setback distance versus drillable land for zoning subcategory EC-C

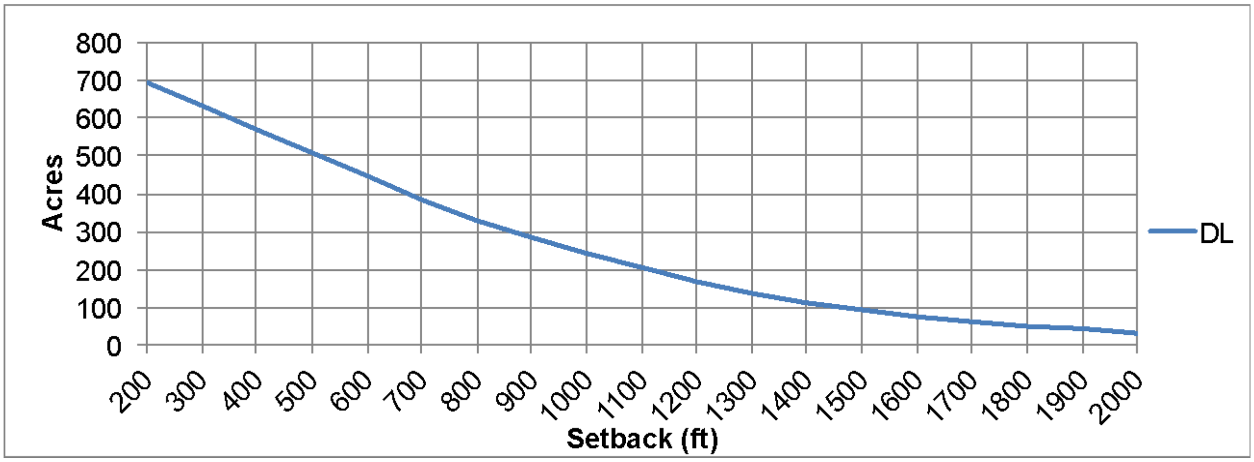

Fig. C.19 Setback distance versus drillable land for zoning subcategory EC-I

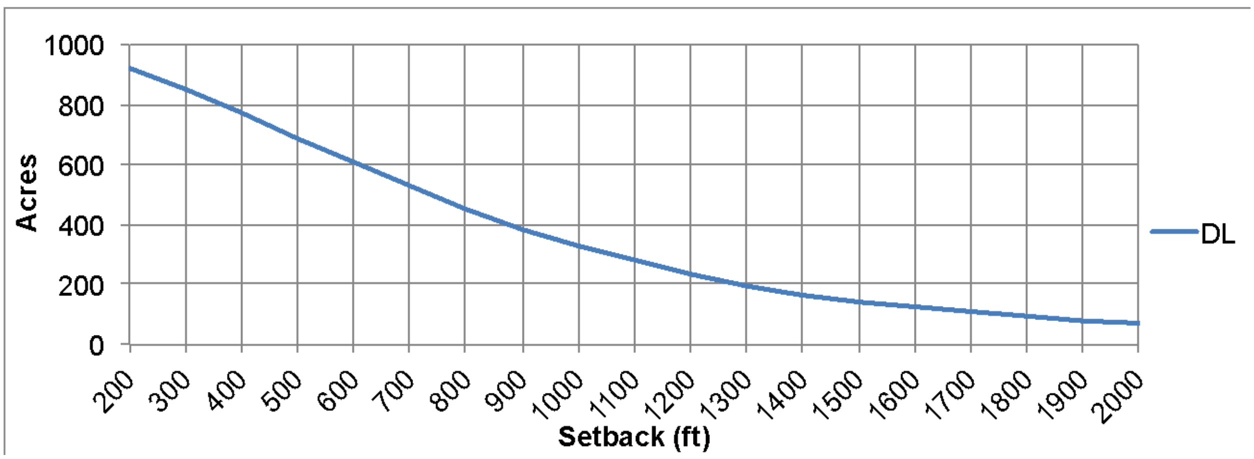

Fig. C.20 Setback distance versus drillable land for zoning subcategory IC-E

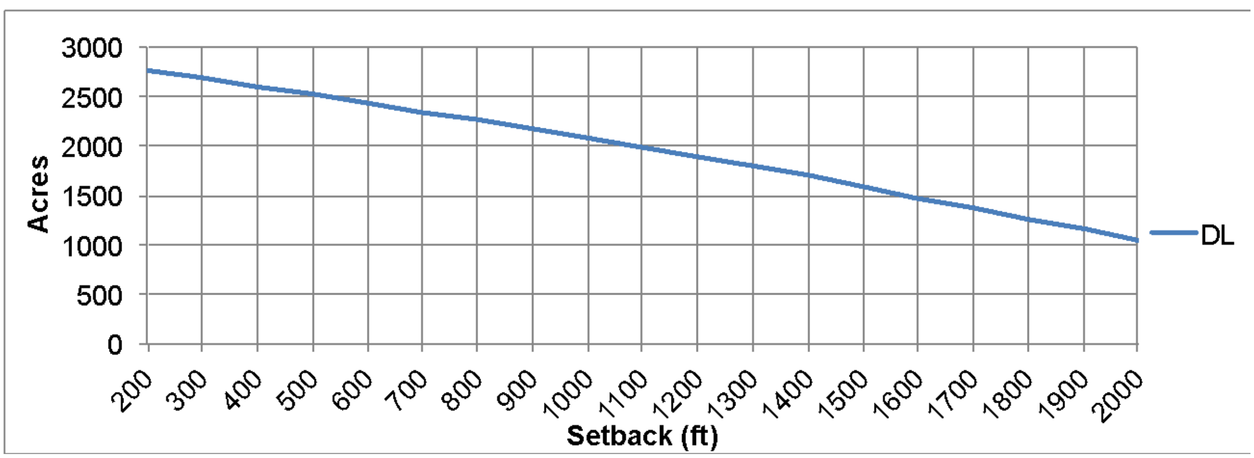

Fig. C.21 Setback distance versus drillable land for zoning subcategory IC-G

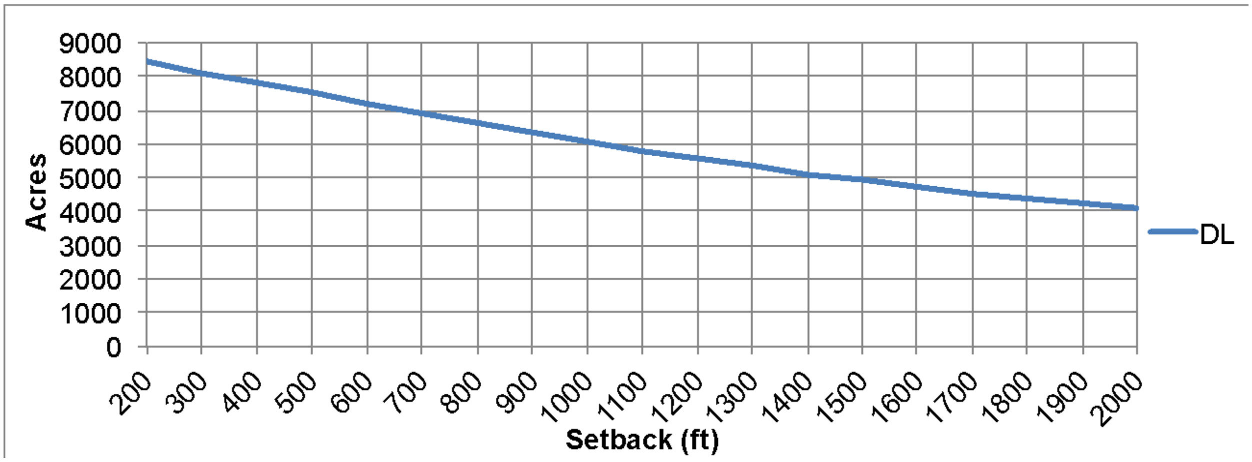

Fig. C.22 Setback distance versus drillable land for zoning subcategory RD-5X

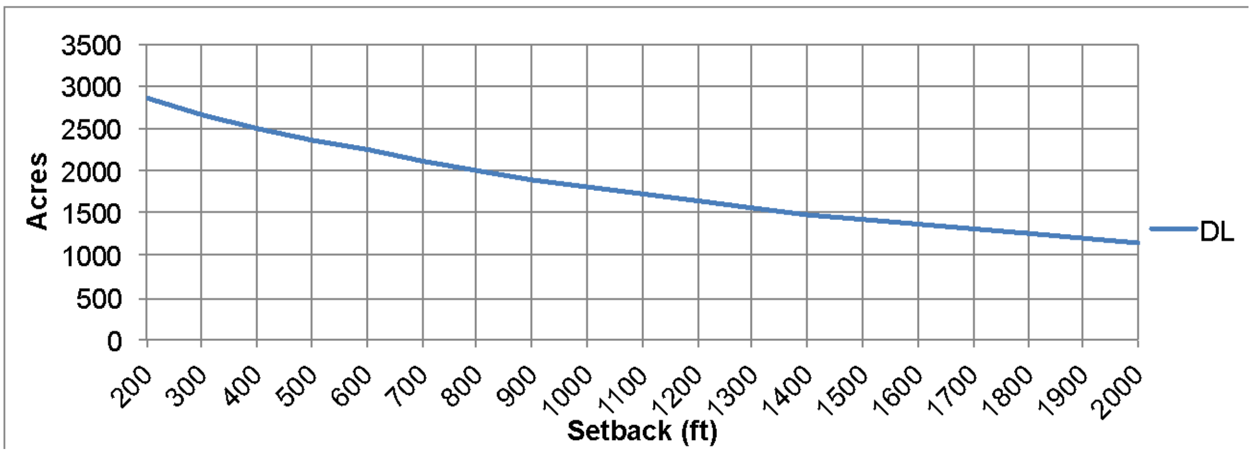

Fig. C.23 Setback distance versus drillable land for zoning subcategory PD

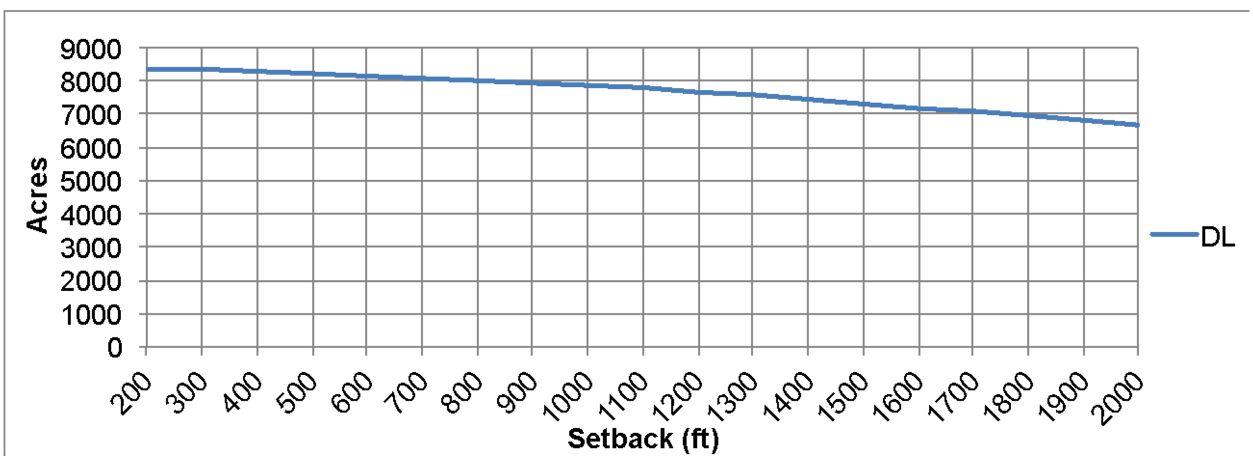

Fig. C.24 Setback distance versus drillable land for zoning subcategory MPC

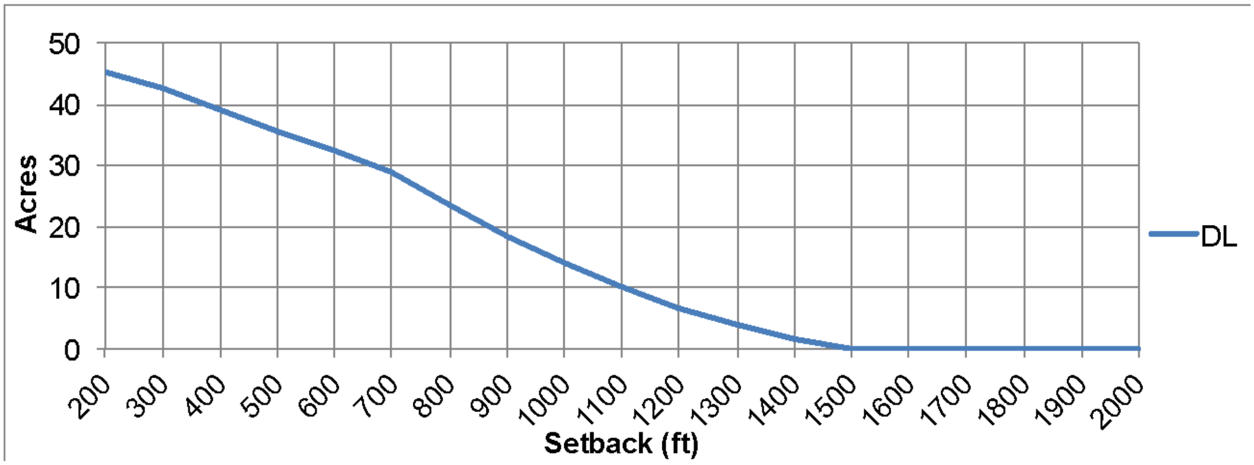

Fig. C.25 Setback distance versus drillable land for zoning subcategory A

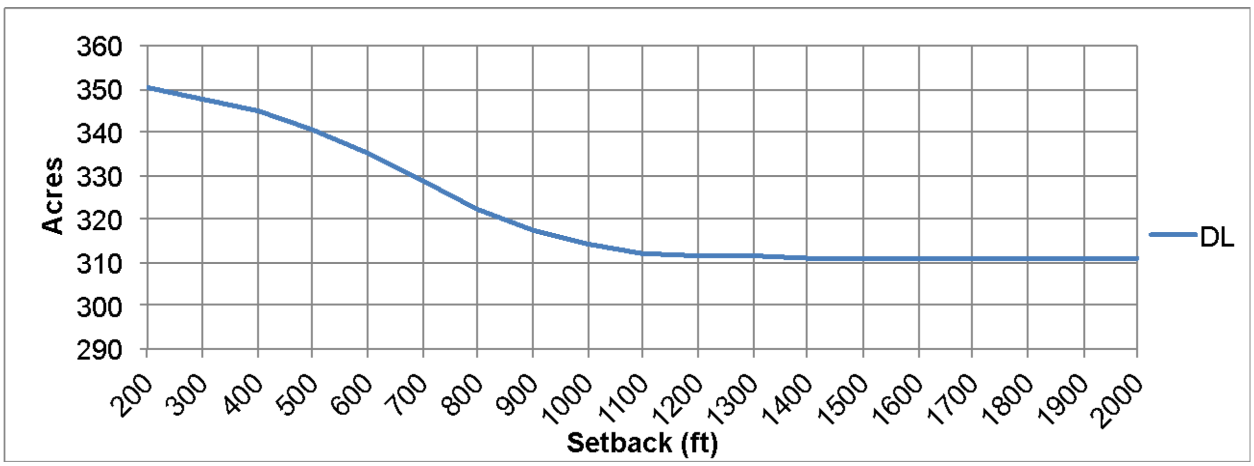

Fig. C.26 Setback distance versus drillable land for zoning subcategory RD-5 and land cover class Mowed/Grazed/Agriculture

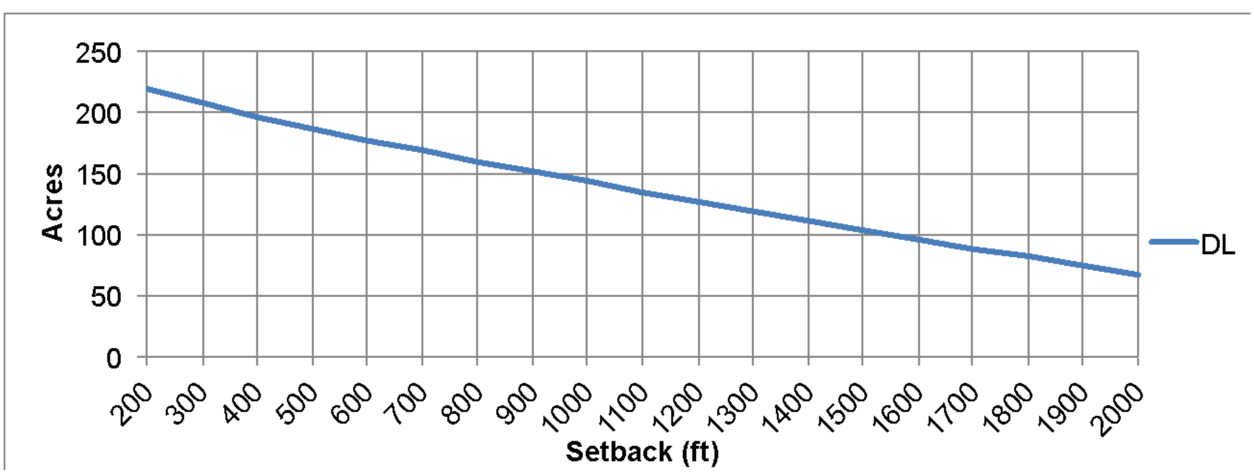

Fig. C.27 Setback distance versus drillable land for zoning subcategory NR-1 and land cover class Mowed/Grazed/Agriculture

