Wildfire Hazard and Risk Assessment

City of Grass Valley, California

JANUARY 2024

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Printed on 30% post-consumer recycled material.

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Executive Summary

The potential for damaging wildfire exists within the assessment area (City of Grass Valley, the City Sphere of Influence, and the area within 1.5 miles of the City and its Sphere of Influence), as highlighted through regional fire and ignition history, existing vegetation types and fuels composition, terrain, local climate, and the proximity of structures and infrastructure to wildland vegetation. Approximately 63% of the assessment area is classified as a wildland urban interface or wildland urban intermix. These are areas where structures and other development meet or intermingle with wildland vegetation. Vegetation conducive to ignition and wildfire spread exists throughout the assessment area, presenting risks to human life, safety, and property.

To evaluate the extent of potential wildfire impacts in the assessment area, a Wildfire Hazard and Risk Assessment was conducted using wildfire hazard and risk modeling tools. Modeling was conducted by combining spatial data sets that influence wildfire risk to the community. While wildfire hazard represents the existing wildfire environment and potential wildfire behavior occurring in that environment, wildfire risk is the intersection of wildfire hazard and resources or assets that could be impacted by fire. Wildfire hazard in areas adjacent to developed areas (structure locations) was used as the basis for determining community wildfire risk. Based on the results of this Wildfire Hazard and Risk Assessment, areas of High, Very High, and Extreme relative risk cover approximately 77% of developed areas within the assessment area.

This report summarizes Dudek's modeling and assessment efforts and includes a discussion of the assessment area's fire environment, including terrain, vegetation and fuels, weather, and fire history, in addition to model inputs and model results. The model results map and identify regions categorized as Low to Extreme relative wildfire risk, highlighting areas where approaches could be implemented to reduce wildfire risk to the community. A description of potential wildfire risk reduction approaches is also provided.

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1 Assessment Area Description

1.1 Location

The assessment area encompasses 34,210 acres in western Nevada County, California (Figure 1). The assessment area includes the entirety of the City of Grass Valley (3,986 acres), the City Sphere of Influence (6,051 acres), and the area within 1.5 miles of the City and its Sphere of Influence (24,173 acres). The City of Nevada City borders the assessment area to the northeast. Unincorporated County areas surround the remaining portions of the assessment area. Highway 49 bisects the assessment area from north to south. State Route 20 and Highway 174 (Colfax Highway) bisect the assessment area from east to west.

1.2 Terrain

The assessment area is topographically diverse and includes features such as ridges, valleys, saddles, and canyons with significant differences in elevation, slope, and aspect. Each of these features affects fire behavior and alters how fire moves across the landscape. Generally, elevation in the assessment area gradually increases when moving from west to east, following the west slope of the Sierra Nevada Mountain range. The urban core of the City of Grass Valley exhibits flat to moderate slopes, with steeper areas generally located near the City's boundaries. Steep canyons and drainages exist within the assessment area, notably within the Deer Creek, Wolf Creek, South Fork Wolf Creek, and Slate Creek canyons. These canyons can facilitate wildfire spread toward urbanized areas due to continuous fuel beds, steeper slopes, and funneling of winds. Topography of the assessment area is presented graphically in Figure 2.

Terrain affects wildfire movement and spread. Steep terrain typically results in faster upslope fire spread due to the pre-heating of uphill vegetation. Flat areas typically result in slower fire spread when absent of windy conditions. Topographic features, such as saddles, canyons, and chimneys (land formations that collect and funnel heated air upward along a slope), may form unique circulation conditions that concentrate or funnel winds and accelerate fire spread. For example, fire generally moves slower downslope than upslope. Terrain may also buffer, shelter, or redirect winds away from some areas based on canyons or formations on the landscape. Saddles occurring at the top of drainages or ridgelines may facilitate the movement of wildfire from one canyon to the next. Various terrain features can also influence fire behavior, as summarized in Table 1.

Table 1. Effects of Topographic Features on Fire Behavior

Topographic Feature	Effect
Narrow Canyon	Surface winds follow canyon direction, which may differ from the prevailing wind; wind eddies/strong upslope air movement expected, which may cause erratic fire behavior; radiant heat transfer between slopes facilitates spotting/ignition on opposite canyon side.
Wide Canyon	Prevailing wind direction not significantly altered; aspect significant contributor to fire behavior. Wide canyons are not as susceptible to cross-canyon spotting except in high winds.
Box Canyon/ Chute	Air is drawn in from canyon bottom; strong upslope drafts. No gaps or prominent saddles to let heated air escape. Fires starting at the canyon bottom can move upslope very rapidly due to a chimney-like preheating of the higher-level fuels and upslope winds.

Table 1. Effects of Topographic Features on Fire Behavior

Topographic Feature	Effect
Ridge	Fires may change direction when reaching ridge/canyon edge; strong air flows likely at ridge point; possibility for different wind directions on different sides of the ridge. Ridges experience more wind. Fires gain speed and intensity moving toward a ridge. Fires burning at a ridge can exhibit erratic fire behavior. Strong air flows can cause a whirling motion by the fire. As the wind crosses a ridge it usually has a leeward eddy where the wind rolls around and comes up the leeward side.
Saddle	Potential for rapid rates of fire spread; fires push through saddles faster during upslope runs. Winds can increase when blowing through saddles due to the funneling effect of the constricted pass. On the other side, winds will slow, but erratic winds potentially occur at the saddle due to eddies.

Sources: NFPA 2011; Teie 1994

1.3 Vegetation and Fuels

The majority of the assessment area has been mapped as having woodland or forest cover. Urban areas represent 12% of the assessment area, concentrated in the urban core of the City of Grass Valley, and surrounding residential neighborhoods and commercial districts. Vegetation coverage for the assessment area is summarized in Table 2 and presented graphically in Figure 3. The following sections describe the dominant vegetation communities in the assessment area, including information about their relative wildfire hazard.

Table 2. Assessment Area Vegetation Communities

Vegetation Community	Total Acreage	Percent of Assessment Area
Montane Hardwood	13,592	40%
Sierran Mixed Conifer	9,276	27%
Urban	3,939	12%
Blue Oak Woodland	2,869	8%
Ponderosa Pine	1,540	5%
Annual Grassland	1,030	3%
Montane Hardwood-Conifer	1,000	3%
Barren	60	<1%
Blue Oak-Foothill Pine	194	1%
Closed-Cone Pine-Cypress	4	<1%
Cropland	95	<1%
Juniper	2	<1%
Lacustrine	27	<1%
Mixed Chaparral	482	1%
Montane Riparian	15	<1%
Pasture	1	<1%
Valley Oak Woodland	2	<1%
Wet Meadow	3	<1%

Source: Sierra Nevada RRK 2023

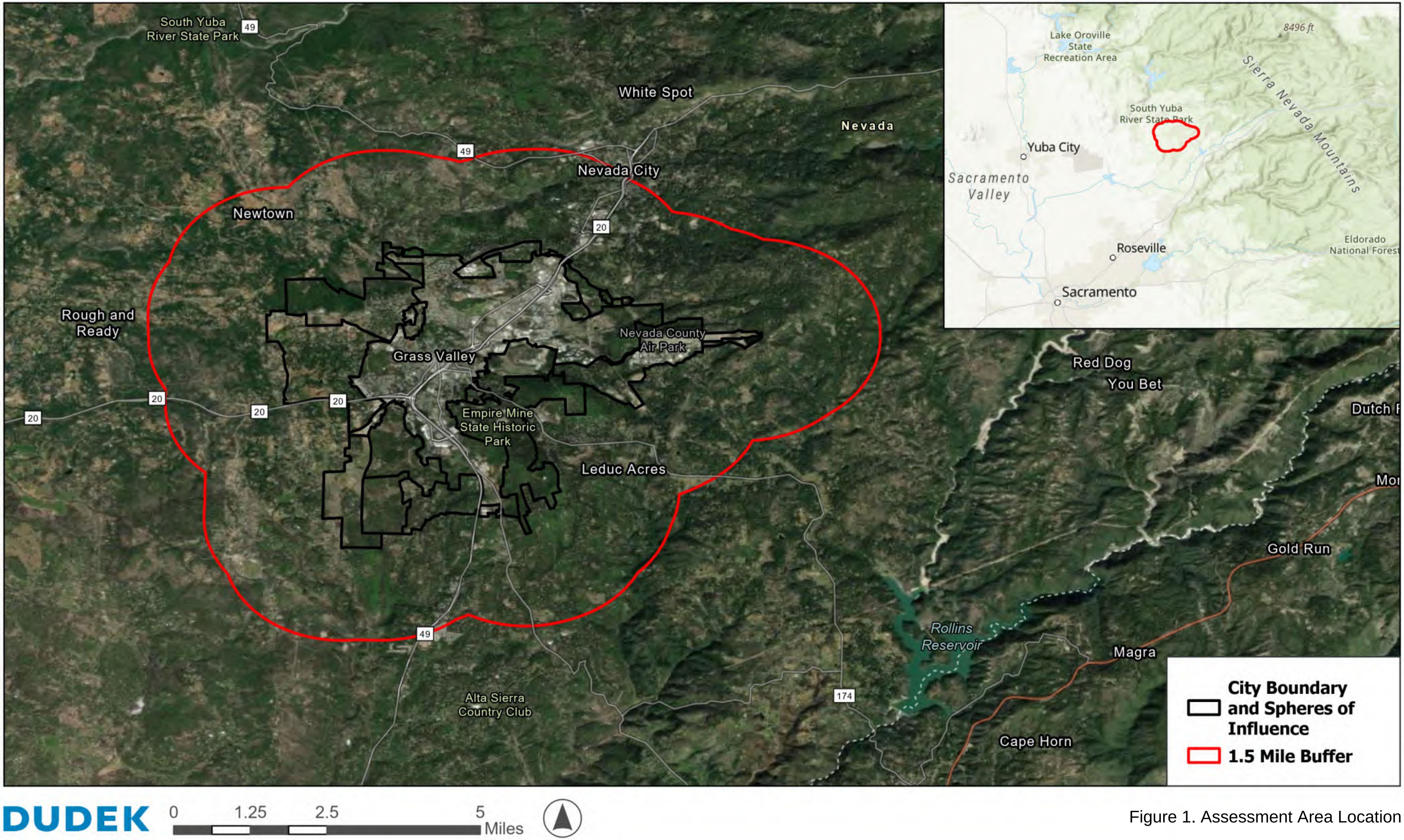

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Figure 1. Assessment Area Location