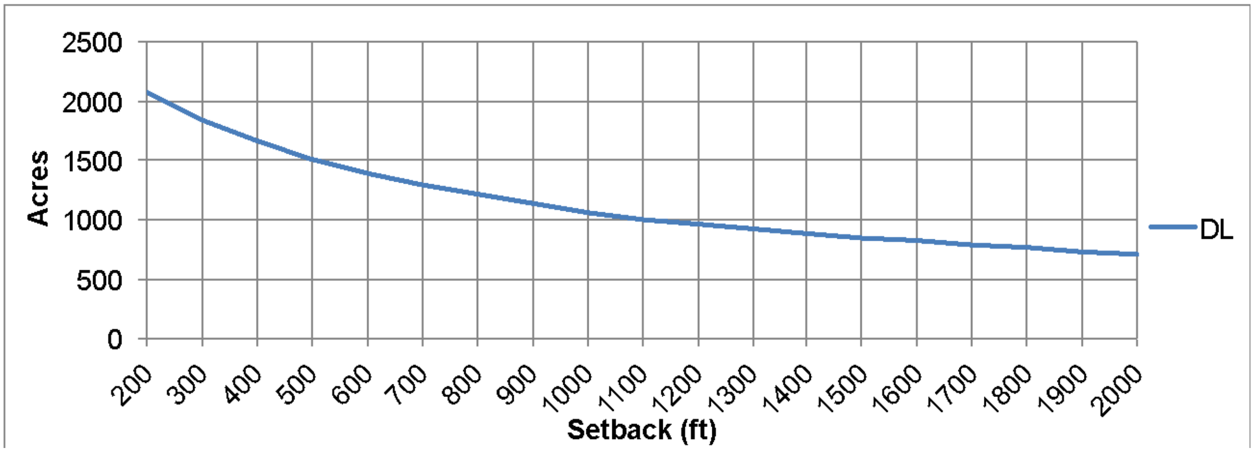

Fig. C.28 Setback distance versus drillable land for zoning subcategory NR-2 and land cover class Mowed/Grazed/Agriculture

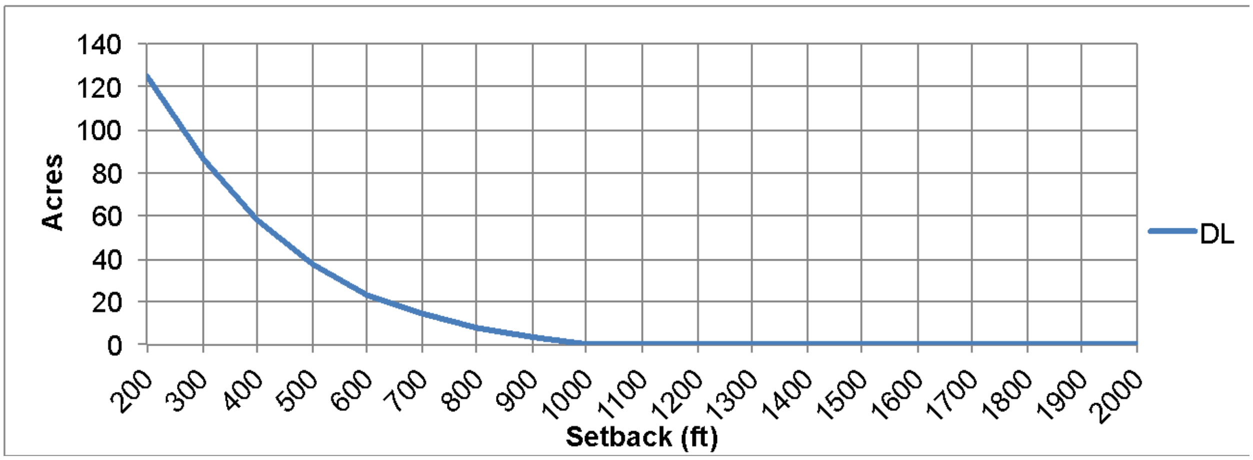

Fig. C.29 Setback distance versus drillable land for zoning subcategory NR-3 and land cover class Mowed/Grazed/Agriculture

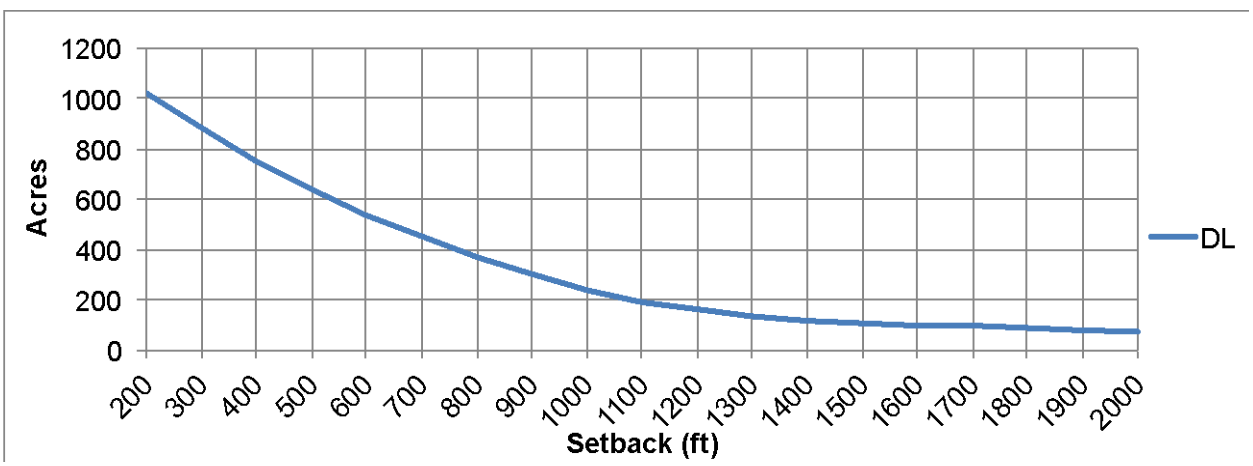

Fig. C.30 Setback distance versus drillable land for zoning subcategory NR-4 and land cover class Mowed/Grazed/Agriculture

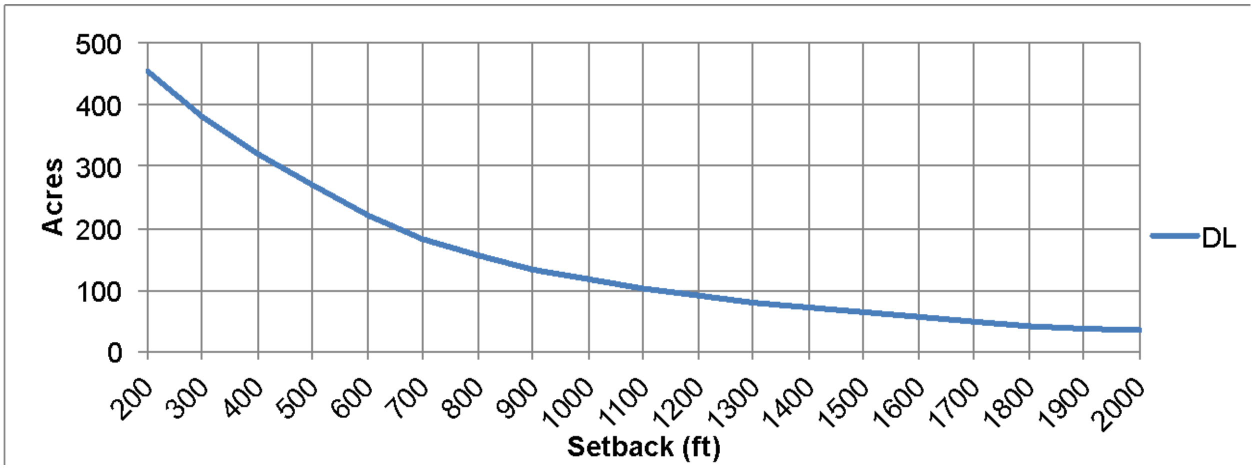

Fig. C.31 Setback distance versus drillable land for zoning subcategory NR-6 and land cover class Mowed/Grazed/Agriculture

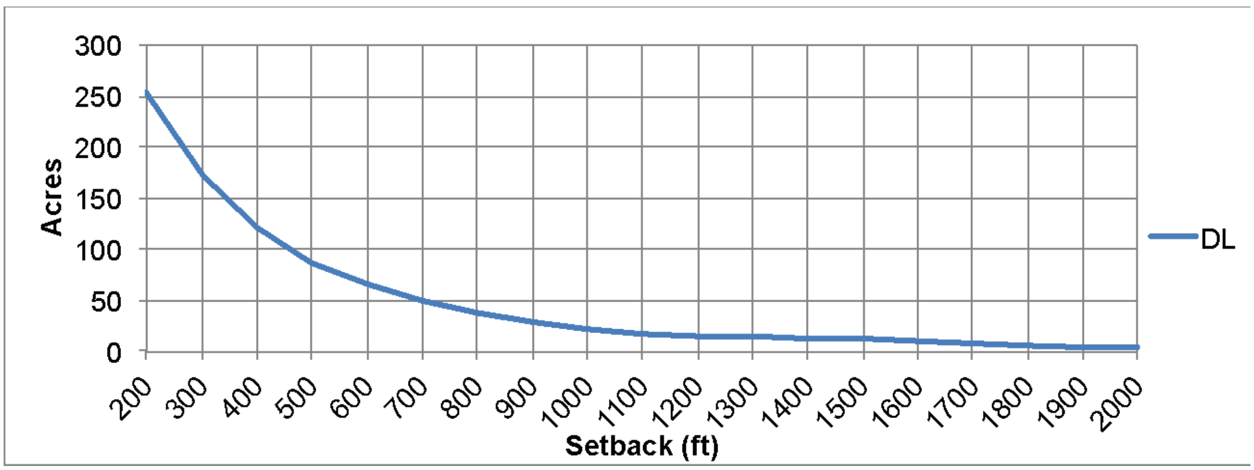

Fig. C.32 Setback distance versus drillable land for zoning subcategory NRMU-12 and land cover class Mowed/Grazed/Agriculture

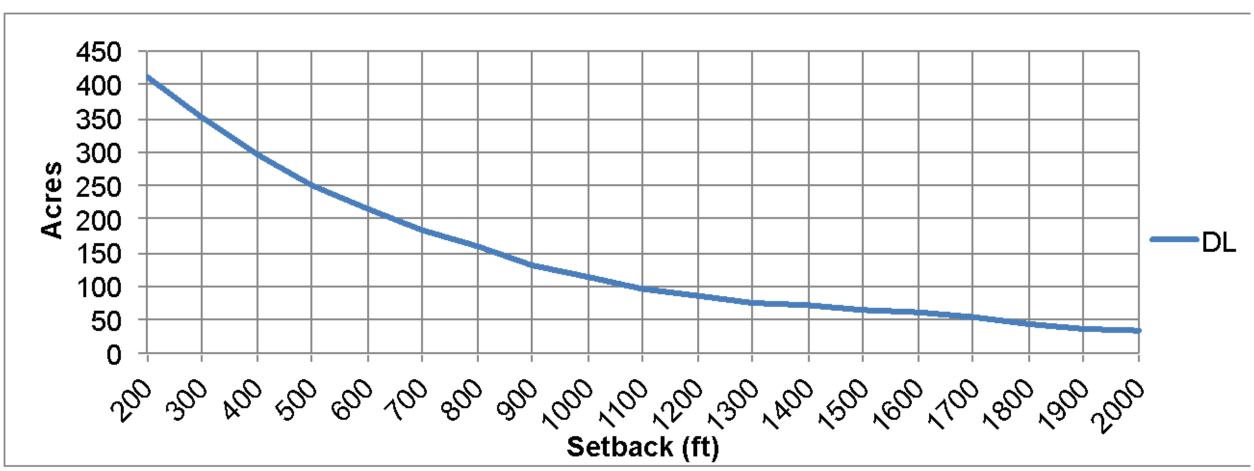

Fig. C.33 Setback distance versus drillable land for zoning subcategory NRMU and land cover class Mowed/Grazed/Agriculture

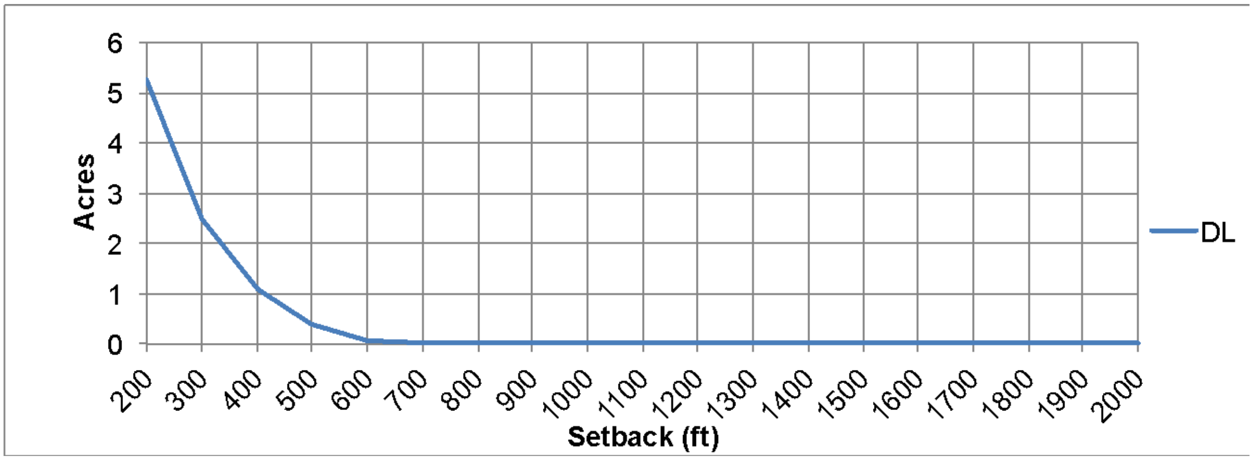

Fig. C.34 Setback distance versus drillable land for zoning subcategory DR-2 and land cover class Mowed/Grazed/Agriculture

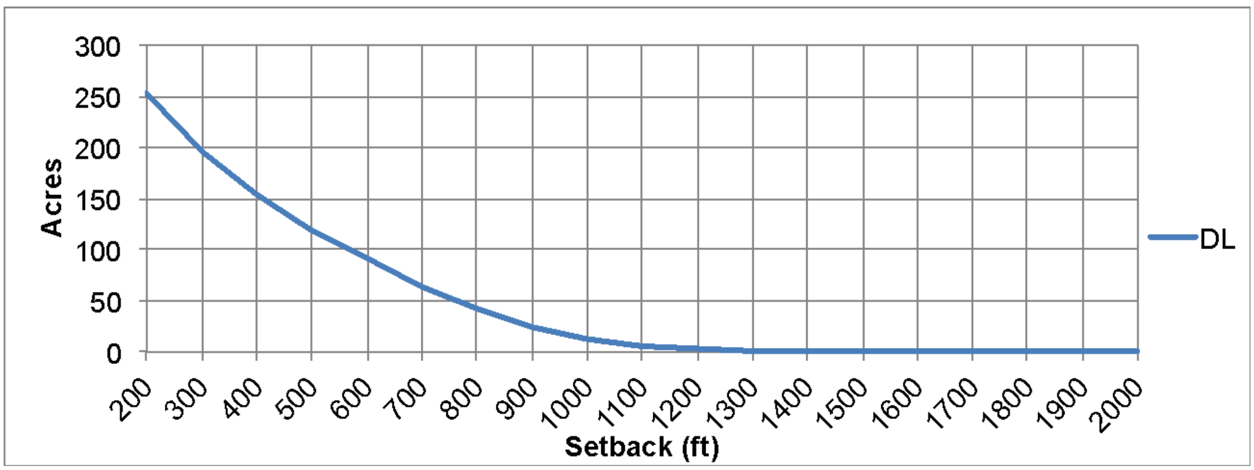

Fig. C.35 Setback distance versus drillable land for zoning subcategory DC-G and land cover class Mowed/Grazed/Agriculture

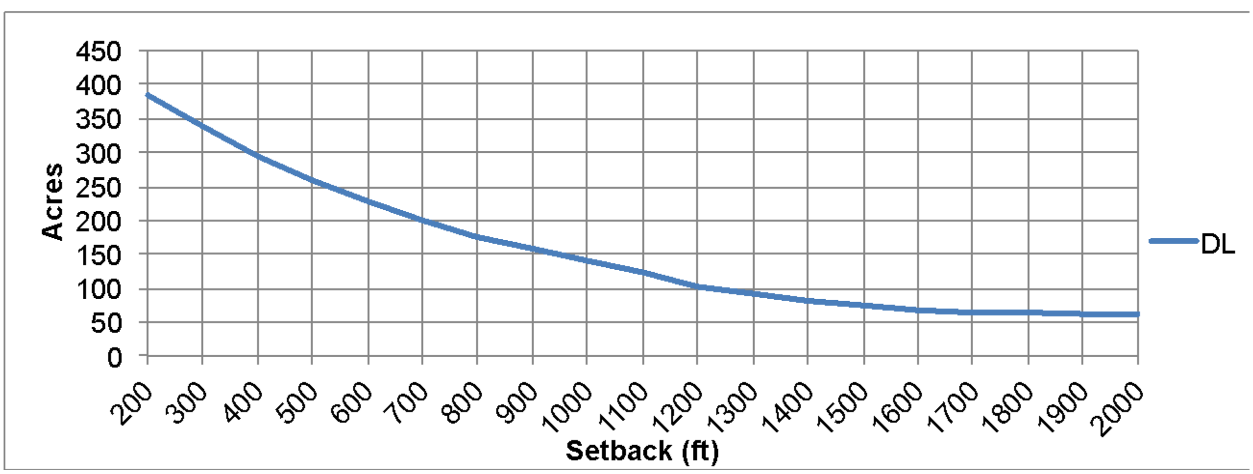

Fig. C.36 Setback distance versus drillable land for zoning subcategory CM-G and land cover class Mowed/Grazed/Agriculture

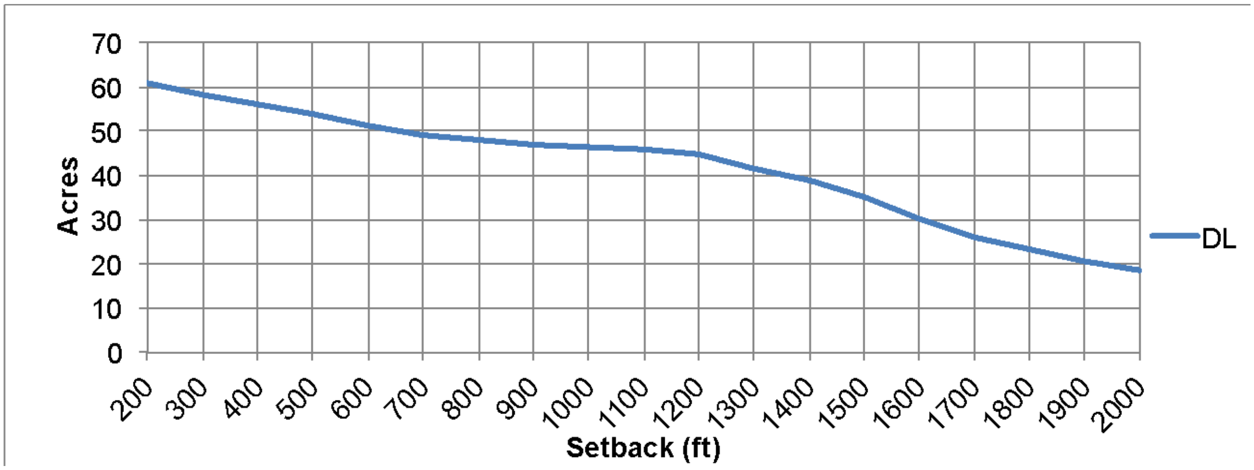

Fig. C.37 Setback distance versus drillable land for zoning subcategory CM-E and land cover class Mowed/Grazed/Agriculture

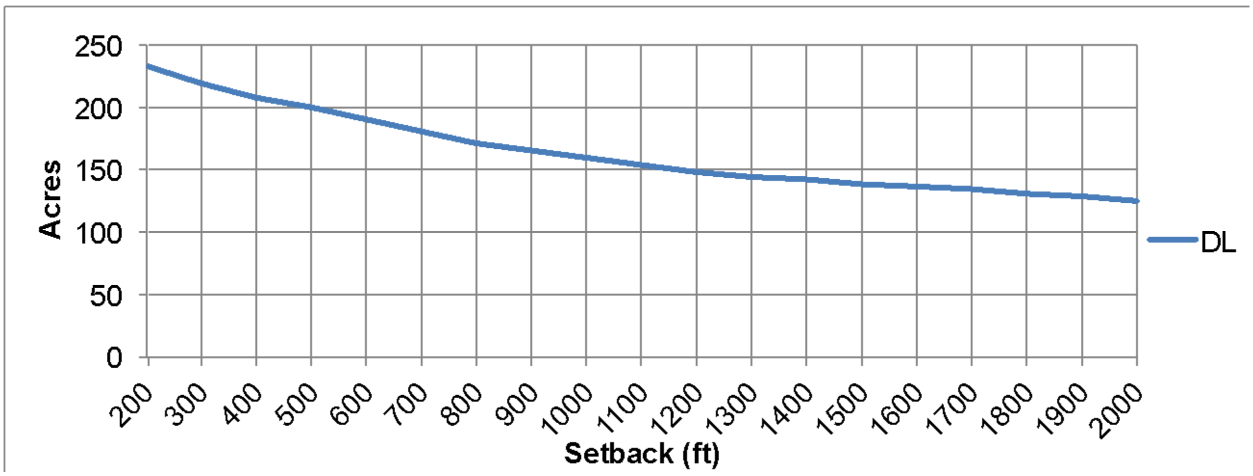

Fig. C.38 Setback distance versus drillable land for zoning subcategory RCR-1 and land cover class Mowed/Grazed/Agriculture

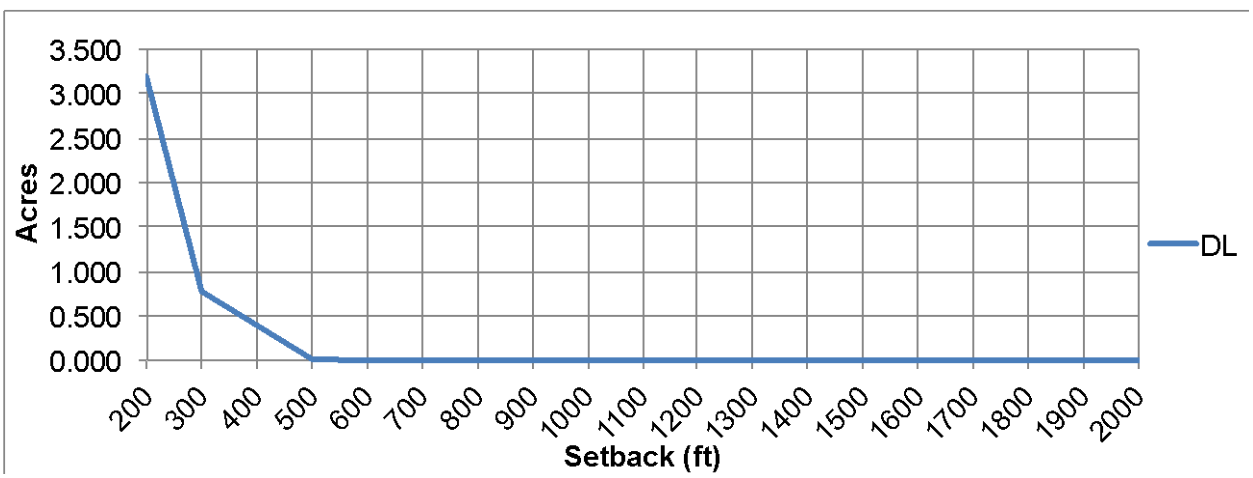

Fig. C.39 Setback distance versus drillable land for zoning subcategory RCR-2 and land cover class Mowed/Grazed/Agriculture

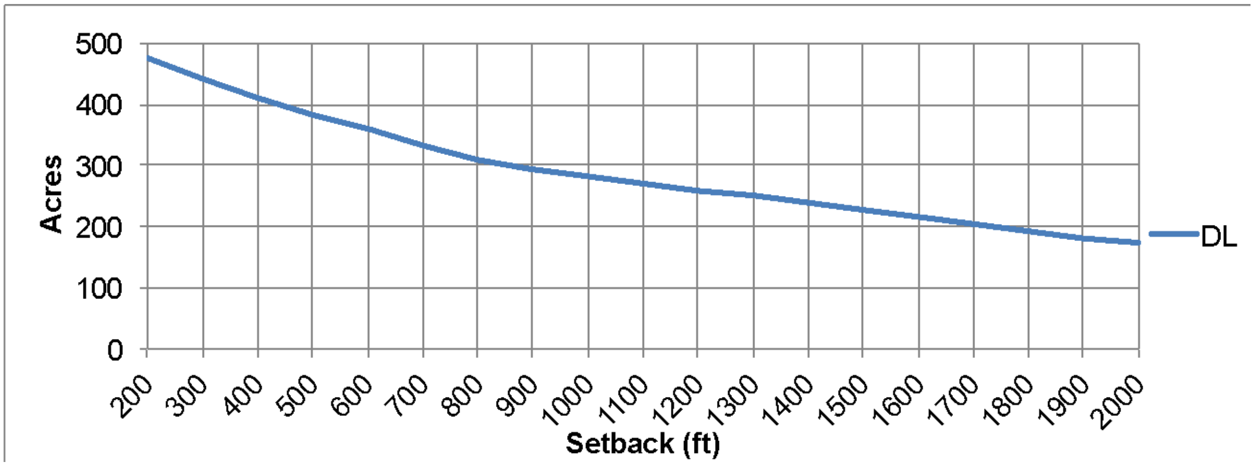

Figure C.40 Setback distance versus drillable land for zoning subcategory RCC-N and land cover class Mowed/Grazed/Agriculture

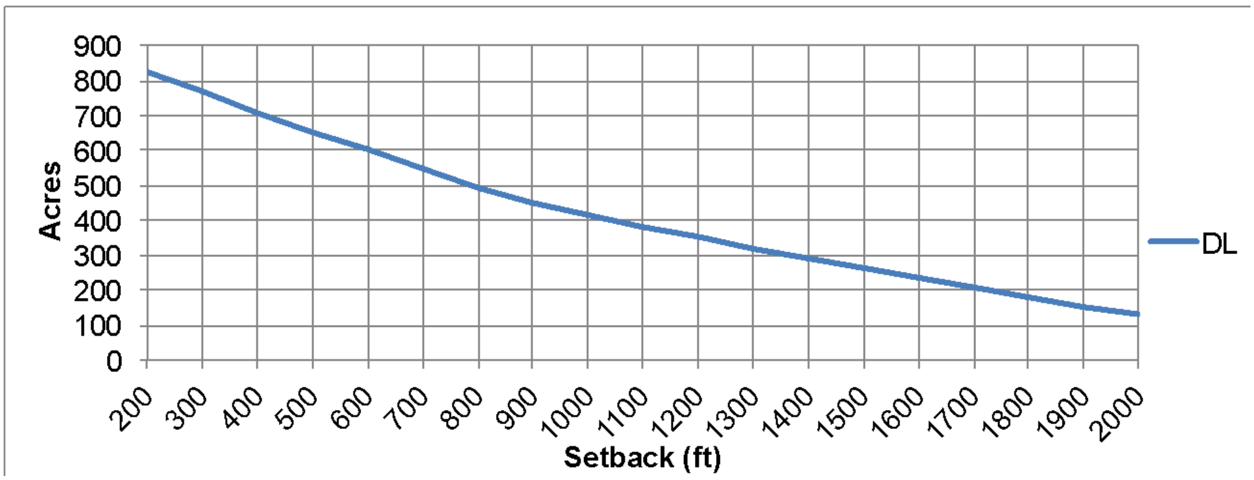

Fig. C.41 Setback distance versus drillable land for zoning subcategory RCC-D and land cover class Mowed/Grazed/Agriculture

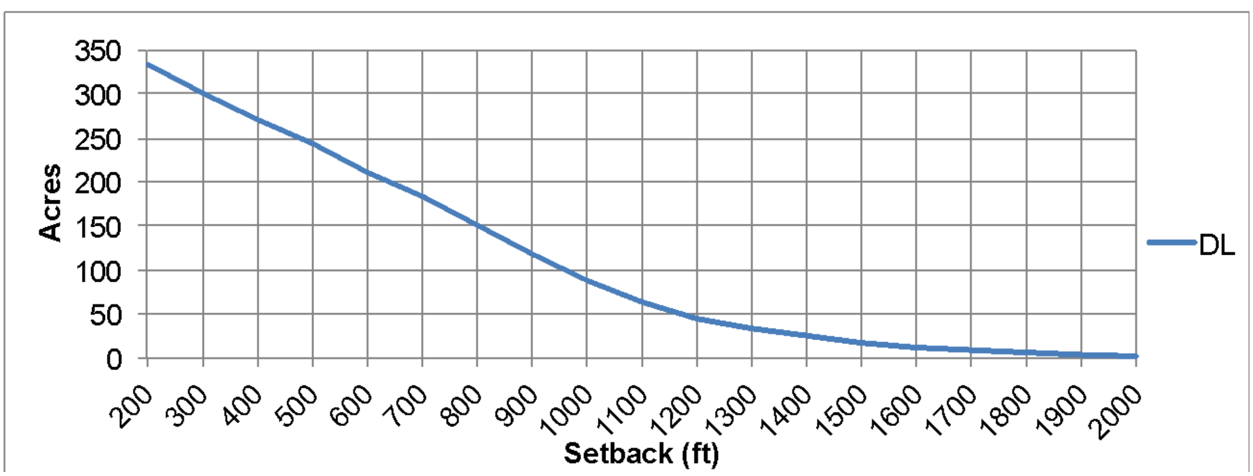

Fig. C.42 Setback distance versus drillable land for zoning subcategory EC-C and land cover class Mowed/Grazed/Agriculture

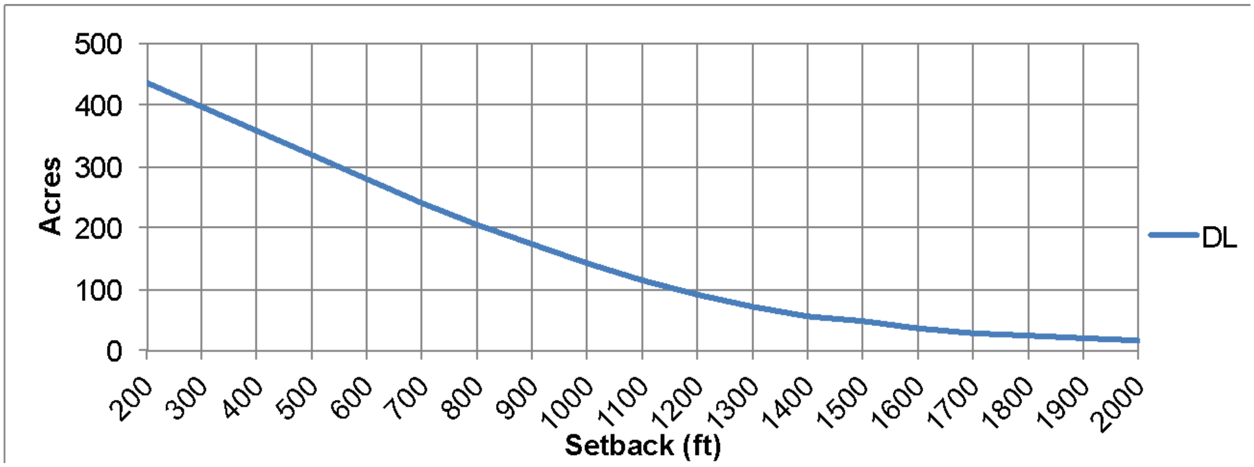

Fig. C.43 Setback distance versus drillable land for zoning subcategory EC-I and land cover class Mowed/Grazed/Agriculture

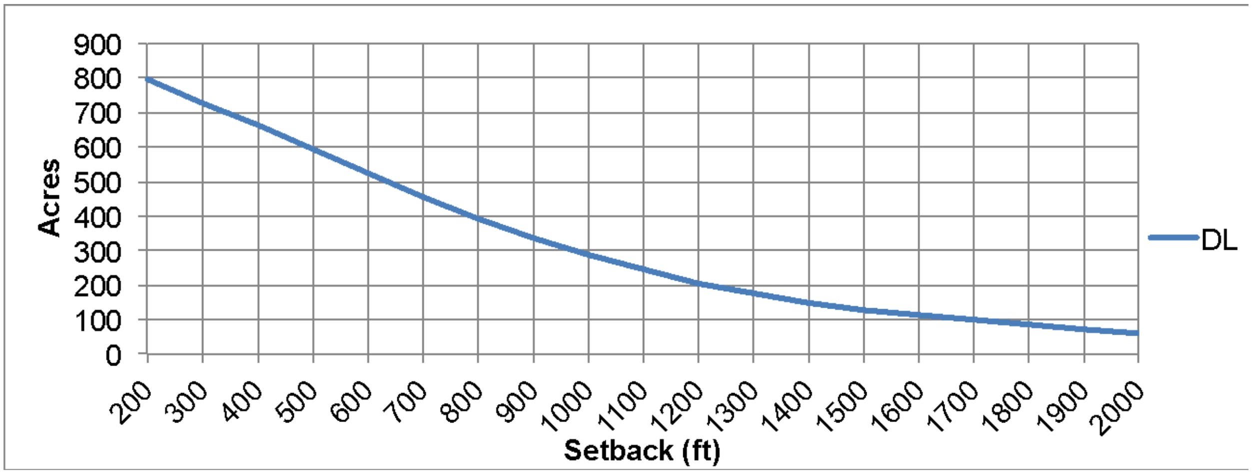

Fig. C.44 Setback distance versus drillable land for zoning subcategory IC-E and land cover class Mowed/Grazed/Agriculture

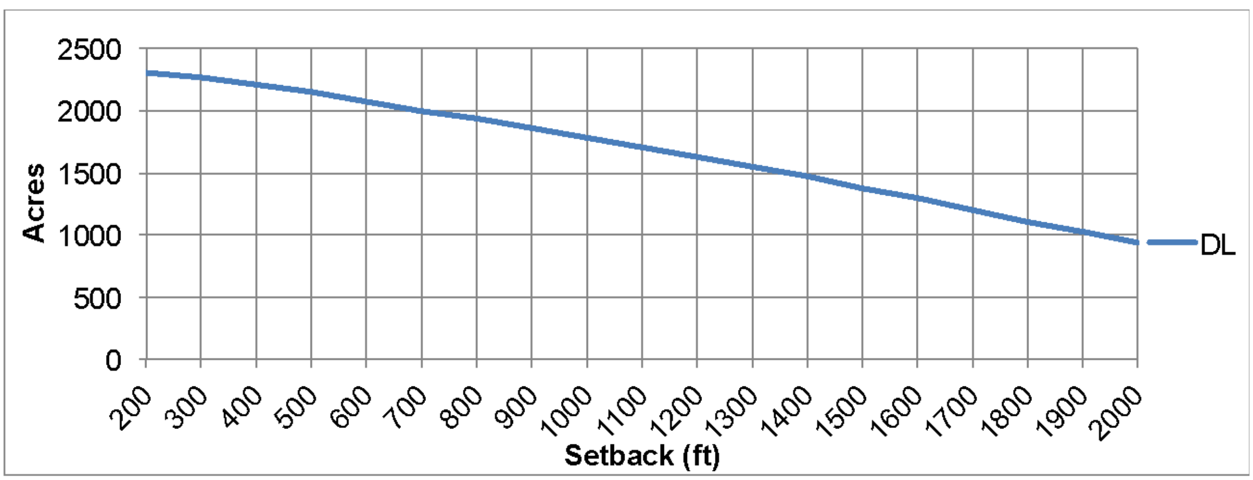

Fig. C.45 Setback distance versus drillable land for zoning subcategory IC-G and land cover class Mowed/Grazed/Agriculture