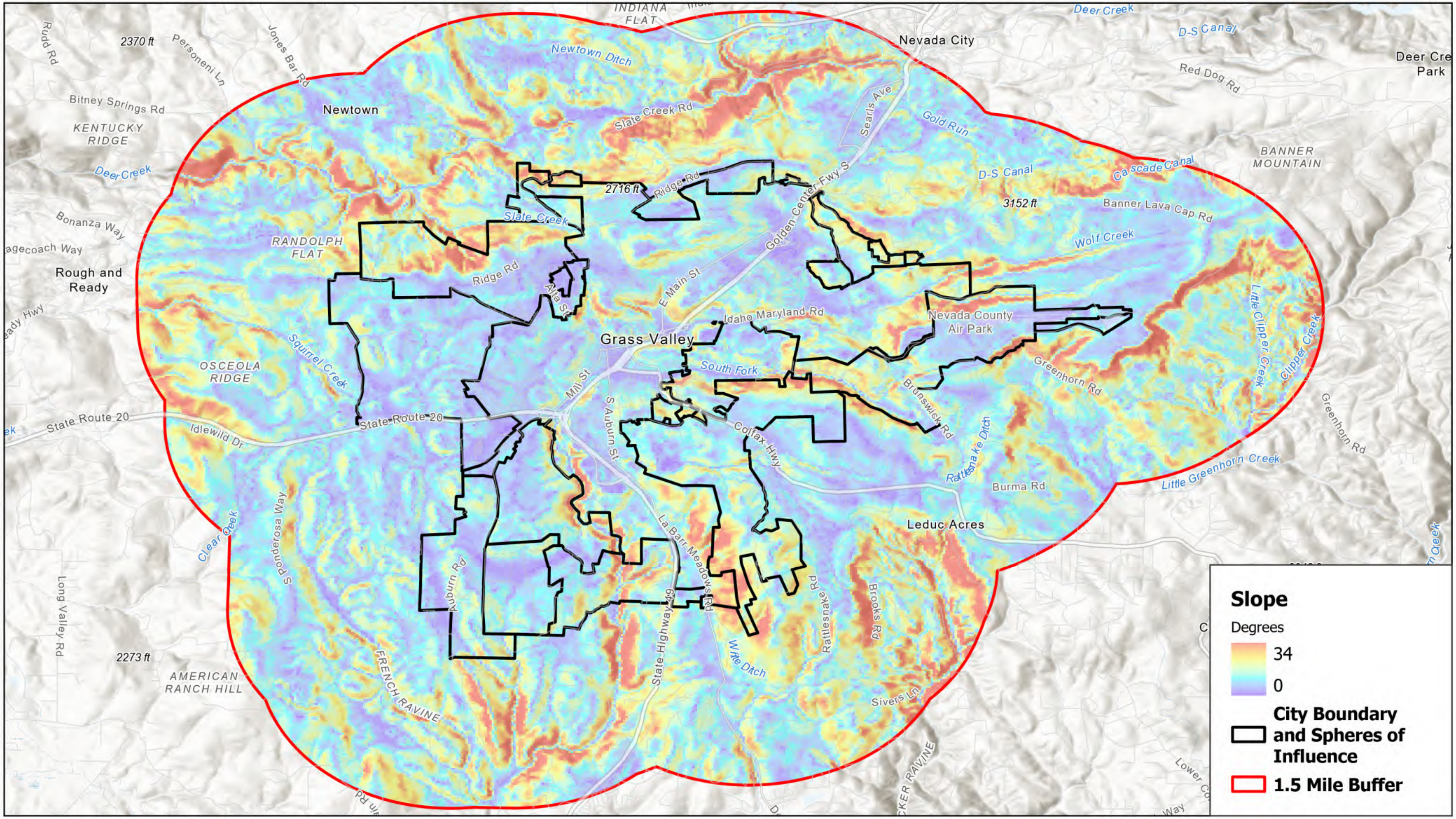

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Figure 2. Assessment Area Terrain

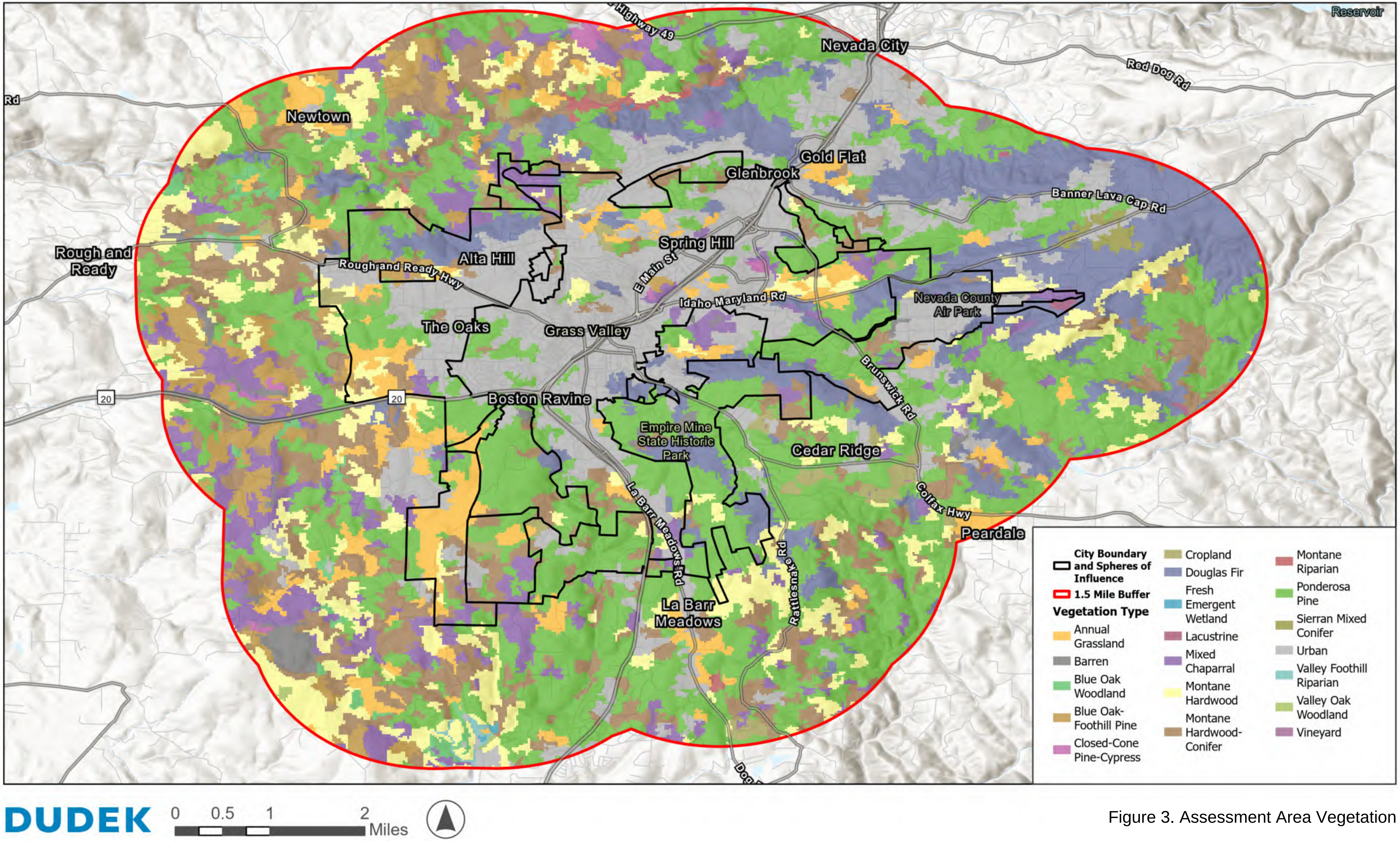

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Figure 3. Assessment Area Vegetation

Montane Hardwood and Montane Hardwood-Conifer

Montane Harwood and Montane Hardwood-Conifer represent 43% of the assessment area. These vegetation communities are largely represented by oak and conifer species including canyon live oak, interior live oak, California black oak, ponderosa pine, Jeffrey pine, gray pine, incense cedar, and Douglas-fir. Montane Hardwood-Conifer vegetation incudes a greater composition of conifer species. Shrubs such as manzanita, poison oak, coffeeberry, and ceanothus may also be present in these vegetation types, although poorly developed. Herbaceous vegetation is generally sparse but is often more prevalent in open canopy stands. The reduction of fire as an ecosystem process in these vegetation communities allows for an accumulation of fuels that had previously been consumed during regular, low-intensity fires. These vegetation types are often highly productive and lead to a build-up of woody vegetation in the understory, including significant increases in dead and downed woody material and ladder fuels connecting ground vegetation to tree canopies. As a result, some stands are more susceptible to severe, crown-consuming wildfires.