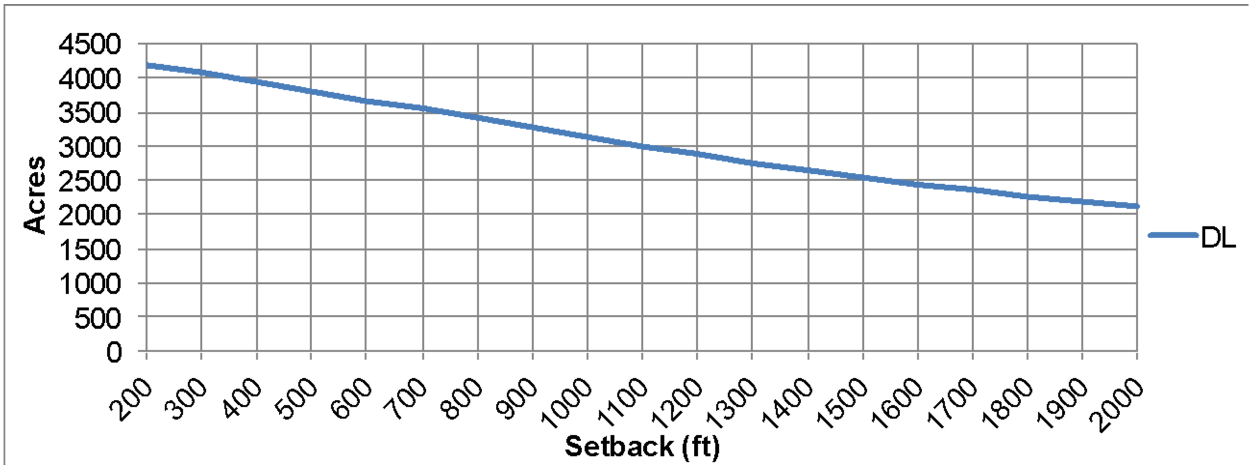

Fig. C.46 Setback distance versus drillable land for zoning subcategory RD-5X and land cover class Mowed/Grazed/Agriculture

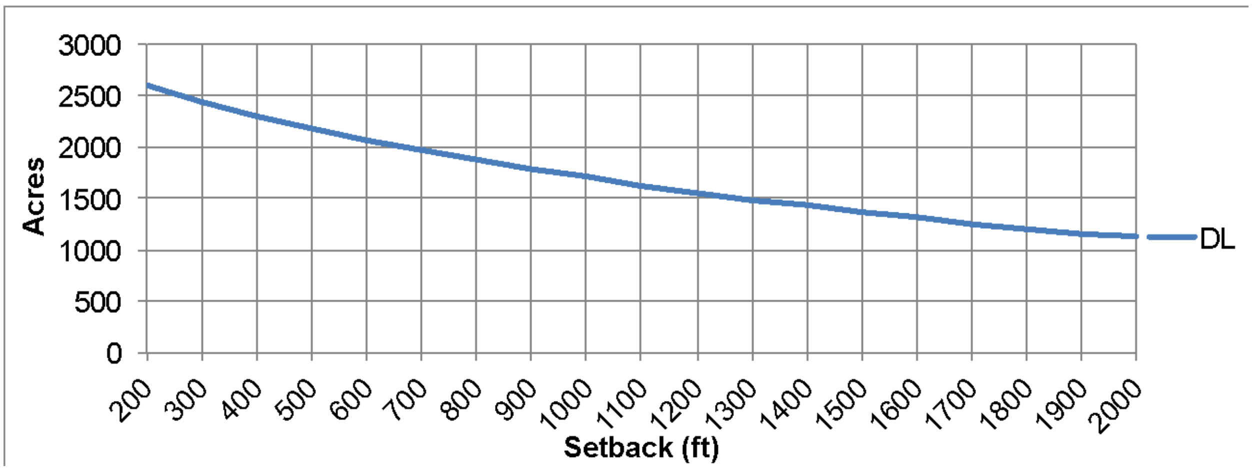

Fig. C.47 Setback distance versus drillable land for zoning subcategory PD and land cover class Mowed/Grazed/Agriculture

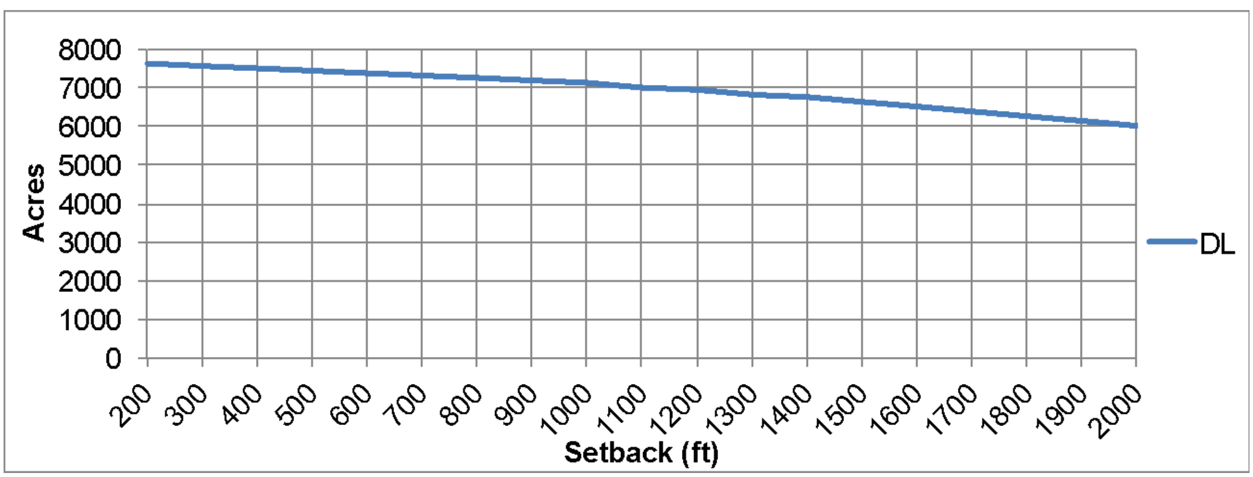

Fig. C.48 Setback distance versus drillable land for zoning subcategory MPC and land cover class Mowed/Grazed/Agriculture

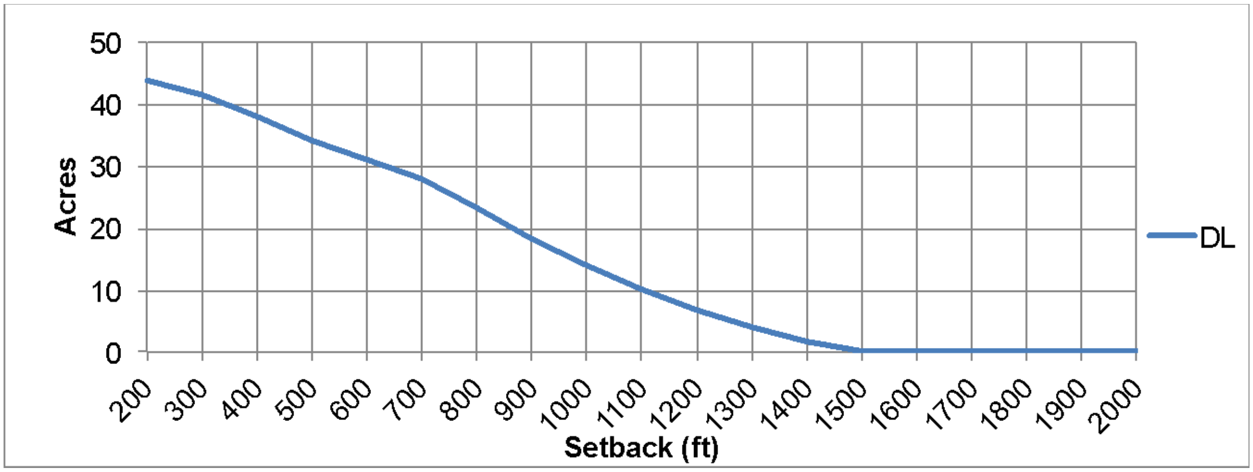

Fig. C.49 Setback distance versus drillable land for zoning subcategory A and land cover class Mowed/Grazed/Agriculture

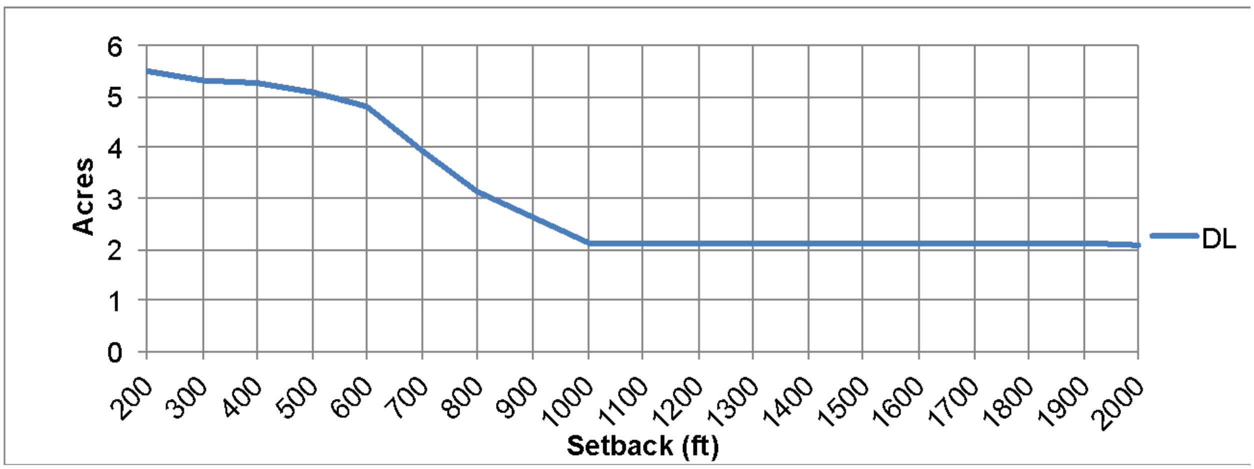

Fig. C.50 Setback distance versus drillable land for zoning subcategory RD-5 and land cover class Trees

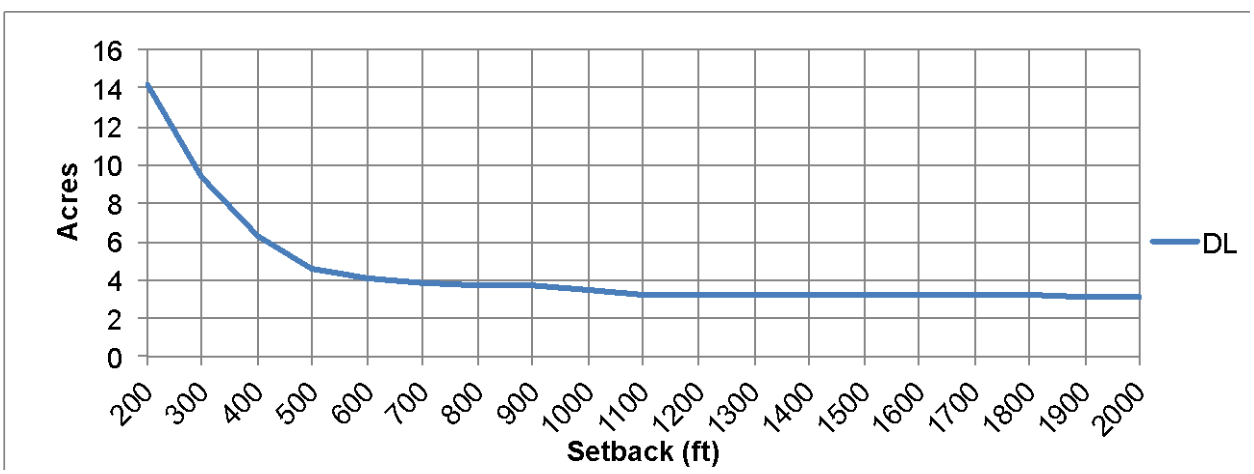

Fig. C.51 Setback distance versus drillable land for zoning subcategory NR-1 and land cover class Trees

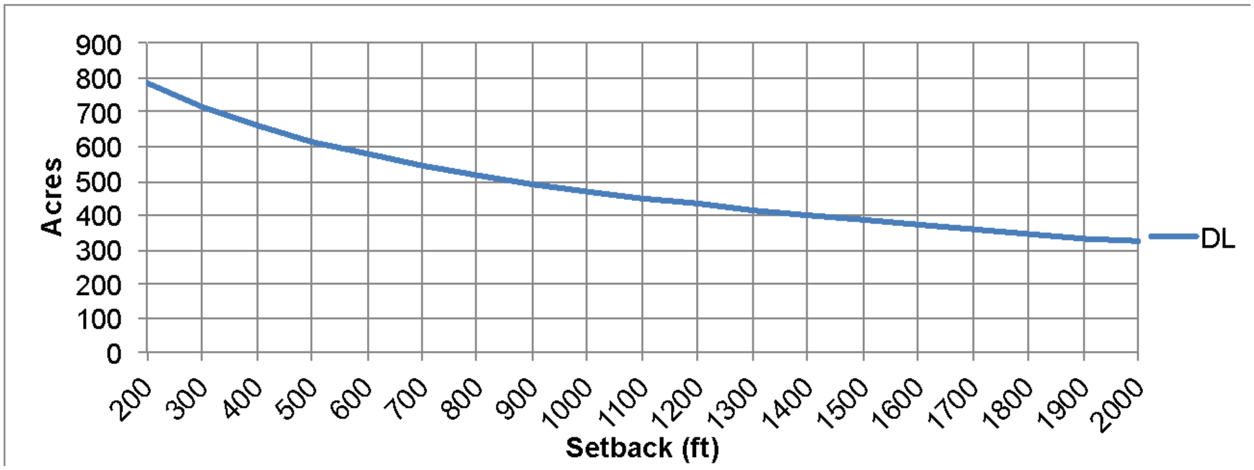

Fig. C.52 Setback distance versus drillable land for zoning subcategory NR-2 and land cover class Trees

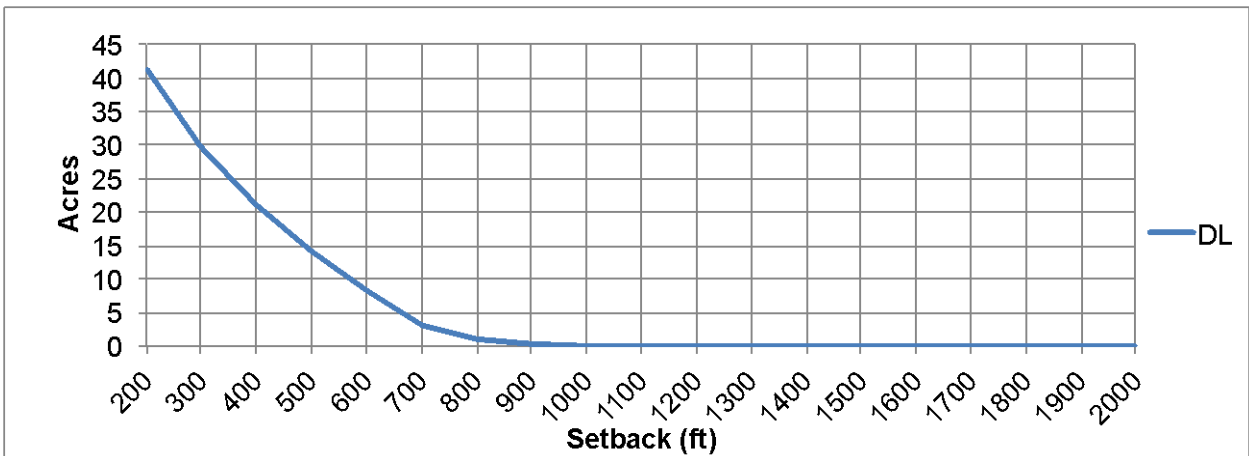

Fig. C.53 Setback distance versus drillable land for zoning subcategory NR-3 and land cover class Trees

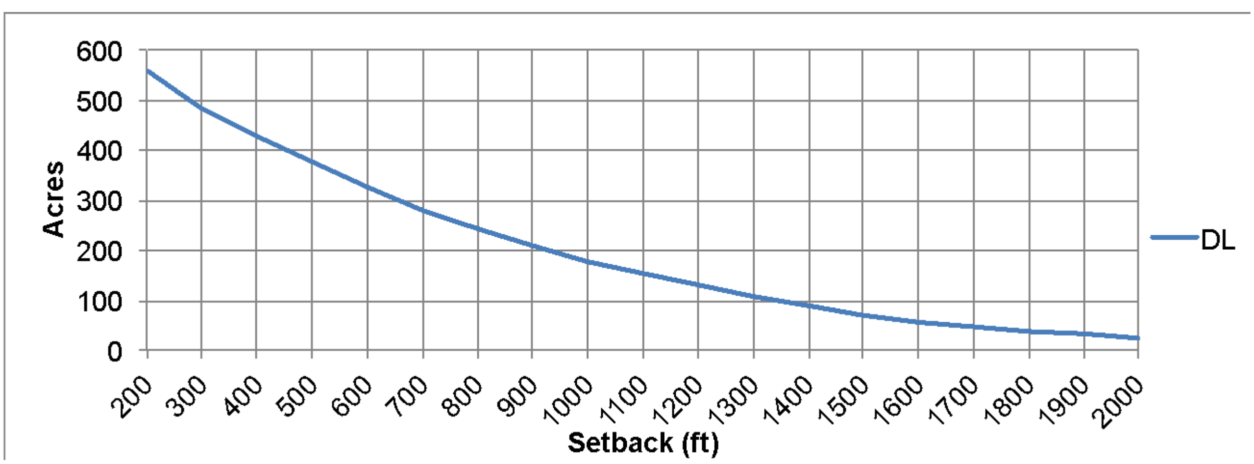

Fig. C.54 Setback distance versus drillable land for zoning subcategory NR-4 and land cover class Trees