Sierran Mixed Conifer

Sierran Mixed Conifer represents 27% of the assessment area. Sierran Mixed Conifer is largely represented by conifer species such as ponderosa pine, Jeffrey pine, sugar pine, incense cedar, and Douglas-fir. California black oaks are also commonly found in this vegetation type. These forests have a multilayered structure and are influenced by factors such as fire, climate, topography, historical management, and soils. The canopies of forested stands are often closed and have multiple layers with almost complete canopy cover overlap (Rundel et al. 1977). Shrubs often grow in the lower layer when there are gaps in the canopy and include species such as deer brush, manzanita, chinquapin, tan oak, bitter cherry, mountain whitethorn, gooseberry, rose, and mountain misery (Kosco 1980). Wildfire behavior in Sierran Mixed Conifer vegetation is highly dependent on forest structure and fuels characteristics. Wildfire hazard is generally highest in stands with minimal crown separation and high accumulations of ladder fuels that can facilitate surface to crown fire transition. Other factors such as drought and forest pests and disease can increase wildfire hazard due to reduced fuel moisture and the increased amount of dead and dying trees.

Blue Oak Woodland

Blue Oak Woodland represents 8% of the assessment area. Blue oak is the dominant species, comprising 85 to 100 percent of the trees present. Trees are generally scattered, although canopies may be closed on better quality sites favorable to tree production. Shrubs may be present but are rarely extensive. Typical understory is composed of annual grasses and forbs. As such, wildfire behavior in Blue Oak Woodland is typically dependent on the structure of understory vegetation. Wildfires may move quickly through flashy surface fuels; however, fuel loads are generally low and typically do not promote high flame lengths.

Grassland

Grassland areas represent 3% of the assessment area. Grasses are fine fuels that are loosely compacted with a low fuel load. Grasses have a high surface-area-to-volume ratio, requiring less heat to remove fuel moisture and raise the fuel to ignition temperature. They are also subject to early seasonal drying in late spring and early summer. Live fuel moisture content in grasses typically reaches its low point in early summer, and grasses begin to cure soon after. Due to these characteristics, grasses have the potential for a high rate of spread, rapid ignition, and facilitation of extreme fire behavior. Their low overall fuel loads typically result in faster-moving fires with lower flame lengths and heat output.

Untreated grasses can spread a fire into other adjacent surface fuel types (e.g., shrubs, small trees) or facilitate surface-to-crown fire transition where grasses exist beneath tree canopies.

Urban

Urban land cover represents 12% of the assessment area. Fire burning in undeveloped areas can pass to urban areas through the presence of flammable or non-maintained landscape or ornamental vegetation. The characteristics and presence of urban vegetation significantly impact the potential for wildfires and their spread within urban environments. The type, density, and condition of vegetation in urban areas influence the availability of fuel for fires. When urban areas contain dense and highly flammable vegetation like dry grasses, shrubs with volatile oils, or trees with combustible foliage, the risk of fires igniting and spreading rapidly increases. Additionally, the accumulation of dead leaves, branches, and plant debris contributes to fuel loads and elevates fire hazard. Urban vegetation also influences the ignition and spotting potential of wildfires. Wind-carried embers and burning debris can ignite new fires in urban areas, especially when highly flammable vegetation is near structures. This raises the risk of embers landing on or near buildings, leading to fire spread within urban areas and an increased likelihood of structure ignitions.

1.4 Weather

The assessment area is generally characterized by a Mediterranean climate with hot, dry summers followed by cool, wet winters. Weather components such as temperature, relative humidity, wind, and lightning also affect the potential for wildfire. High temperatures and low relative humidity dry out fuels that feed wildfires, creating a situation where fuel will ignite more readily and burn more intensely. Thus, during periods of drought, the threat of wildfire increases (County of Nevada 2017).

Winds can be significant at times in the assessment area and drive wildfire spread. While less common, north/northeast winds in Nevada County can occur during hot, dry conditions, which can lead to “red flag” days indicating extreme fire danger. In addition to wind speed, wind shifts can occur suddenly due to temperature changes or the interaction of wind with topographical features such as slopes or steep hillsides (County of Nevada 2017). Predominate winds are from the southwest but commonly become north to northeast following weather system changes. The regional prevailing weather pattern is a diurnal wind pattern. This results in a daytime wind from the south/southwest (up-canyon), and nighttime winds from the north/northeast (down-canyon). During the summer season, diurnal winds can be slightly stronger than the winds during the winter season due to greater pressure gradient forces. These winds can contribute to fire hazards when appropriate conditions exist for wildfire ignition and spread. Surface winds can also be influenced locally by terrain variations. The varied terrain of the assessment area also affects wind velocity and patterns. Annually, fire weather conditions often become critical in late July through October.

It should be noted, however, that microclimates exist due to the diversity in elevation and aspects within the assessment area. As such, conditions are variable on a daily and seasonal basis throughout the assessment area. Microclimatic conditions can greatly affect fire hazards and would need to be considered when determining vegetation treatments and implementation timing. Such conditions are often not captured in weather station datasets or recorded in easily referenced weather almanacs but are usually well known to locals, land managers, and local fire agency personnel.

1.4.1 Climate Change

According to the Sierra Nevada Region Report for California's Fourth Climate Assessment (Dettinger et al. 2018), wildfire is expected to increase in frequency and intensity within the Sierra Nevada region as a result of climate change. Effects of climate change including increased temperatures, higher likelihood of severe weather events including heat waves and dry lightning storms, and reduced precipitation and snowpack. These effects are expected the increase wildfire severity. Overall, the region is expected to become dryer, reducing fuel and air moisture content over longer periods of time. This is likely to exacerbate wildfire severity as conditions would be more favorable to extreme wildfire behavior. Reduced precipitation is also expected to increase tree mortality in the region leading to an increased accumulation of hazardous fuels.

1.5 Fire Hazard Severity Zones

Fire Hazard Severity Zones (FHSZs) are geographical areas designated pursuant to California Public Resources Code Sections 4201 through 4204; they are classified as Very High, High, or Moderate in State Responsibility Areas, or as Local Responsibility Area Very High FHSZ designated pursuant to California Government Code Sections 51175 through 51189. California Public Resources Code Sections 4201–4204 and Government Code Sections 51175–51189 direct the California Department of Forestry and Fire Protection (CAL FIRE) to map areas of significant fire hazard based on fuels, terrain, weather, and other relevant factors. The resulting FHSZs define the application of various mitigation strategies to reduce the risk associated with wildland fires (OSFM 2023). The model used to determine the extent of FHSZs is based on an analysis of potential fire behavior and fire probability predicated on the frequency of fire weather, ignition patterns, expected rate of spread, ember (brand) production, and past fire history (OSFM 2023). Structures built in FHSZs are subject to more stringent fire-hardening requirements than those that are not. The FHSZ classifications for State Responsibility Area (SRA) and Local Responsibility Area (LRA) lands in the assessment area are provided in Figure 4 and Tables 3 and 4.

Table 3. FHSZ Classifications in State Responsibility Area of Assessment Area

FHZS Classification	Acres in Assessment Area	Percent of Assessment Area
Very High	21,345	62%
High	7,290	21%

Source: CAL FIRE 2023a

Table 4. FHSZ Classifications in Local Responsibility Area of Assessment Area

FHZS Classification	Acres in Assessment Area*	Percent of Assessment Area
Very High	2,558	7%