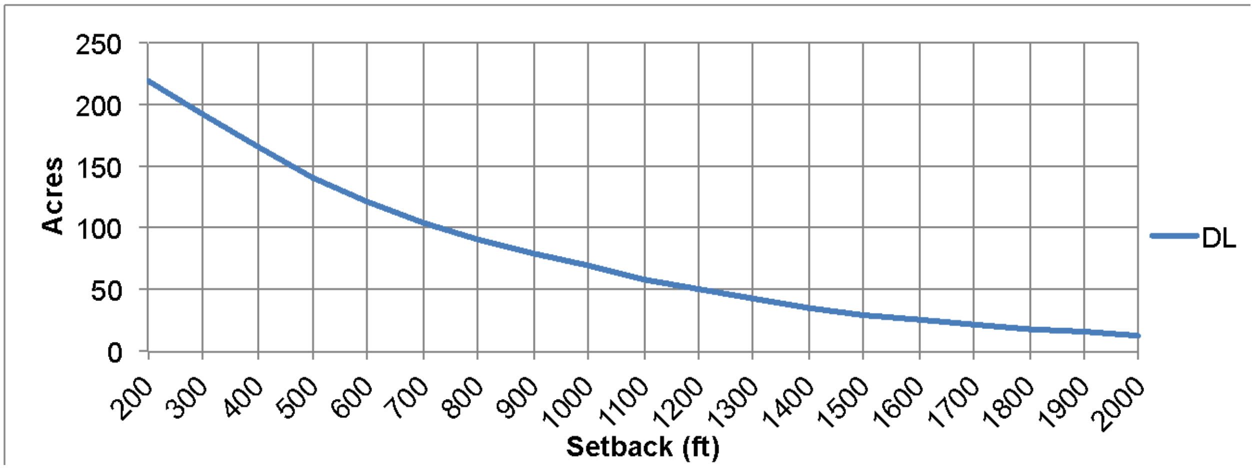

Fig. C.55 Setback distance versus drillable land for zoning subcategory NR-6 and land cover class Trees

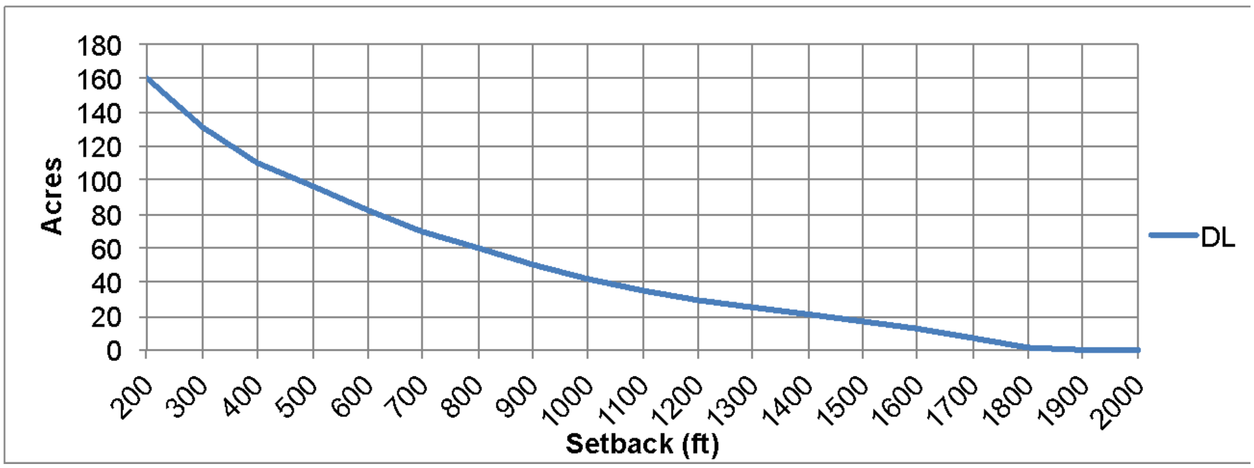

Fig. C.56 Setback distance versus drillable land for zoning subcategory NRMU-12 and land cover class Trees

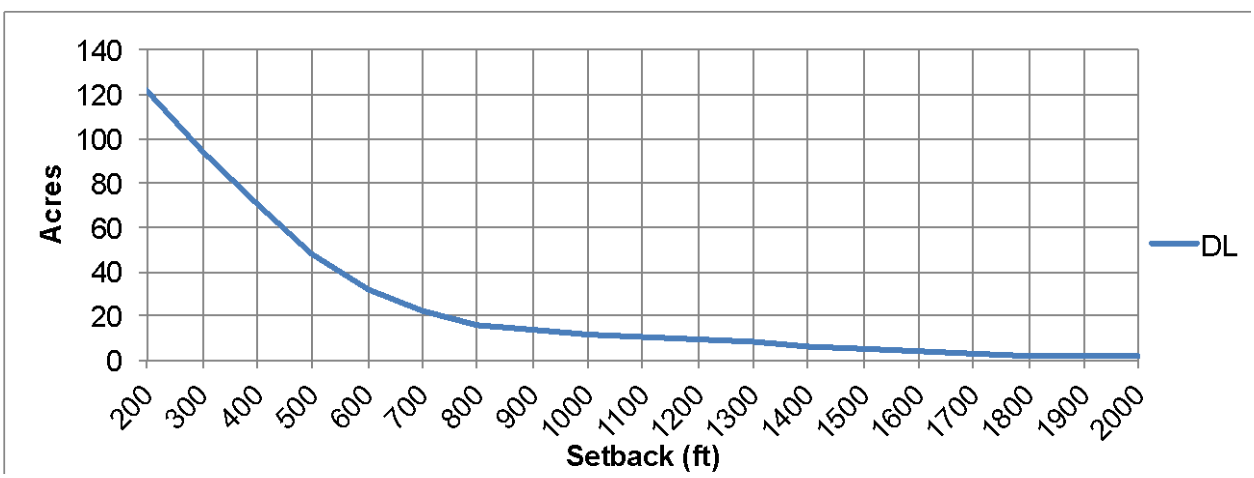

Fig. C.57 Setback distance versus drillable land for zoning subcategory NRMU and land cover class Trees

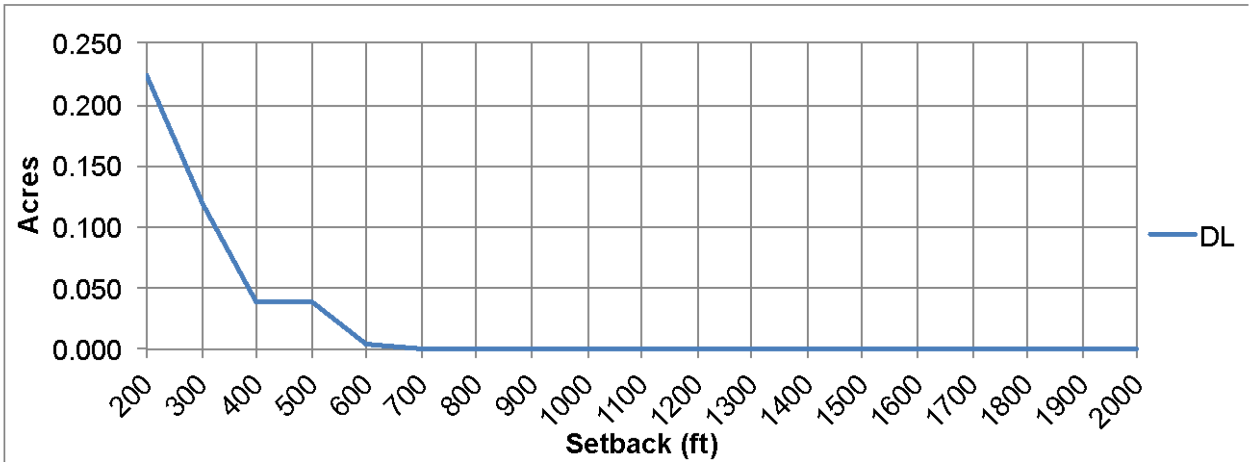

Fig. C.58 Setback distance versus drillable land for zoning subcategory DR-2 and land cover class Trees

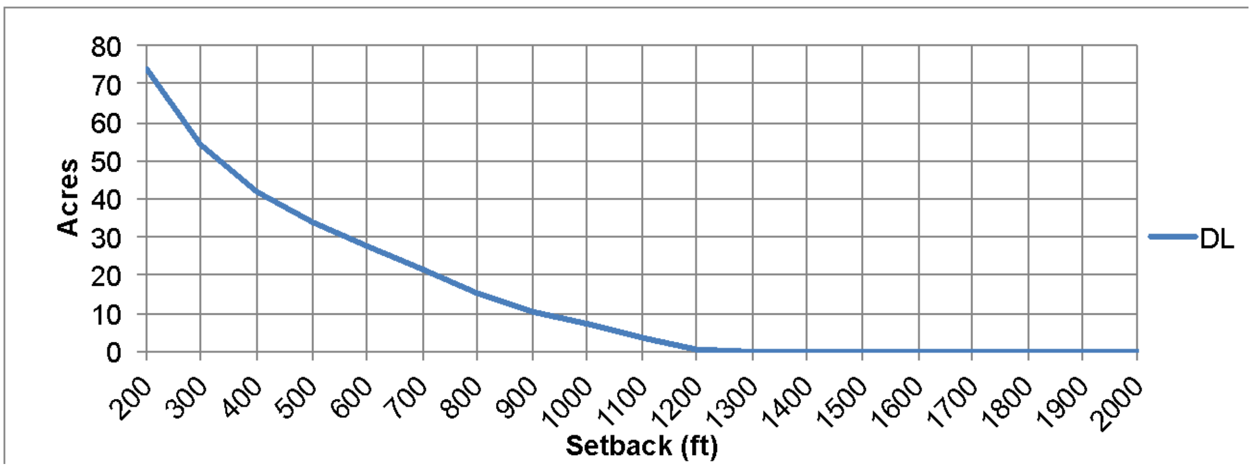

Fig. C.59 Setback distance versus drillable land for zoning subcategory DC-G and land cover class Trees

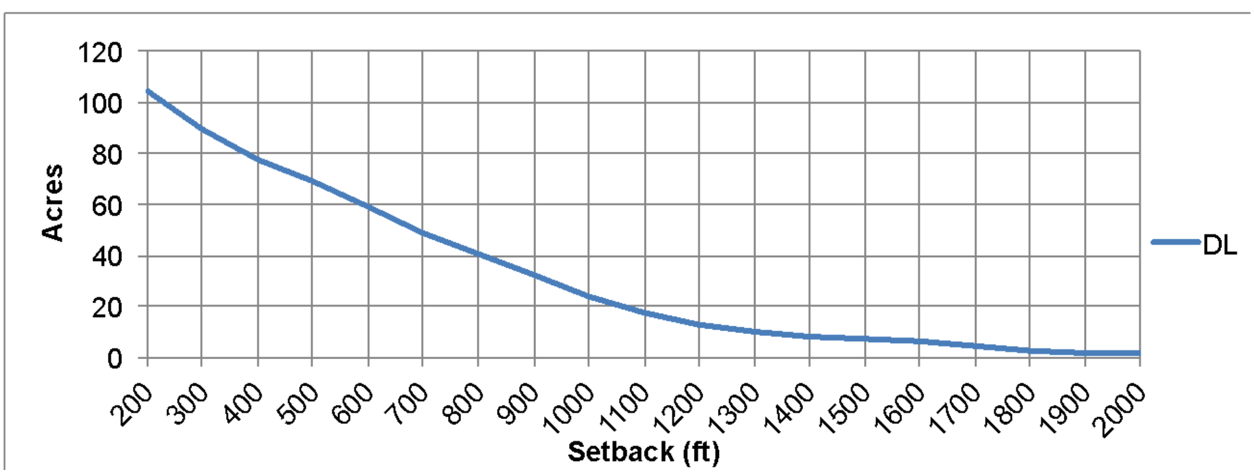

Fig. C.60 Setback distance versus drillable land for zoning subcategory CM-G and land cover class Trees

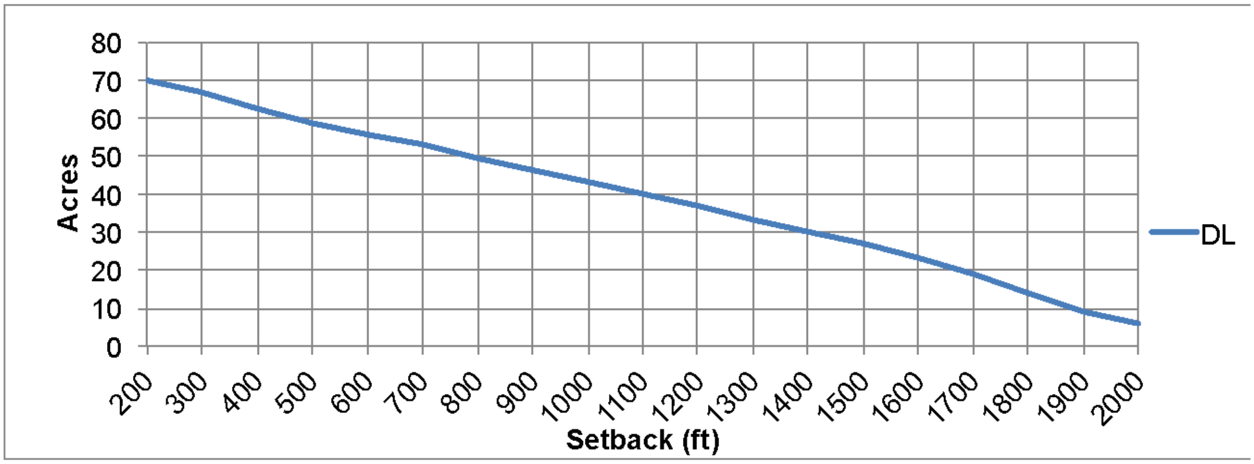

Fig. C.61 Setback distance versus drillable land for zoning subcategory CM-E and land cover class Trees

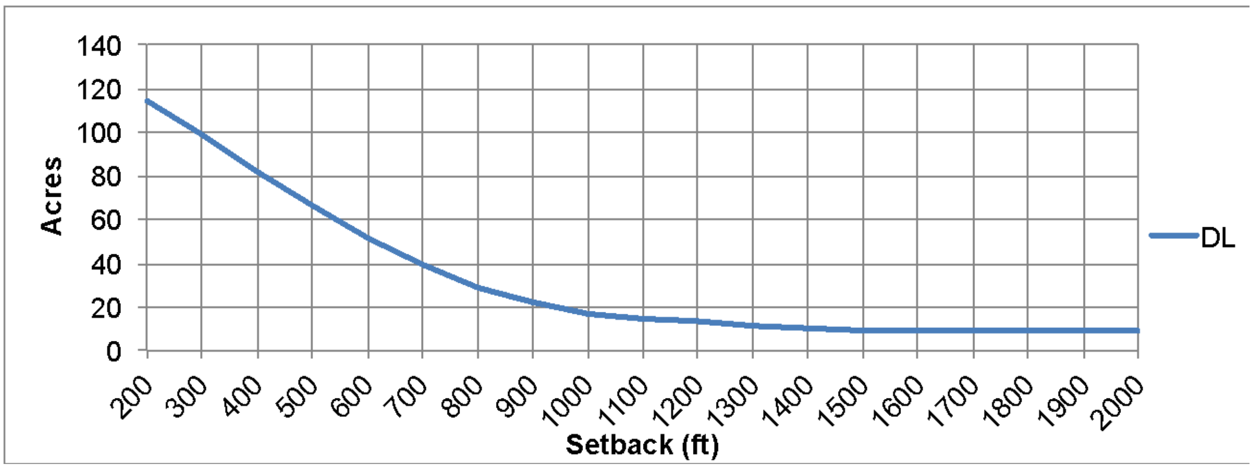

Fig. C.62 Setback distance versus drillable land for zoning subcategory RCR-1 and land cover class Trees

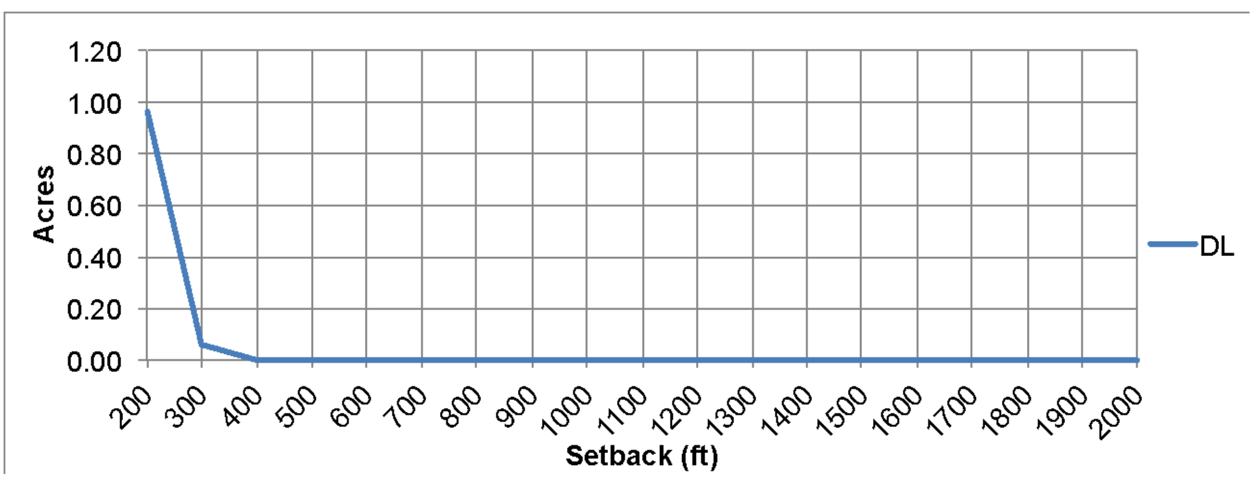

Fig. C.63 Setback distance versus drillable land for zoning subcategory RCR-2 and land cover class Trees