Source: CAL FIRE 2023b
*Includes a portion of the Nevada City FHSZ in LRA

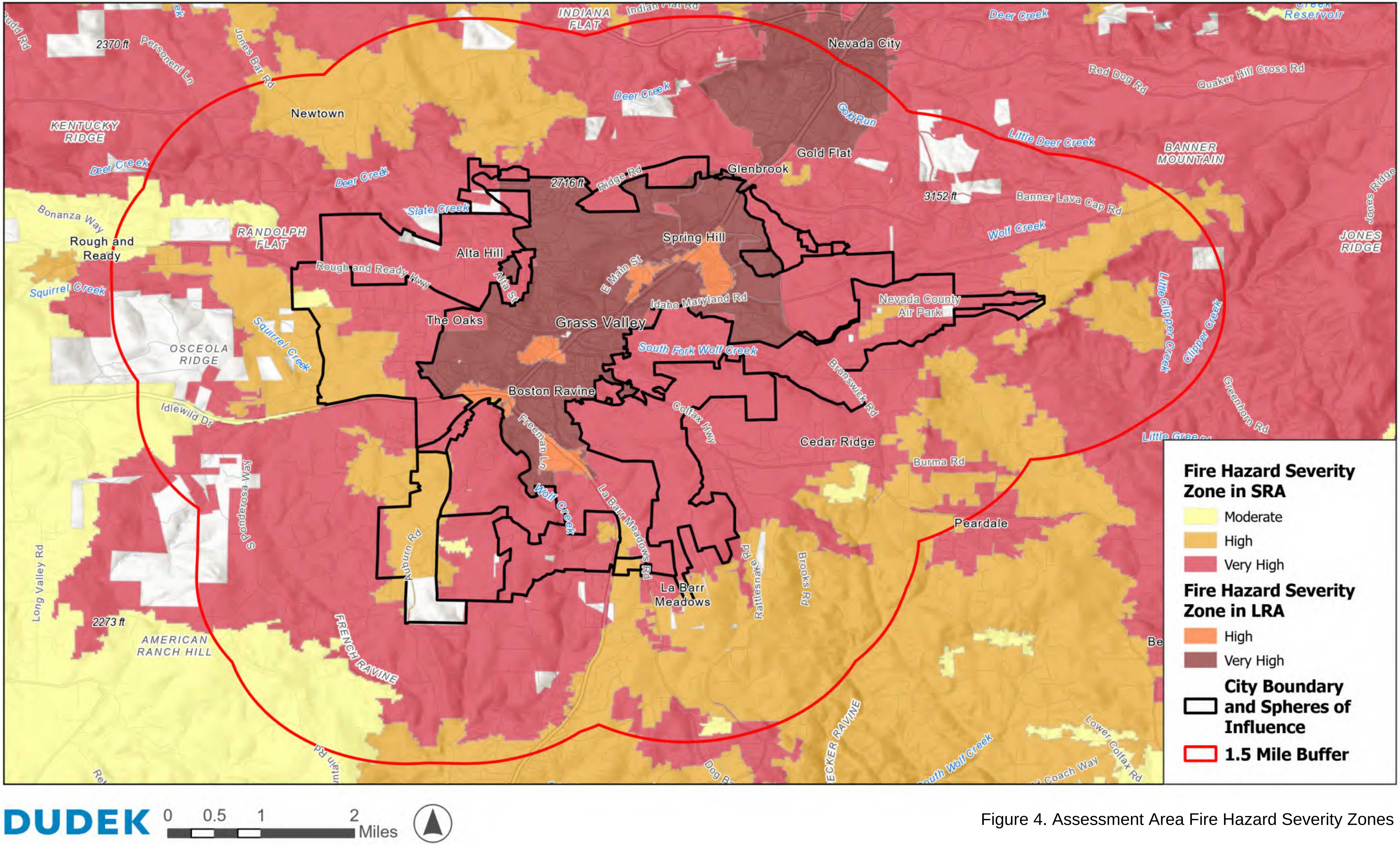

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Figure 4. Assessment Area Fire Hazard Severity Zones

1.6 Fire and Ignition History

Fire history can provide an understanding of a variety of factors related to fires, including frequency, type and behavior, most vulnerable community areas, and significant ignition sources, among others. One important use for this information is as a tool for pre-planning. It is advantageous to know which areas may have burned recently and therefore may provide a tactical defense position, what type of fire burned in the area, and how a fire may spread. CAL FIRE's Fire and Resource Assessment Program (FRAP) summarizes fire perimeter data from the late 1800s to 2022 (fires over 10 acres in size).

According to this data set, eight wildfires have occurred within the assessment area (Table 5 and Figure 5). Most recently in August 2021, the human-caused Bennet Fire burned 50 acres near East Bennet Road and resulted in mandatory evacuations. The Jones Fire in August 2020 burned 706 acres and destroyed over 20 structures after lighting strikes ignited the fire approximately 1 mile southwest of the South Yuba River Bridge. Other recent fires in the assessment area include the arson-caused Auburn Fire in 2016 which was started near South Auburn Street burning 28 acres and threatening nearby structures, and the McCourtney Fire in 2017 which ignited along McCourtney Road and burned 76 acres just north of Quail Valley Country Club.

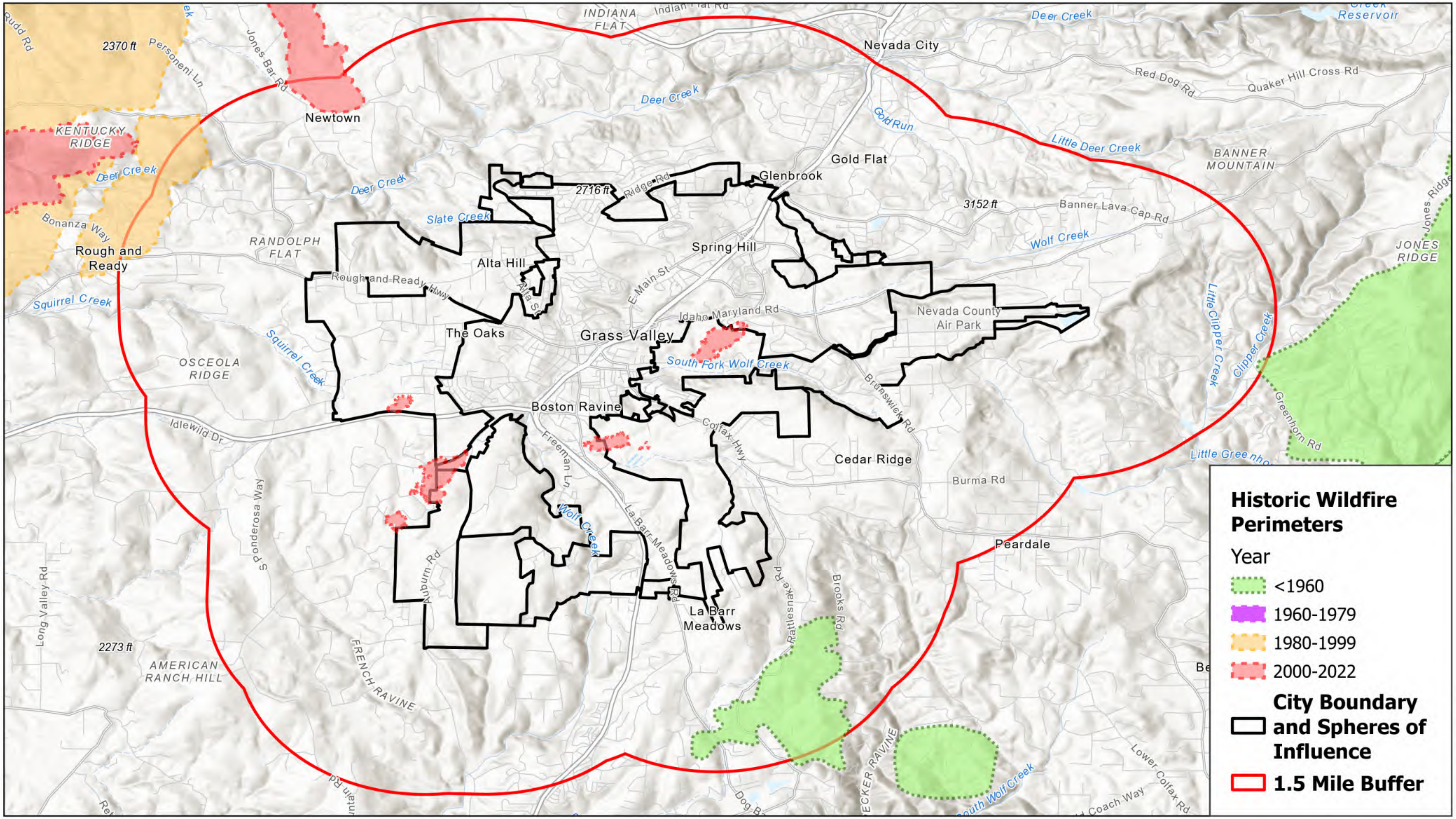
Although considerable numbers of historical wildfires have occurred in proximity to the assessment area, the relatively low number of historical wildfires within the assessment area suggests that the vegetation within undeveloped and non-maintained areas has likely matured and accumulated a significant amount of dead and dying material, which results in increased fuel loads that can contribute to high-severity wildfire.

Table 5. Historical Wildfires within the Assessment Area

Year	Fire Name	Total Acreage
1916	Unnamed	3,923
1951	Rattlesnake	586
1994	Trauner	536
2016	Auburn	24
2017	Rex	12
2017	McCourtney	76
2020	Jones	706
2021	Bennett	50

Source: CAL FIRE 2023c

An analysis of wildfire ignition data can also help to understand where ignitions are occurring and inform wildfire mitigation project development. The National Interagency Fire Occurrence dataset contains a spatial database of wildfires that occurred in the United States from 1992 to 2020 using wildfire records were acquired from the reporting systems of federal, state, and local fire organizations (Short 2023). Wildfire ignition data from 2020 to 2023 was obtained from the Wildfire Incident Locations database for incidents reported to the Integrated Reporting of Wildland Fire Information (IRWIN) system (NIFC 2023). Between 1992 and 2023, 831 wildland fire ignitions have been recorded within the assessment area. These are visually presented in Figure 6. Ignitions generally occur along main roadways (Highways 20, 49, and 174, Idaho Maryland Road, Brunswick Road, McCourtney Road, and South Auburn Street), near the Nevada County Air Park, and in vegetation proximate to residential areas.



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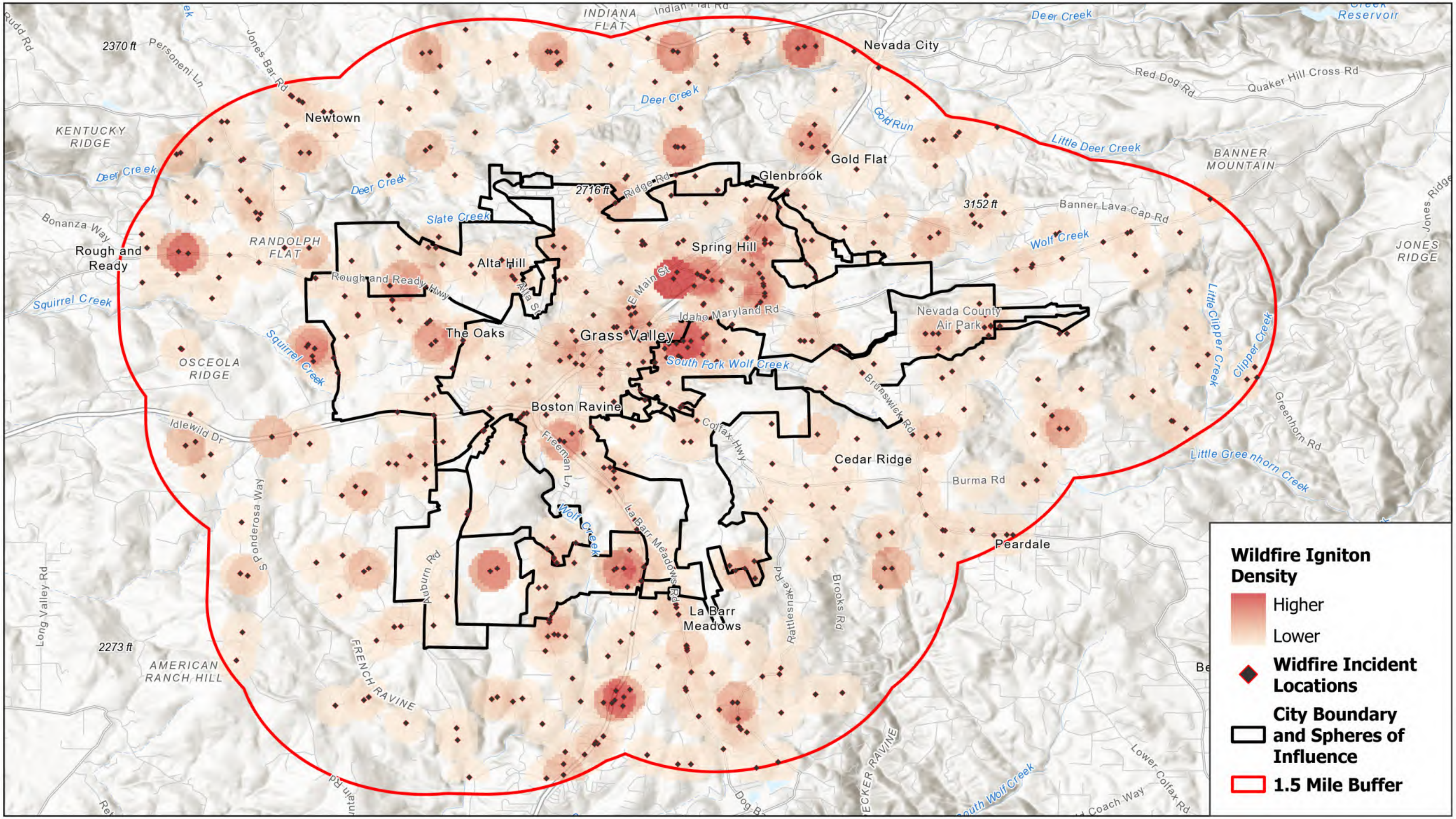
0 0.5 1 2 Miles

Figure 5. Assessment Area Fire History



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0 0.5 1 2 Miles

Figure 6. Assessment Area Wildfire Ignition Locations

1.7 Wildland Urban Interface/Intermix

The wildland urban interface (WUI) is an area in which wildfire risk mitigation projects may be conducted to reduce wildland fire threats to communities at risk. The pattern of development and land use within the assessment area creates conditions that can be described as either a wildland urban interface or a wildland urban intermix. The wildland urban interface/intermix has been mapped (Sierra Nevada RRK 2023). Table 6 presents the acreage of land in each classification for the assessment area. These are visually presented in Figure 7. Both conditions present advantages and disadvantages with respect to reducing wildfire risk, as described in the following sections.

Table 6. Wildland Urban Interface/Intermix in the Assessment Area

Wildland/Urban Type	Acres in Assessment Area	Percent of Assessment Area
Interface	3,930	11%
Intermix	17,799	52%
Non-WUI	12,485	36%

Source: Sierra Nevada RRK 2023

1.7.1 Wildland Urban Interface

The area where urban development occurs within 1.5 miles of an area of vegetation measuring at least 5 square kilometers (and with at least 75% vegetation) would be characterized as a wildland urban interface (Interface or WUI) (Sierra Nevada RRK 2023). The wildland fire risk associated with WUI areas includes propagation of fire via house-to-house fire spread, landscaping-to-house fire spread, or ember intrusion. For Grass Valley, the WUI is concentrated within the downtown core, along Highway 49, and in more densely develop neighborhoods near the downtown core.

Advantages and disadvantages associated with WUI areas are provided below.

WUI Advantages

- Community water supply systems in place
- Multiple homes accessed by a single road.
- Emergency equipment protects multiple assets at once.
- Houses usually only exposed to flammable fuels on one side.

WUI Disadvantages

- High housing density
- Congested roads during emergencies
- Limited options if the community water systems fail.

1.7.2 Wildland Urban Intermix

Intermix areas are those where housing and vegetation intermingle. In an intermix area, wildland vegetation is continuous, and more than half of the land area is vegetated with combustible fuels (Sierra Nevada RRK 2023). The wildland fire risk associated with intermix areas includes vegetation-to-house fire spread or ember intrusion. For Grass Valley, the intermix is located along the edges of the WUI and in less densely developed neighborhoods

(Sunset View, The Oaks, Glenbrook, Bennett Road, Freeman Road, Allison Ranch Road, and near Empire Mine State Historic Park).

Advantages and disadvantages associated with intermix areas are provided below.

Intermix Advantages

- Low housing density
- Diversity in water supply systems

Intermix Disadvantages

- Increased risk to firefighters
- Emergency equipment can only protect single assets.
- Delayed emergency equipment response times due to the following:
  - Rural roads (single lane, windy, heavy fuel loading)
  - Long driveways
- Congested roads during emergencies
- Diversity in water supply systems
- Houses surrounded by vegetation.

1.8 At-Risk Community

The Healthy Forest Restoration Act of 2003 identifies at-risk communities as an area:

(A) that is comprised of—

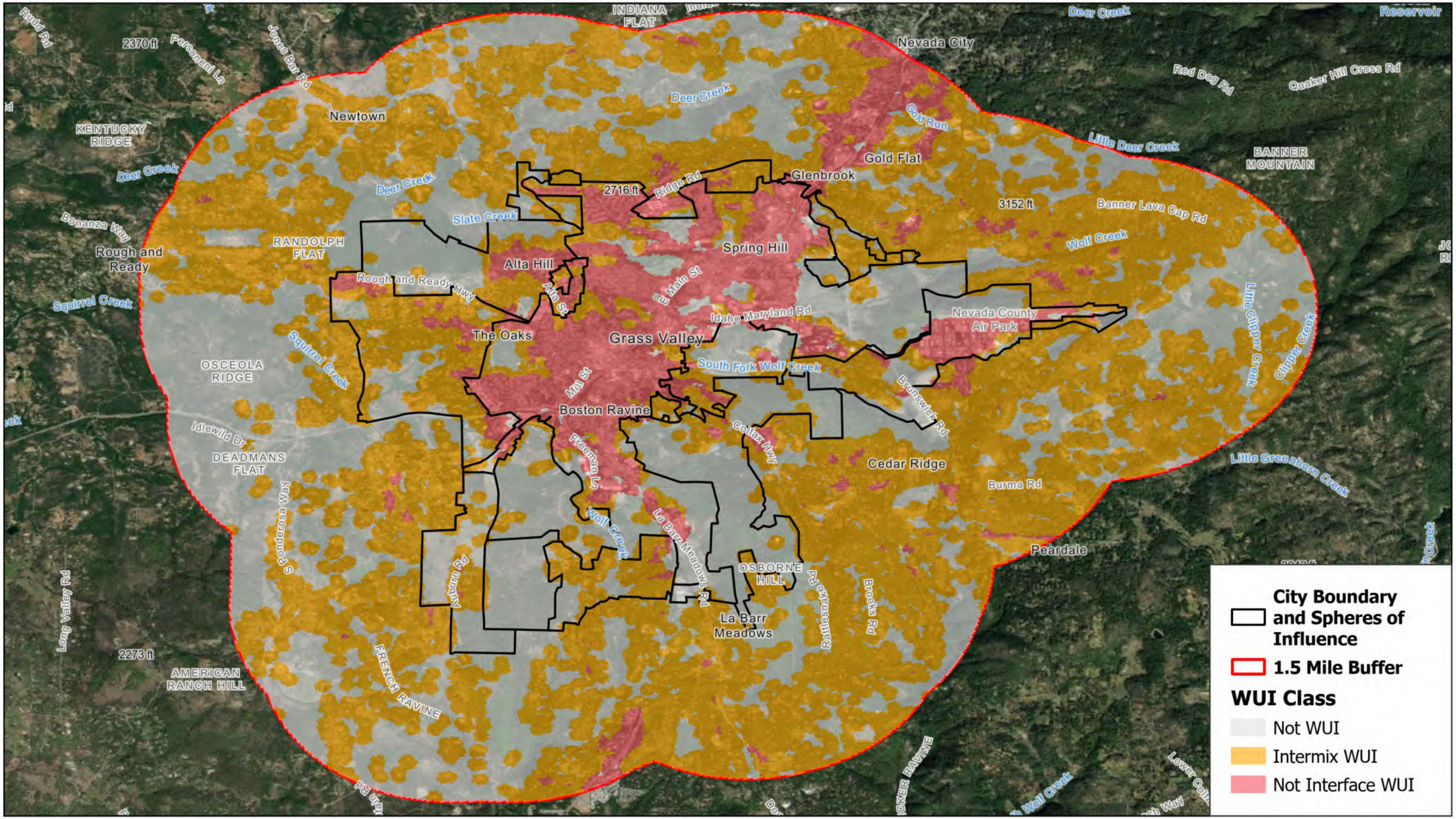
(i) an interface community as defined in the notice entitled ‘‘Wildland Urban Interface Communities Within the Vicinity of Federal Lands That Are at High Risk From Wildfire’’ issued by the Secretary of Agriculture and the Secretary of the Interior in accordance with title IV of the Department of the Interior and Related Agencies Appropriations Act, 2001 (114 Stat. 1009) (66 Fed. Reg. 753, January 4, 2001); or