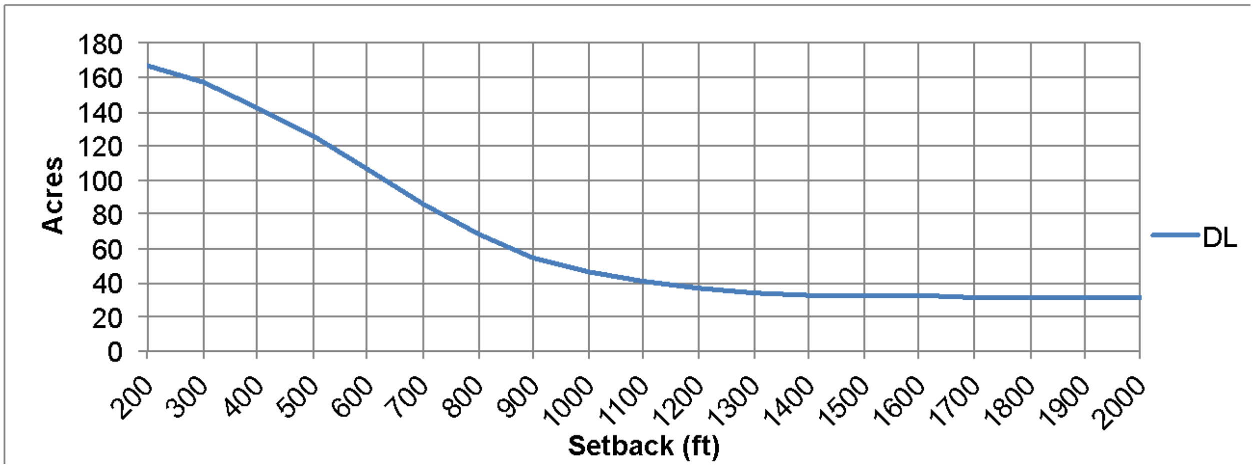

Fig. C.64 Setback distance versus drillable land for zoning subcategory RCC-N and land cover class Trees

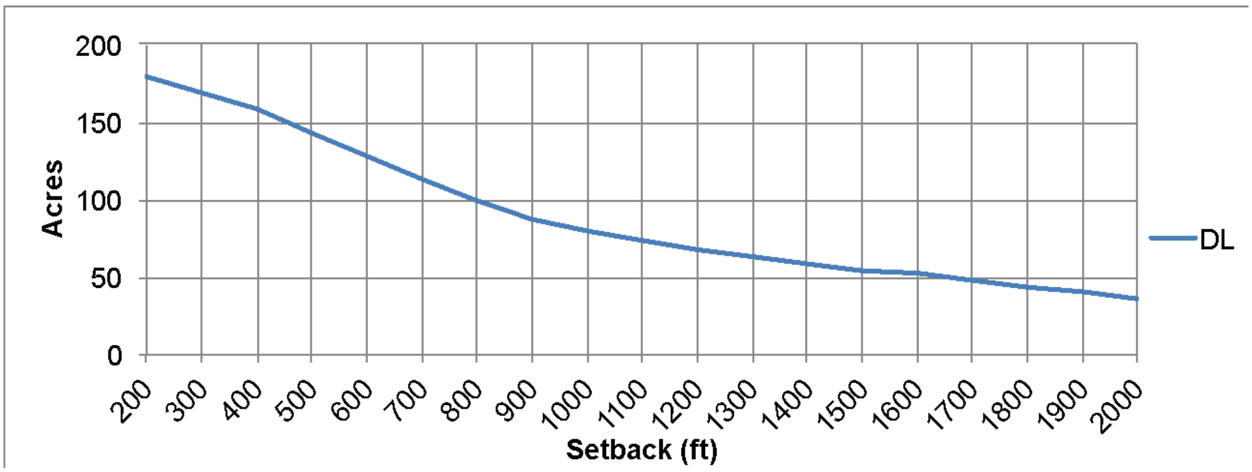

Fig. C.65 Setback distance versus drillable land for zoning subcategory RCC-D and land cover class Trees

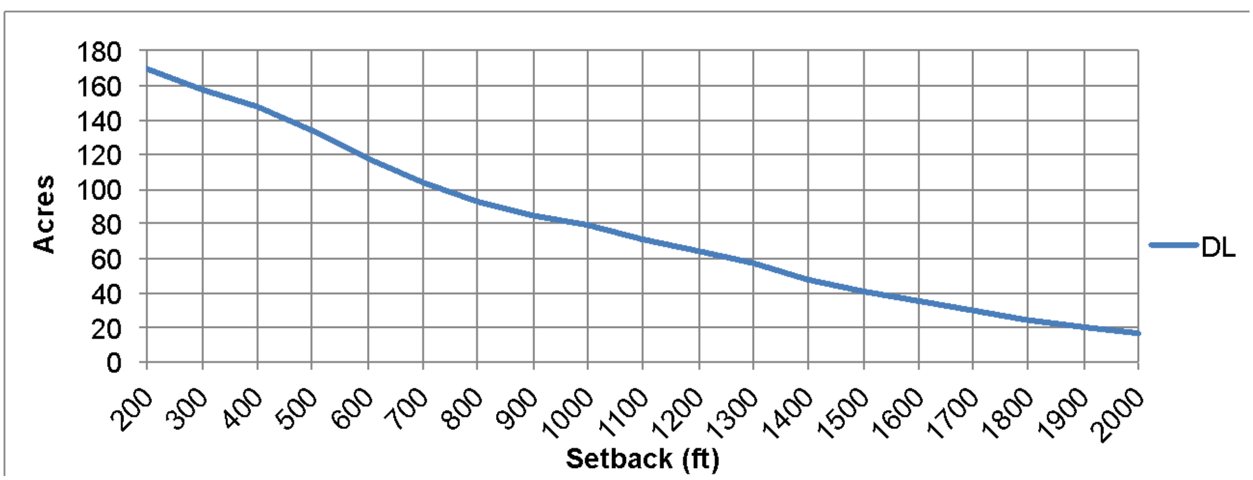

Fig. C.66 Setback distance versus drillable land for zoning subcategory EC-C and land cover class Trees

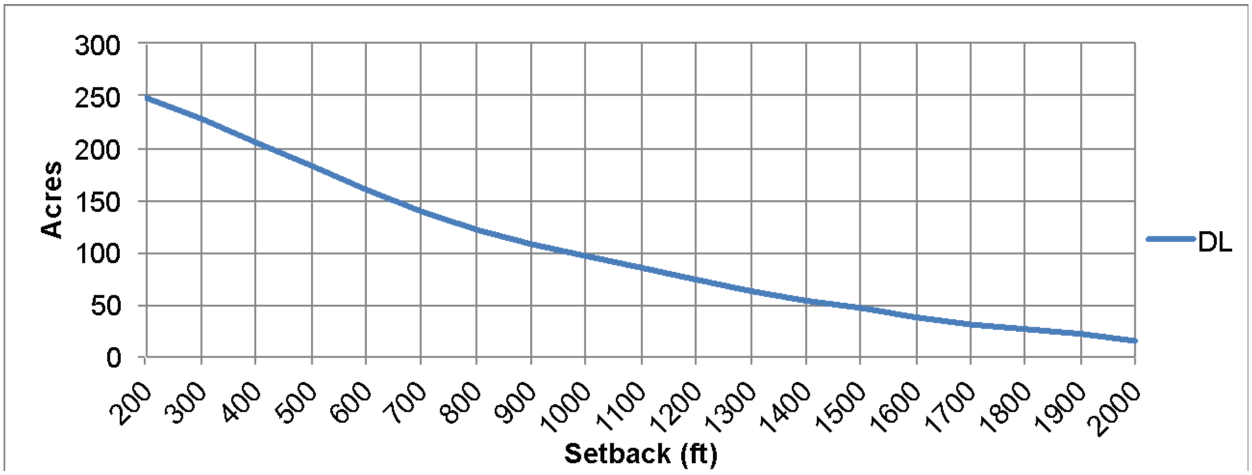

Fig. C.67 Setback distance versus drillable land for zoning subcategory EC-I and land cover class Trees

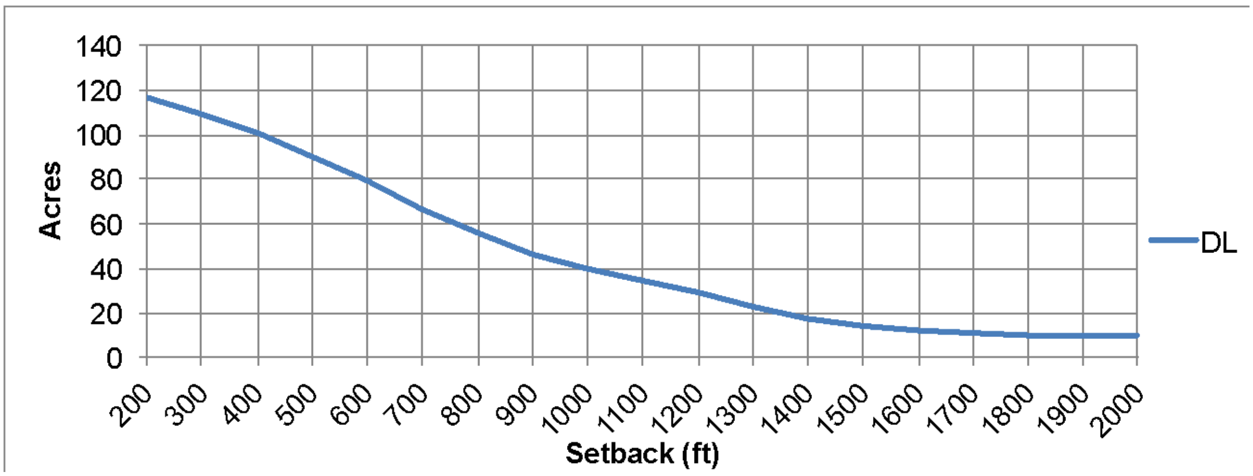

Fig. C.68 Setback distance versus drillable land for zoning subcategory IC-E and land cover class Trees

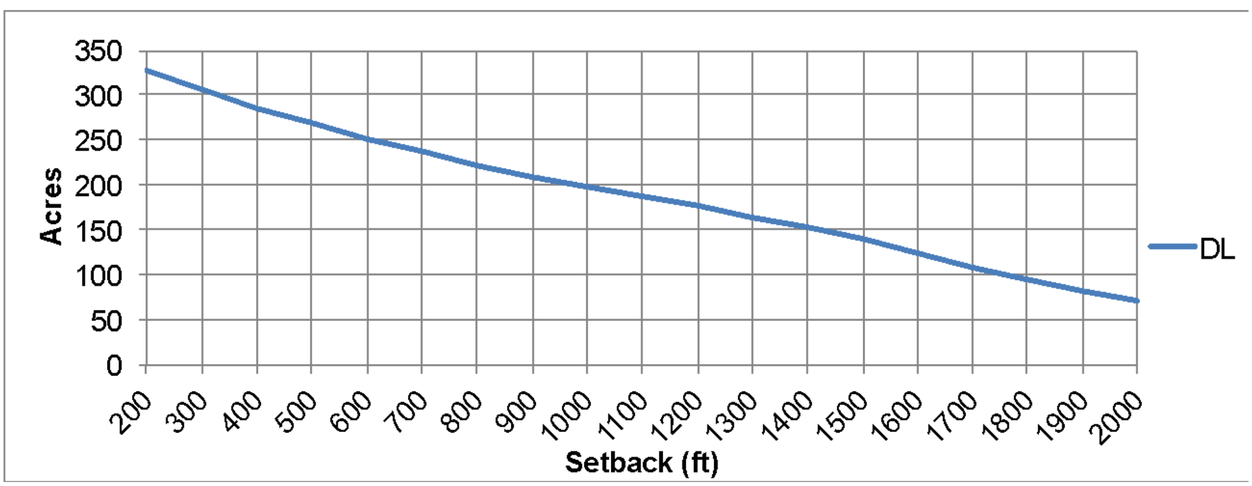

Fig. C.69 Setback distance versus drillable land for zoning subcategory IC-G and land cover class Trees

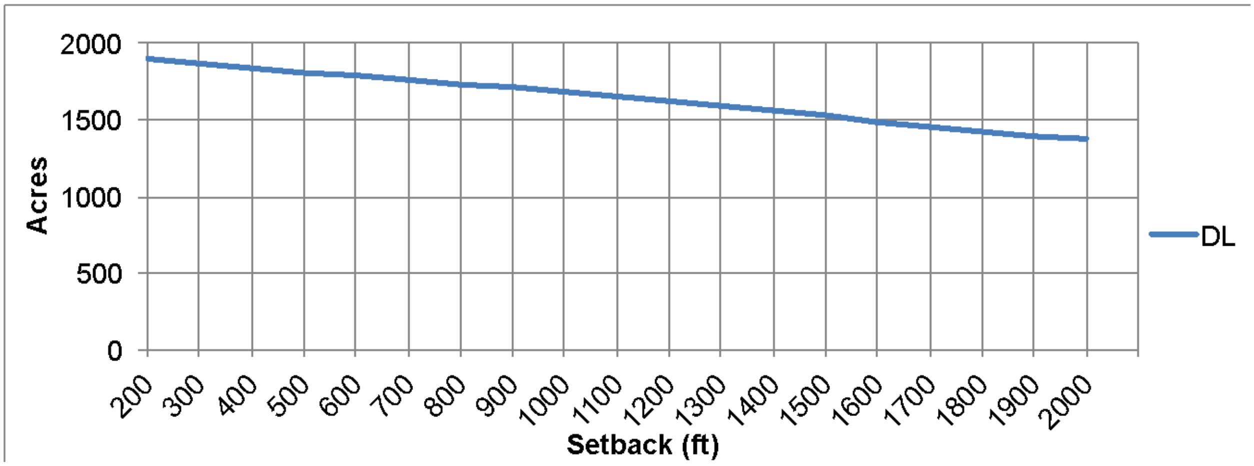

Fig. C.70 Setback distance versus drillable land for zoning subcategory RD-5X and land cover class Trees

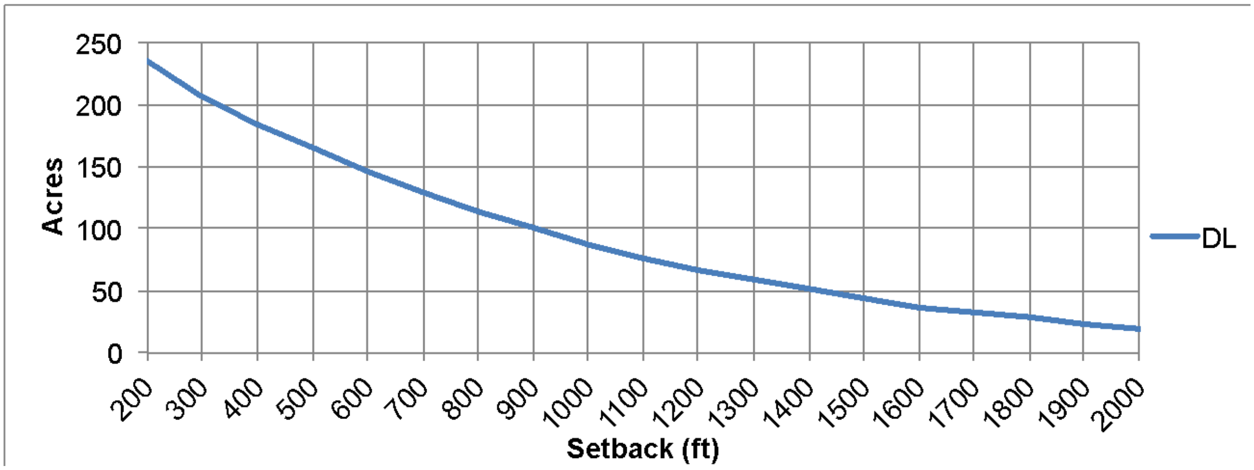

Fig. C.71 Setback distance versus drillable land for zoning subcategory PD and land cover class Trees

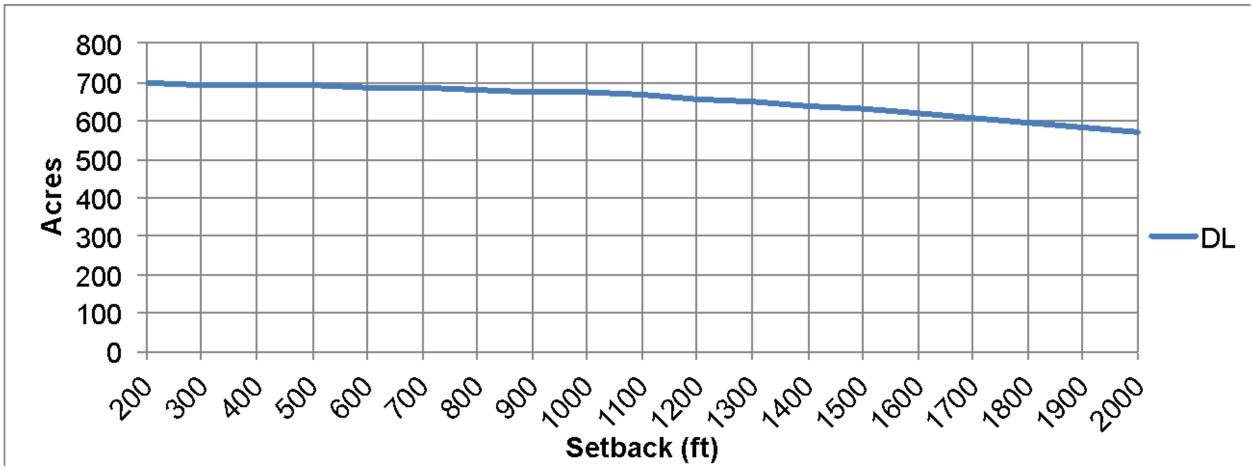

Fig. C.72 Setback distance versus drillable land for zoning subcategory MPC and land cover class Trees