(ii) a group of homes and other structures with basic infrastructure and services (such as utilities and collectively maintained transportation routes) within or adjacent to Federal land.

(B) in which conditions are conducive to a large-scale wildland fire disturbance event; and

(C) for which a significant threat to human life or property exists as a result of a wildland fire disturbance event.

In addition to this definition, the California Office of the State Fire Marshal maintains a list of Communities at Risk. The National Fire Plan directs funding to be provided for projects designed to reduce the fire risks to communities. These high-risk communities identified within the WUI were published in the Federal Register in 2001 and include those communities neighboring federal lands. The City of Grass Valley is identified as a Community at Risk in the Federal Register.



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0 0.5 1 2 Miles

Figure 7. Assessment Area Wildland Urban Interface

2 Hazard and Risk Assessment

A focused wildfire hazard and risk assessment was conducted for the assessment area to identify areas of relatively higher wildfire risk and potential areas for future wildfire risk mitigation efforts. This assessment was conducted in a geographic information systems (GIS) environment and involved analyzing and processing several GIS data sets as well as modeling potential fire behavior within the assessment area. All GIS analysis was conducted in a 30-meter raster environment. The wildfire hazard and risk assessment was conducted in two distinct steps:

- **Hazard Assessment:** The hazard assessment component involved evaluating six different wildfire-related data sets. It also included modeling potential fire behavior for the assessment area to evaluate flame length and crown fire potential, used as metrics to evaluate extreme fire behavior.

- **Risk Assessment:** The risk assessment component involved evaluating the hazard assessment data sets in relation to community areas. This involved evaluating and processing structure location data to map the development area. It also included ranking and weighting the hazard data sets based on their relative contribution to wildfire risk. The result was a new composite wildfire risk GIS map layer for the assessment area.

The following sections outline the assessment approach, identify input data layers, and summarize the assessment results.

2.1 Hazard Assessment

2.1.1 Extreme Fire Behavior

Several wildfire types exist, as summarized below:

- **Ground Fire:** A fire burning on the ground that consumes organic material beneath surface litter (NWCG 2023).
- **Surface Fire:** A fire that burns loose debris on the surface, which includes dead branches, leaves, and low vegetation (NWCG 2023).
- **Crown Fire:** A fire that has burned upward from the ground and into the tree canopy. There are three types of crown fires:
  - **Passive Crown Fire:** A crown fire in which individual or small groups of trees torch out, but solid flaming in the canopy cannot be maintained except for short periods. Passive crown fire encompasses a wide range of crown fire behavior from the occasional torching of an isolated tree to a nearly active crown fire. Also called torching (Scott and Reinhardt 2001).
  - **Active Crown Fire:** A crown fire in which the entire fuel complex becomes involved, but the crowning phase remains dependent on heat released from the surface fuels for continued spread. Also called running and continuous crown fire (Scott and Reinhardt 2001).
  - **Independent Crown Fire:** A crown fire that spreads without the aid of a supporting surface fire (Scott and Reinhardt 2001).

Another component of fire behavior is spotting, the transfer of fire brands (embers) ahead of a fire front which can ignite smaller vegetation fires (NWCG 2023). These smaller fires can burn independently or merge with the main fire. Spotting can also result in structural ignitions when transported embers reach a receptive fuel bed (e.g., combustible roofing), especially in wind-driven fires. Structure fires as well as vegetation-fueled fires can generate fire brands. Additionally, landscape features like ridges can dramatically affect fire behavior by changing prevailing wind patterns, funneling air, and increasing wind speeds, thereby intensifying fire behavior.

Each of the aforementioned fire types may occur within the assessment area, depending on site-specific conditions. Fire behavior is the manner in which a wildland fire reacts to weather, fuels, and topography. The difficulty of controlling and suppressing a wildfire is typically determined by fire behavior characteristics, such as rate-of-spread, fireline intensity, torching, crowning, spotting, fire persistence, and by resistance to control (NWCG 2023). Extreme fire behavior is that which precludes methods of direct control (e.g., flame lengths 8 feet and greater), behaves unpredictably and erratically, and typically involves high spread rates, crowning and/or spotting, the presence of fire whirls, and a strong convective column (NWCG 2023).

Fire behavior characteristics are an important component in understanding fire risk and fire agency response capabilities. Flame length—the length of the flame of a spreading surface fire within the flaming front—is measured from midway in the active flaming combustion zone to the average tip of the flames (Andrews et al. 2008). While it is a somewhat subjective and nonscientific measure of fire behavior, it is extremely important to fireline personnel when evaluating fireline intensity, and is worth considering as an important fire variable (Rothermel 1993). Fireline intensity is a measure of heat output from the flaming front and also affects the potential for a surface fire to transition to a crown fire. The information in Table 7 presents an interpretation of flame length and its relationship to fire suppression efforts.

Table 7. Fire Behavior Interpretation

Flame Length	Fireline Intensity	Interpretation
Under 4 feet	Under 100 BTU/ft/s	Fires can generally be attacked at the head or flanks by persons using hand tools. Hand line should hold the fire.
4 feet to 8 feet	100–500 BTU/ft/s	Fires are too intense for a direct attack on the head by persons using hand tools. Hand line cannot be relied on to hold the fire. Equipment such as dozers, pumpers, and retardant aircraft can be effective.
8 feet to 11 feet	500–1,000 BTU/ft/s	Fires may present serious control problems—torching out, crowning, and spotting. Control efforts at the fire head will probably be ineffective.
Over 11 feet	Over 1,000 BTU/ft/s	Crowning, spotting, and major fire runs are probable. Control efforts at the head of fire are ineffective.

Source: Roussopoulos and Johnson 1975.
Note: BTU/ft/s = British thermal units per foot per second.

Fire behavior in the assessment area was modeled using the Interagency Fuel Treatment Support System (IFTDSS) using the Landscape Fire Behavior tool. Landscape Fire Behavior in IFTDSS is driven by FlamMap, a fire behavior mapping and analysis software application that computes potential fire behavior characteristics over an entire landscape under constant weather and fuel moisture conditions input by the user. The fire behavior analysis did not incorporate burn probability. The 2022 LANDFIRE data set (embedded in the IFDTSS software application) was used to represent the terrain (elevation, slope, and aspect) and the vegetation/fuel for the assessment area.

From a wildfire behavior modeling perspective, the assessment area exhibits characteristics that result in inaccuracies in the LANDFIRE Landscape file, specifically fuel model designations. LANDFIRE fuel models are determined through satellite imagery and are generally most accurate when representing large continuous tracts of natural vegetation. The assessment area includes patches of natural vegetation intermixed with structures and urbanized areas. When analyzing the default LANDFIRE landscape fuels data, it was noted that many areas of natural vegetation were not recognized due to their proximity to urbanized areas (and were therefore mapped as non-vegetation). The converse was also evident, as many urban areas were assigned vegetative fuel models even though the ground surface is non-burnable. This is due to the considerable amount of urban vegetation in the assessment area and the 30-meter scale of the LANDFIRE mapping data.

The 2019 National Land Cover Database (NLCD) was used to modify the fuel model layer for the assessment area to better represent fuel models in urbanized areas. The NLCD is created in cooperation with the Multi-Resolution Land Characteristics Consortium, a partnership of federal agencies that produce nationally consistent land cover datasets for the United States. The NLCD includes an impervious surfaces layer, which allows for the identification of urban ground cover, including paved areas and structures.

Landscape fire behavior was modeled using the inputs provided in Table 8, consistent with modeling efforts conducted for Nevada County's Community Wildfire Protection Plan update effort.

Table 8. Fire Behavior Modeling Weather and Fuel Moisture Inputs

Input	Value
Wind Speed	20 mph
Default Wind Azimuth	45 degrees
Wind Flow Type	Downslope
1-hour Fuel Moisture	3%
10-hour Fuel Moisture	5%
100-hour Fuel Moisture	8%
Live Herbaceous Fuel Moisture	30%
Live Woody Fuel Moisture	60%
Foliar Moisture Content	100%
Crown Fire Calculation Method	Scott and Reinhardt 2011

Landscape fire behavior modeling outputs (flame length and crown fire type) were utilized to identify areas anticipated to experience extreme fire behavior. Modeled flame length and crown fire types are presented in Figures 8 and 9, respectively. Areas with modeled flame lengths greater than or equal to 8 feet were aggregated with areas where crown fires were modeled to create a GIS layer representing extreme fire behavior for the assessment area. Areas of extreme fire behavior are presented in Figure 10.