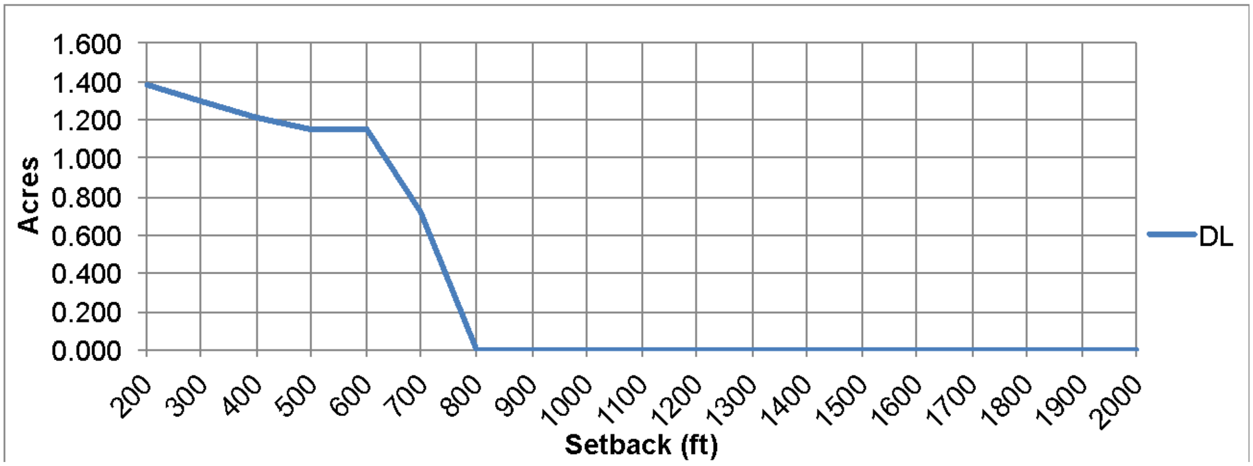

Fig. C.73 Setback distance versus drillable land for zoning subcategory A and land cover class Trees

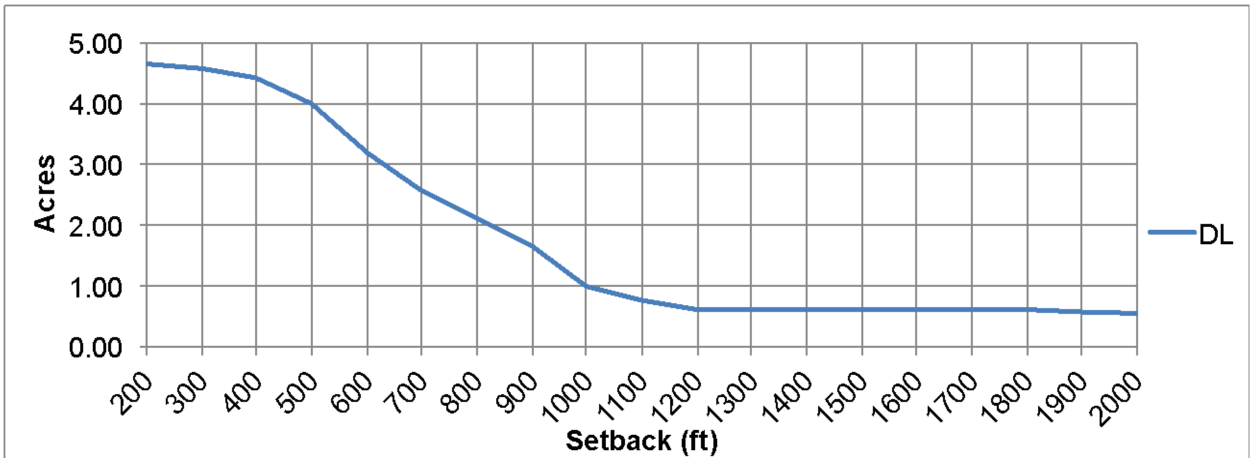

Fig. C.74 Setback distance versus drillable land for zoning subcategory RD-5 and land cover class Herbaceous

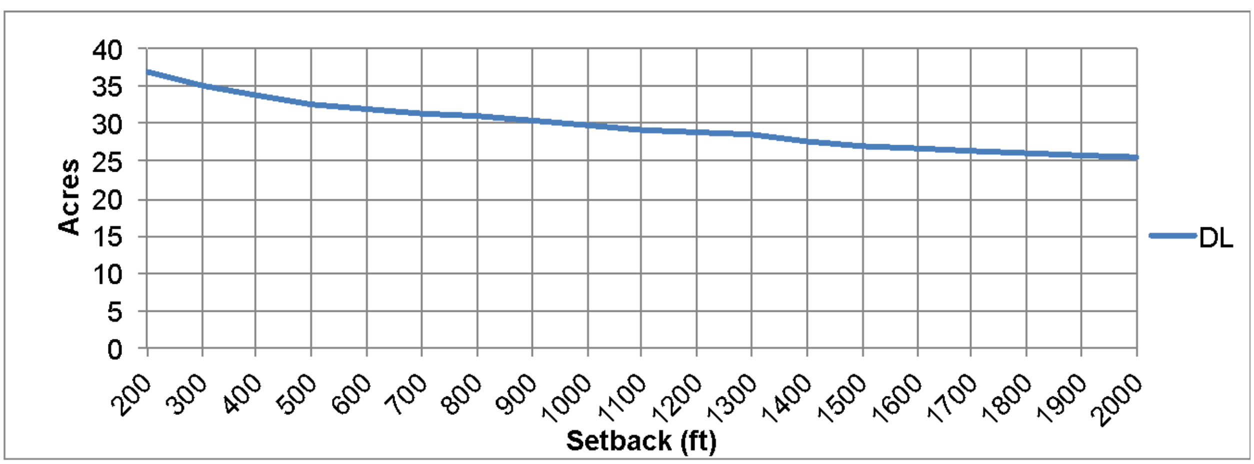

Fig. C.75 Setback distance versus drillable land for zoning subcategory NR-2 and land cover class Herbaceous

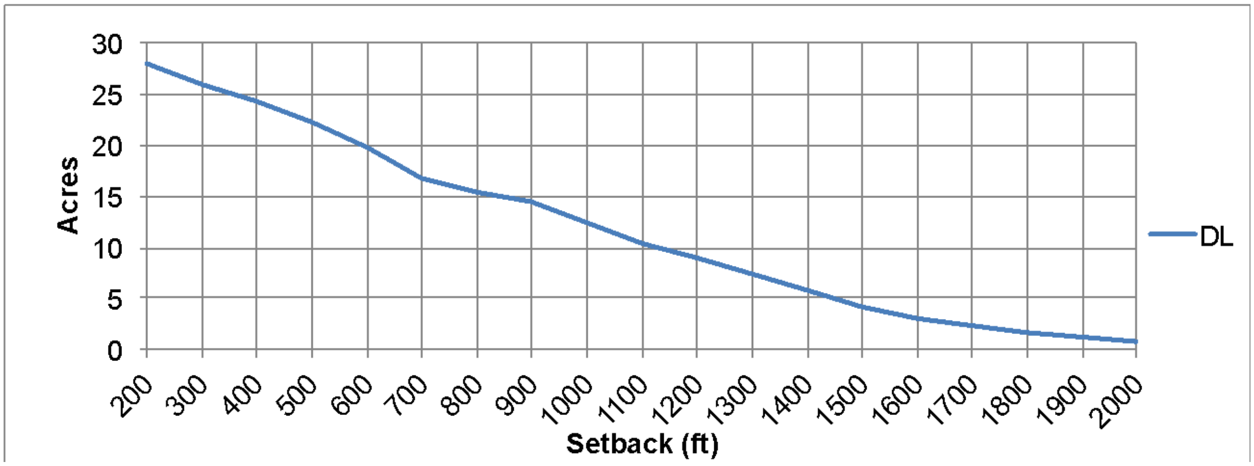

Fig. C.76 Setback distance versus drillable land for zoning subcategory NR-4 and land cover class Herbaceous

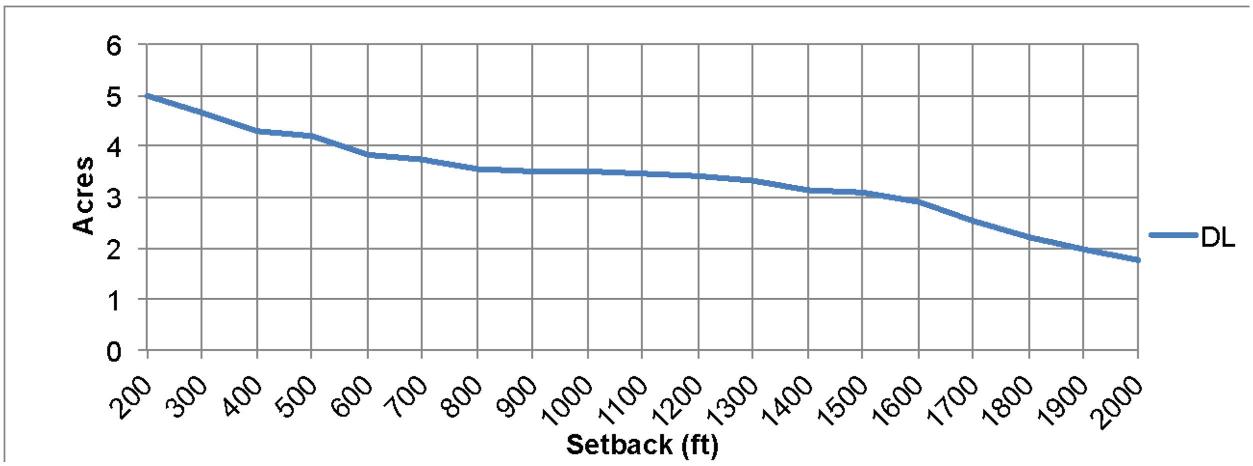

Fig. C.77 Setback distance versus drillable land for zoning subcategory NR-6 and land cover class Herbaceous

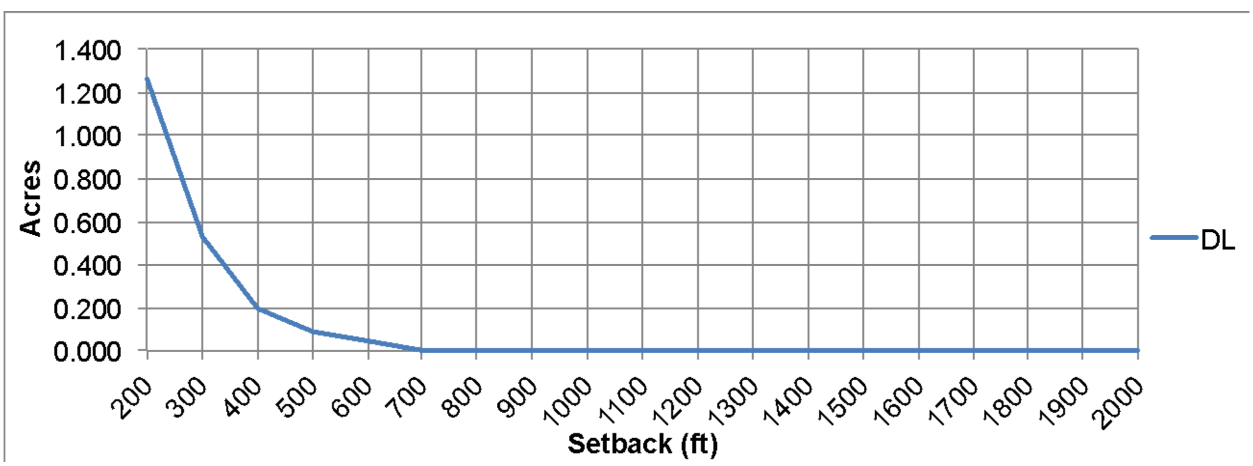

Fig. C.78 Setback distance versus drillable land for zoning subcategory NRMU-12 and land cover class Herbaceous

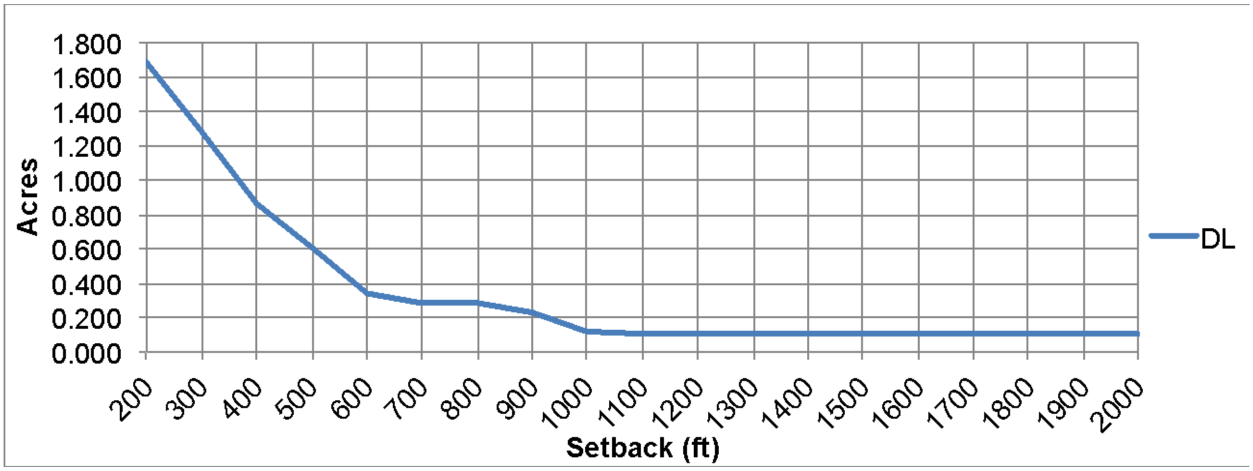

Fig. C.79 Setback distance versus drillable land for zoning subcategory NRMU and land cover class Herbaceous

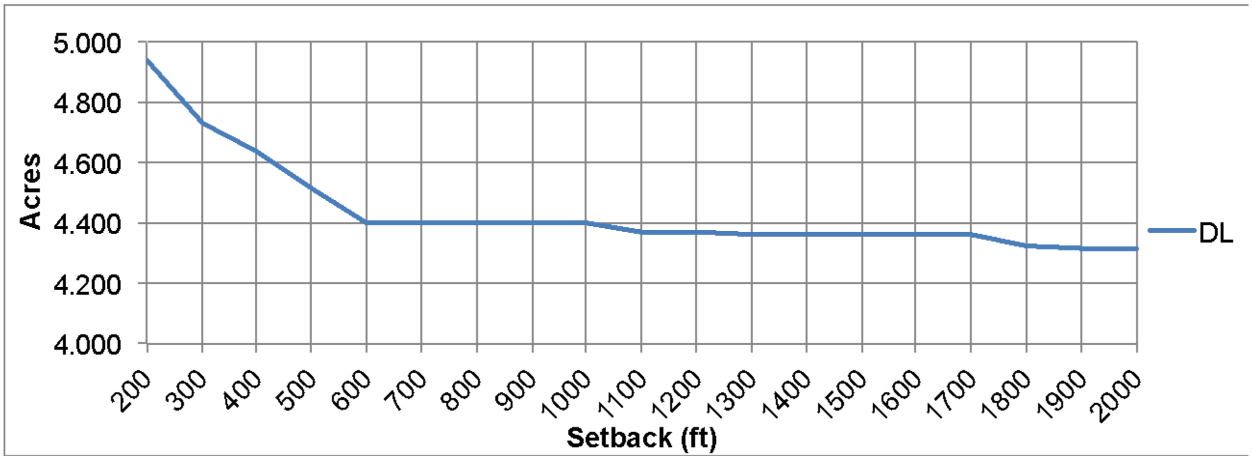

Fig. C.80 Setback distance versus drillable land for zoning subcategory CM-G and land cover class Herbaceous

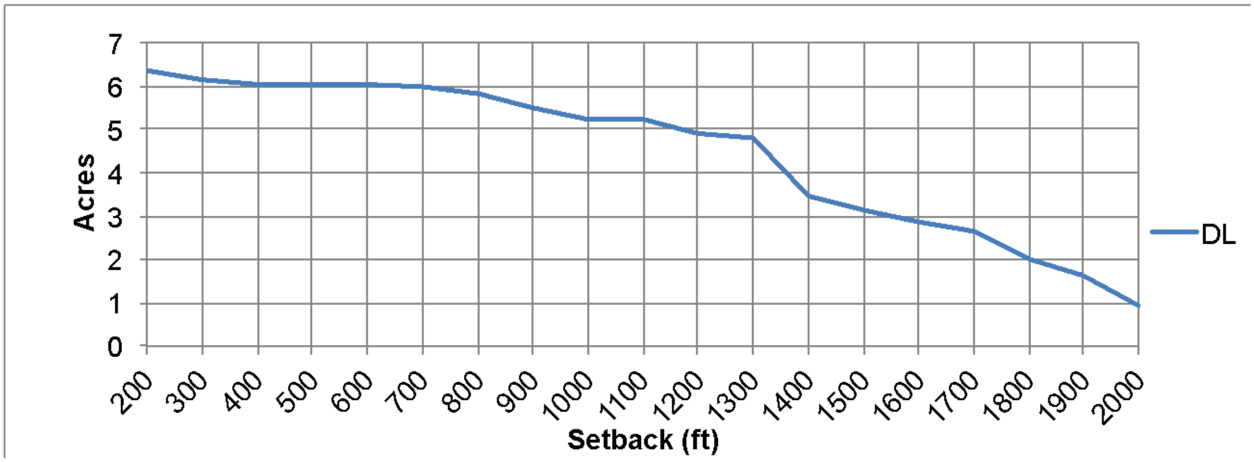

Fig. C.81 Setback distance versus drillable land for zoning subcategory CM-E and land cover class Herbaceous