2.1.2 Ember Load

It is estimated that up to 90% of structure losses from wildfire are caused by embers rather than the main fire front (IBHS 2020). Ember load quantifies the relative number of airborne embers that may fall onto an area from a nearby wildfire. Ember load relates to spotting distance, which quantifies the distance airborne embers may travel from their source. Ember load data was obtained from the Conditional Ember Load Index dataset created by Pyrologix (Pyrologix 2021). This data set incorporates surface and canopy fuels characteristics, climate, and topography to determine the relative amount of embers landing per pixel in a 30-meter raster environment. This dataset does not account for burn probability. Figure 11 presents the Ember Load layer for the assessment area.

2.1.3 Hazardous Fuels

Hazardous fuels are excess woody materials on the ground or in the forest understory or canopy that can increase the severity of a wildfire. When proximate to communities, hazardous fuels can promote extreme wildfire conditions that can overpower wildfire suppression efforts and result in substantial damages. Hazardous fuels data was obtained from the Total Fuel Exposed to Fire dataset. This dataset exists within the Regional Resource Kit for the Sierra Nevada Region, a data hub provided by the California Wildfire and Forest Resilience Task Force. This dataset quantifies the sum of standing dead fuels, ladder fuels, and dead and down fuels, represented as the total amount of biomass available to contribute to the extreme fire intensity and spread rates that lead to high severity fire (Sierra Nevada RRK 2023). Figure 12 presents the Proximity to Hazardous Fuels layer for the assessment area.

2.1.4 Wildfire Suppression Difficulty

The wildfire Suppression Difficulty Index (SDI) is a spatial data layer that considers the effect of terrain, fuels, anticipated fire behavior during extreme fire weather conditions, firefighter line production rates, and proximity to roads and trails (access) in rating the relative difficulty in performing fire suppression activities. The data is categorized into six classes, ranked from lowest to highest difficulty. The SDI dataset was obtained from Pyrologix and the USDA Forest Service's Contemporary Wildfire Hazard Across California (USFS 2019). Figure 13 presents the SDI for the assessment area.

2.1.5 Urban Tree Canopy Cover

Urban vegetation can contribute to the transmission of wildfires from natural vegetation to developed regions. During intense wildfires, embers that land in urban vegetation can result in additional fire starts within communities, even if they are located a significant distance away from the primary fire front. Some tree species (e.g., conifers) have characteristics that may make them highly flammable, including the production of needle or leaf litter and peeling bark, or the presence of volatile oils and resins. Dense urban tree canopies, particularly those comprised of conifer species, can increase the liklihood of crown fire within urban areas.

Urban tree canopy cover was obatined from the USA NLCD Tree Canopy Cover database which displays the proportion of the land surface covered by trees fror the years 2011-2021 (USFS 2023). Figure 14 presents the urban tree canopy cover for the assessment area.

2.1.6 Ignition Density

As described in Section 1.6, the assessment area frequently experiences vegetation fires, with 831 ignitions occurring between 1992 and 2023. Using the ignition data for the assessment area, a density analysis was performed to determine areas with high ignition density. These areas are presented in Figure 15.

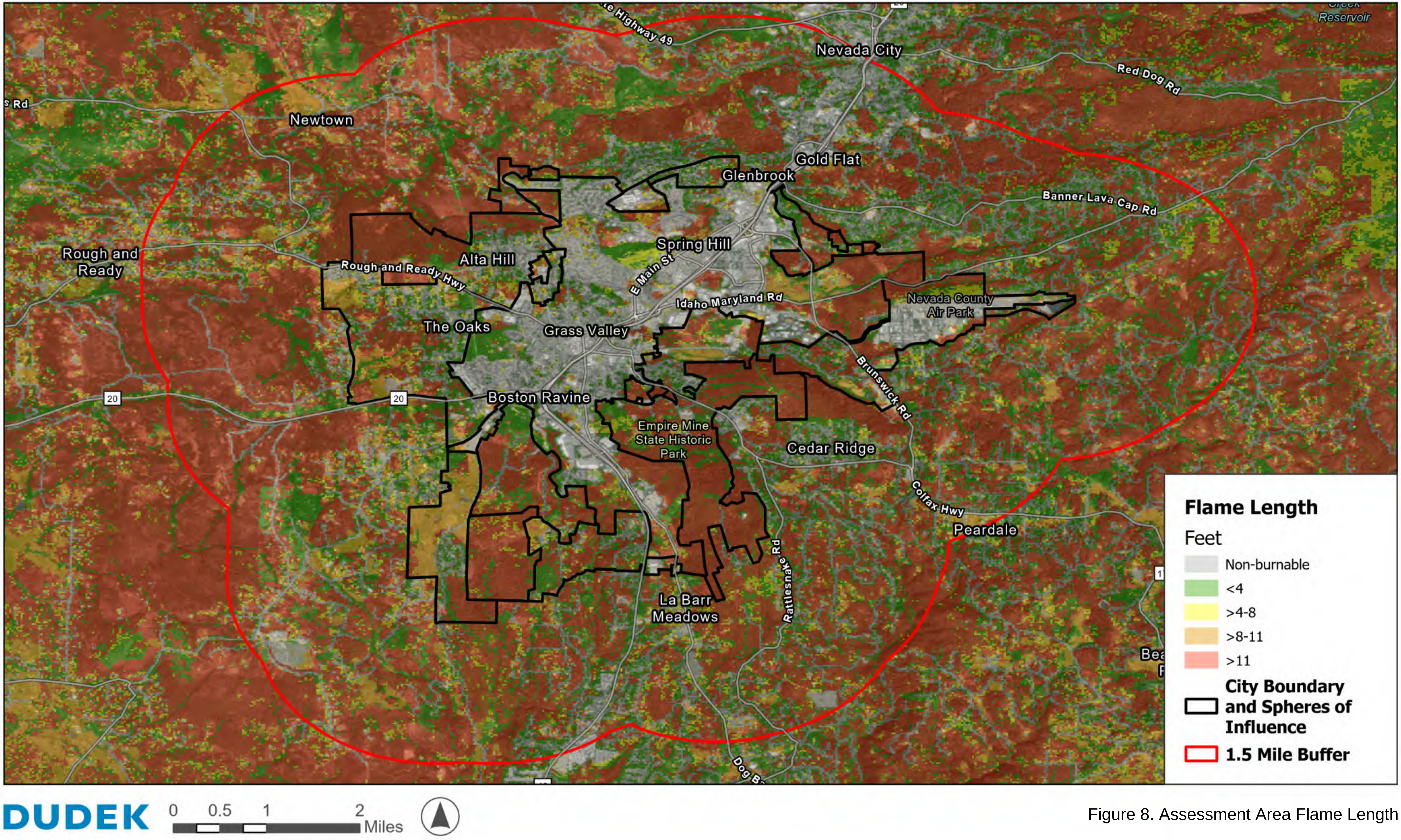

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Figure 8. Assessment Area Flame Length