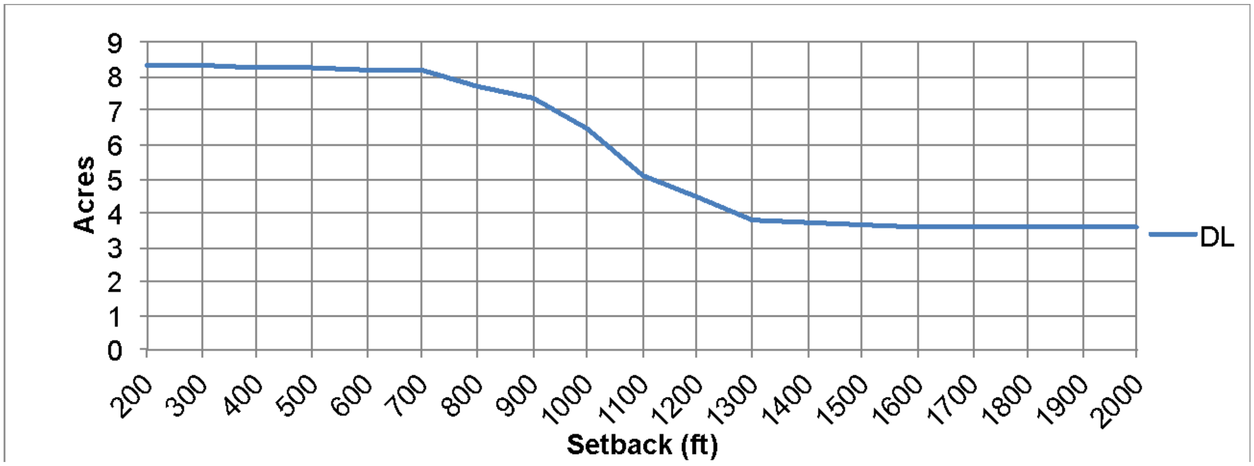

Fig. C.82 Setback distance versus drillable land for zoning subcategory RCC-N and land cover class Herbaceous

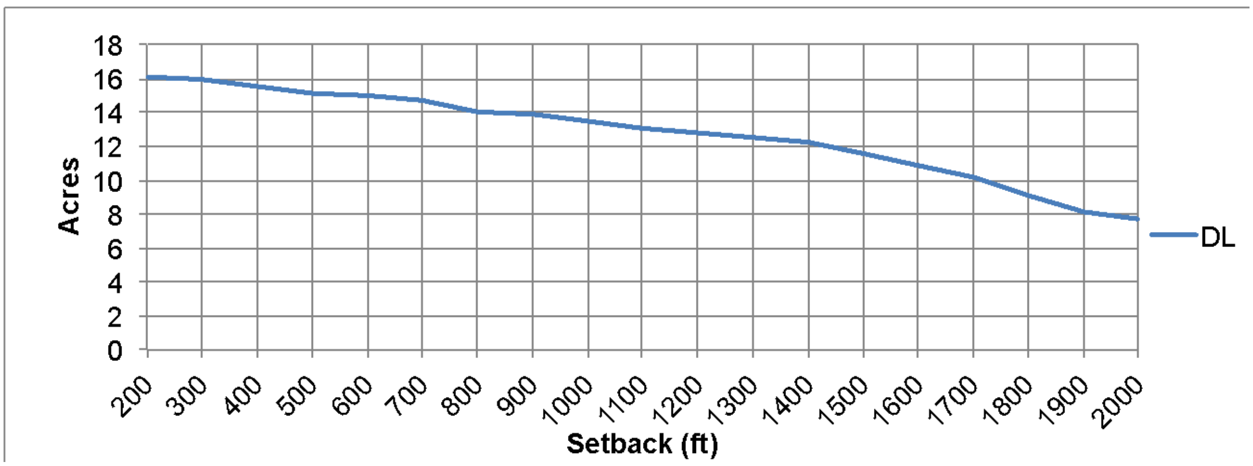

Fig. C.83 Setback distance versus drillable land for zoning subcategory RCC-D and land cover class Herbaceous

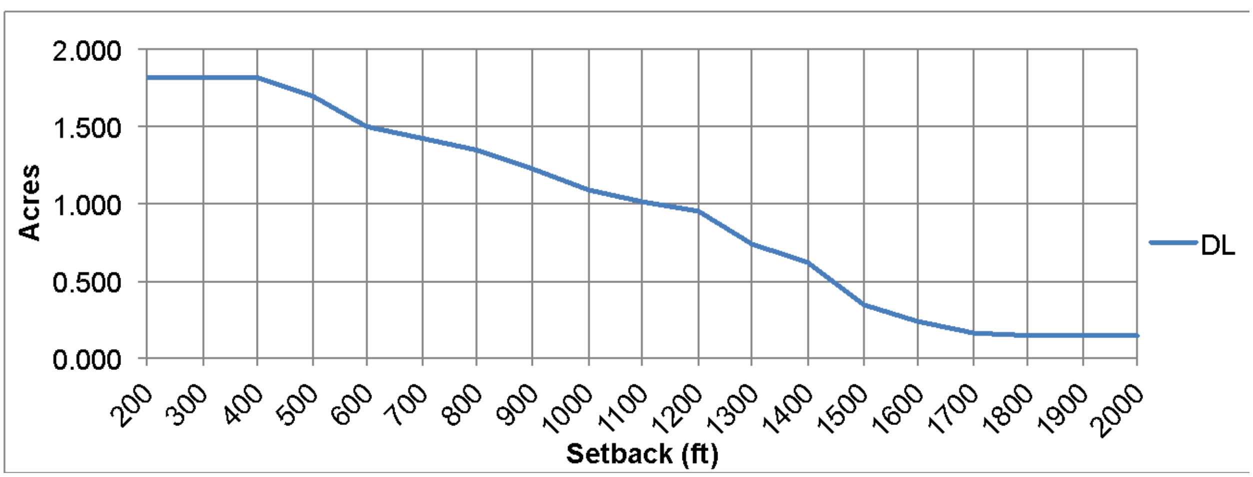

Fig. C.84 Setback distance versus drillable land for zoning subcategory EC-C and land cover class Herbaceous

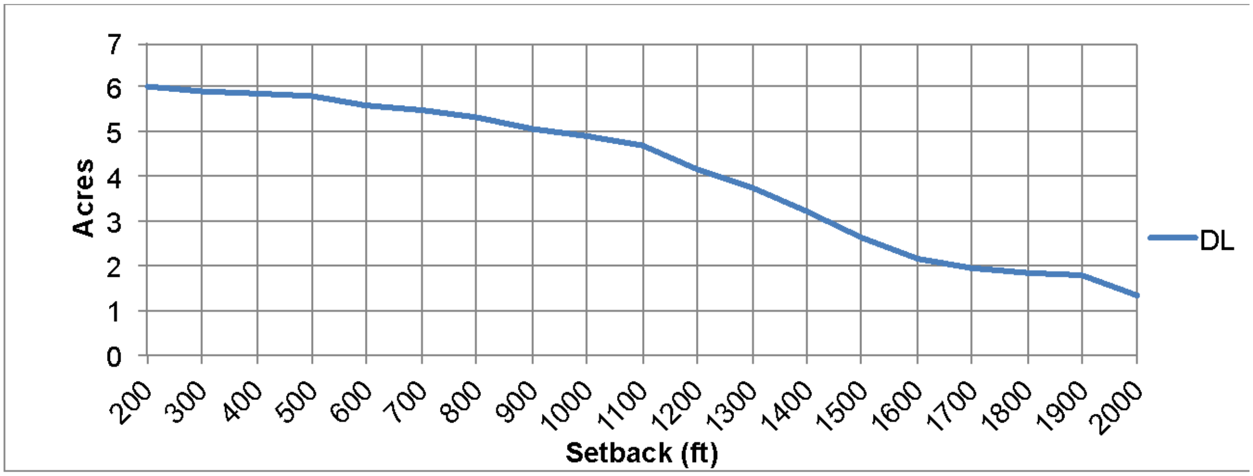

Fig. C.85 Setback distance versus drillable land for zoning subcategory EC-I and land cover class Herbaceous

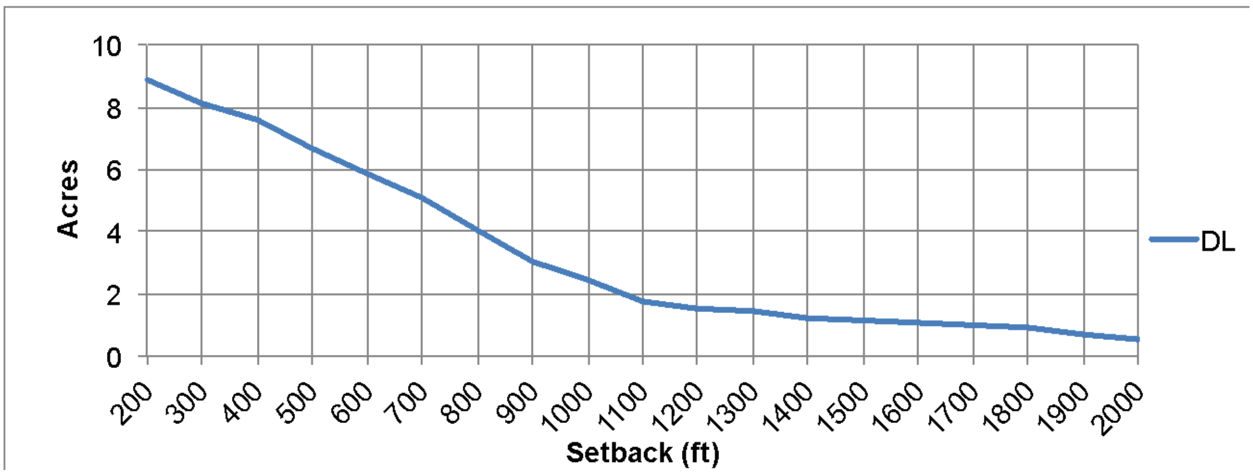

Fig. C.86 Setback distance versus drillable land for zoning subcategory IC-E and land cover class Herbaceous

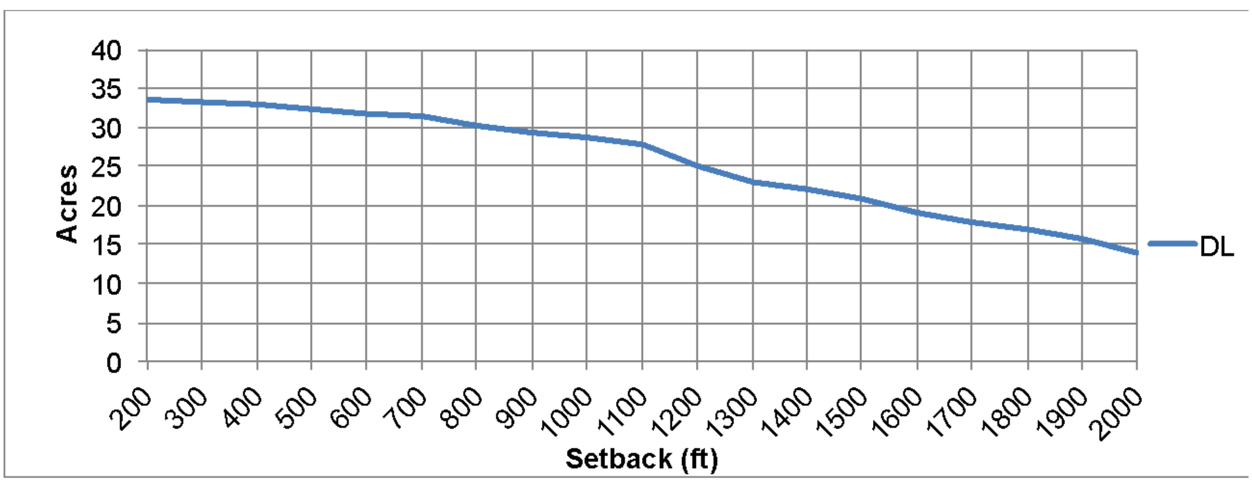

Fig. C.87 Setback distance versus drillable land for zoning subcategory IC-G and land cover class Herbaceous

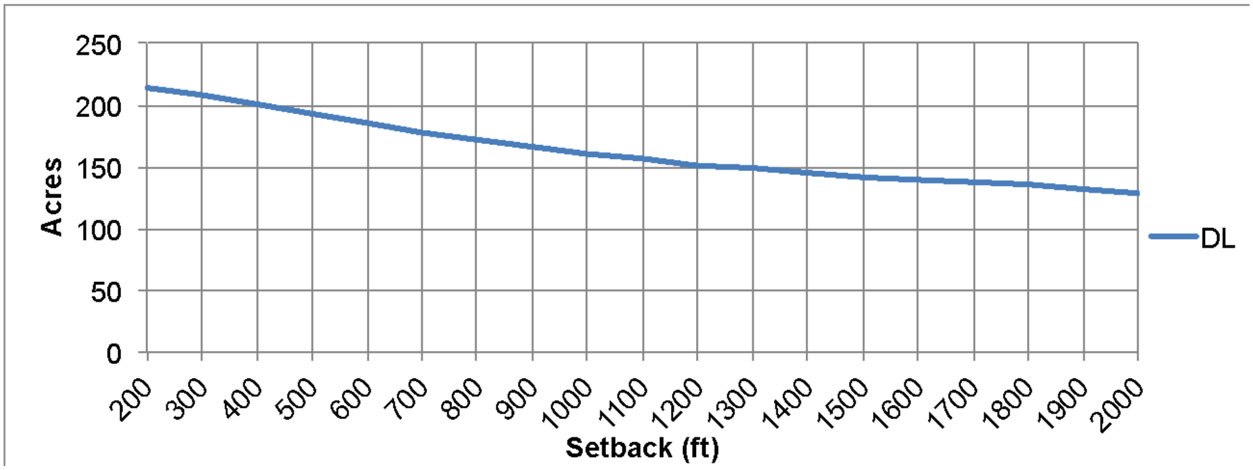

Fig. C.88 Setback distance versus drillable land for zoning subcategory RD-5X and land cover class Herbaceous

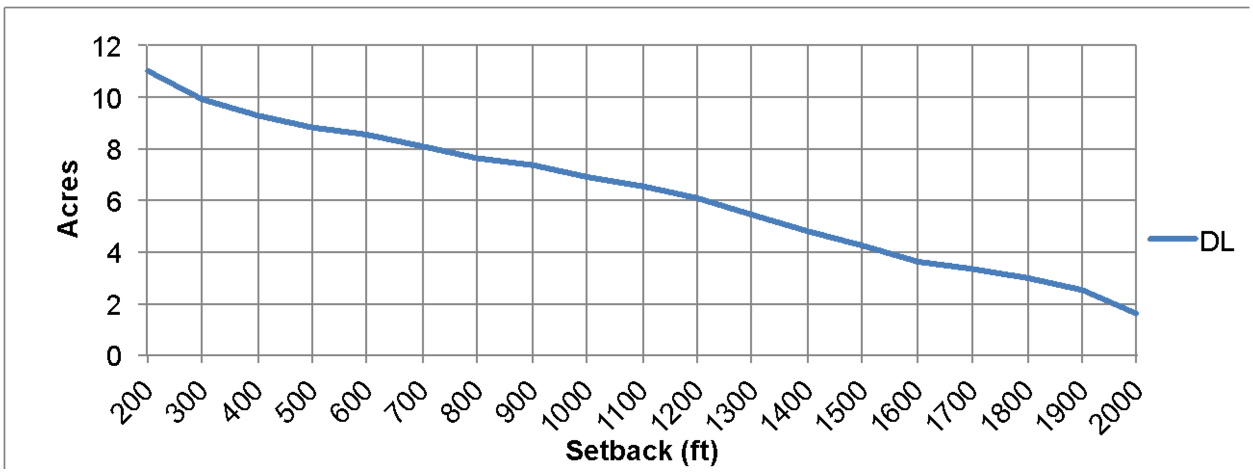

Fig. C.89 Setback distance versus drillable land for zoning subcategory PD and land cover class Herbaceous

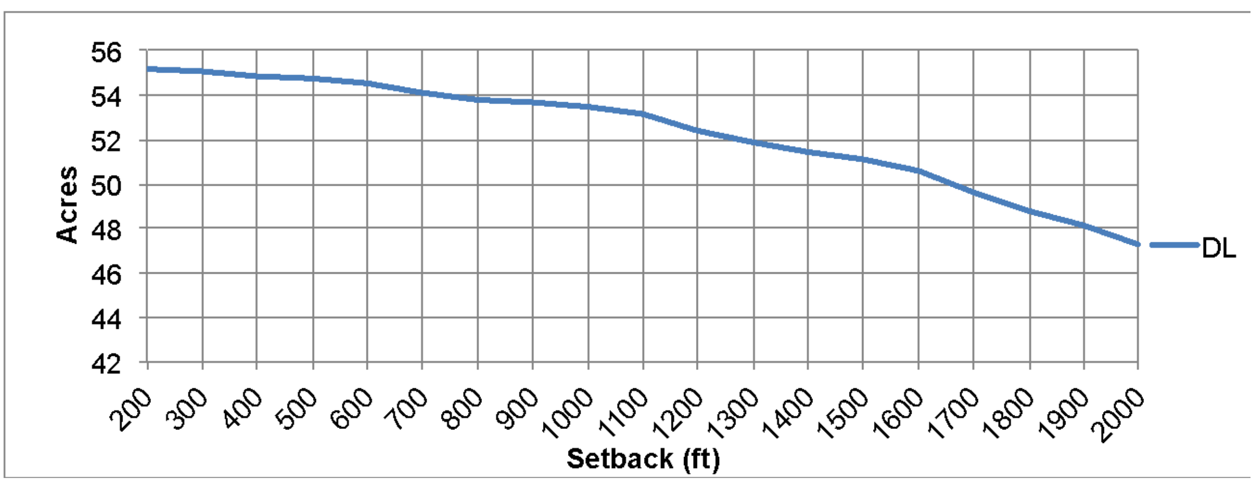

Fig. C.90 Setback distance versus drillable land for zoning subcategory MPC and land cover class Herbaceous

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