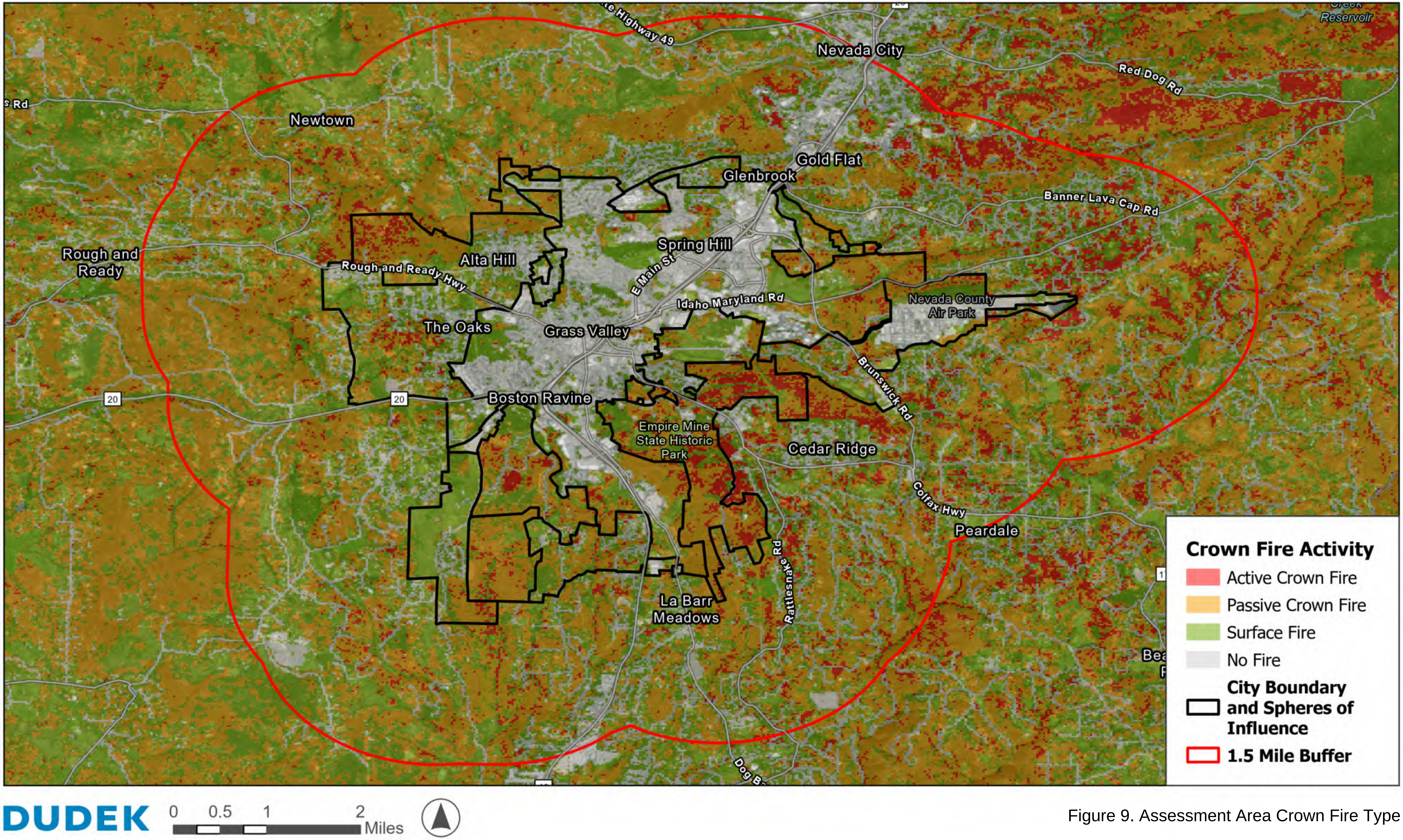

Figure 9. Assessment Area Crown Fire Type

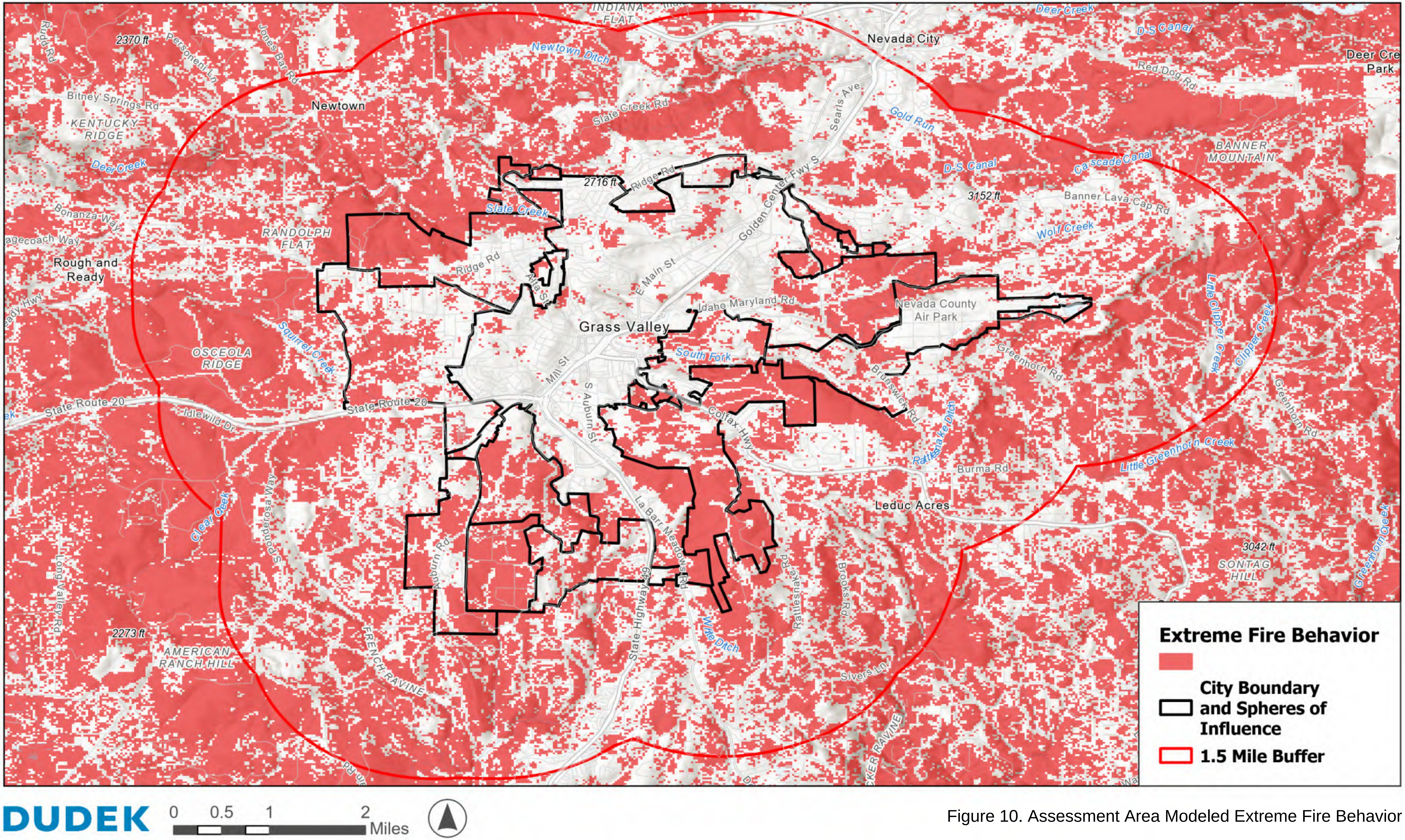

Figure 10. Assessment Area Modeled Extreme Fire Behavior

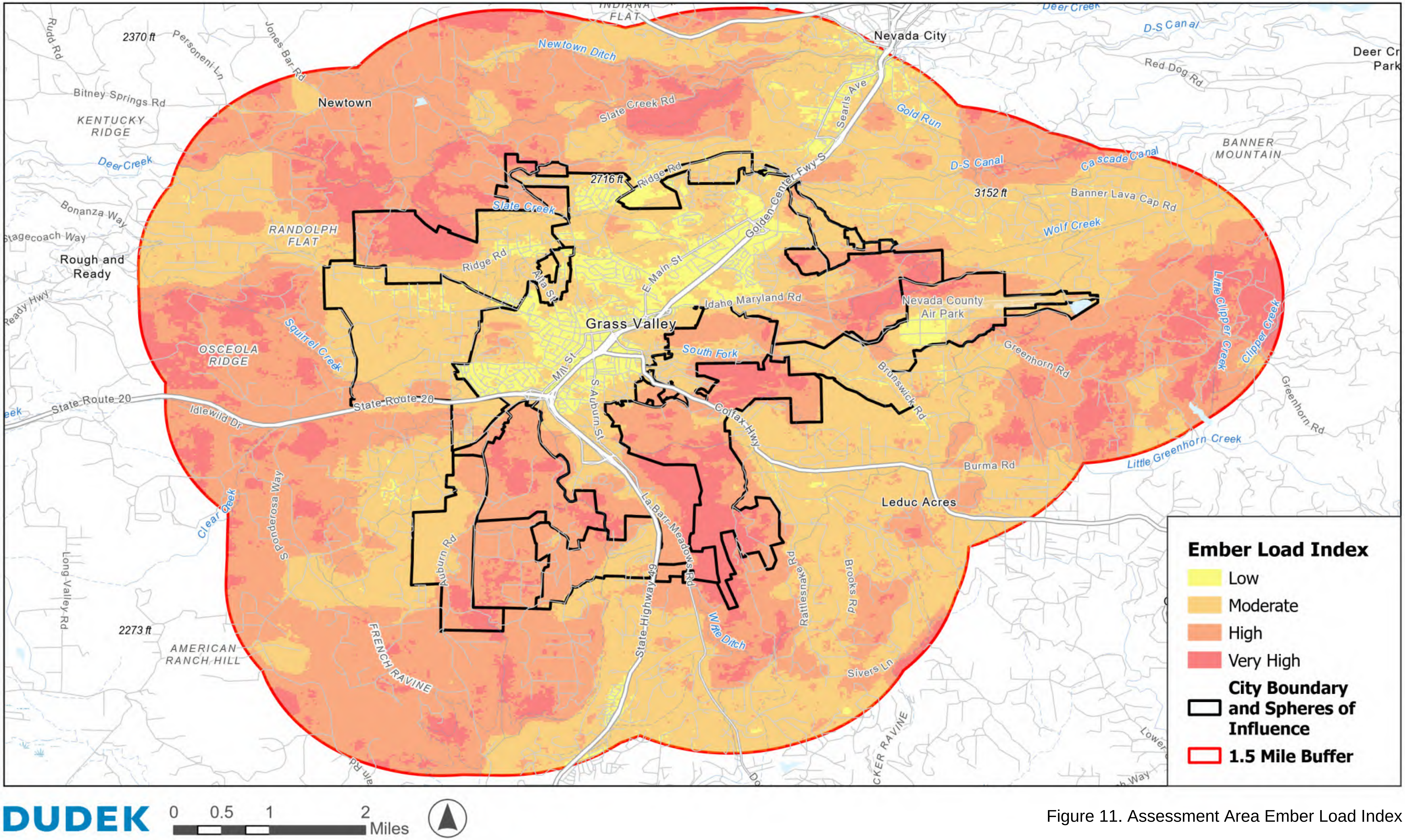

Figure 11. Assessment Area Ember Load Index

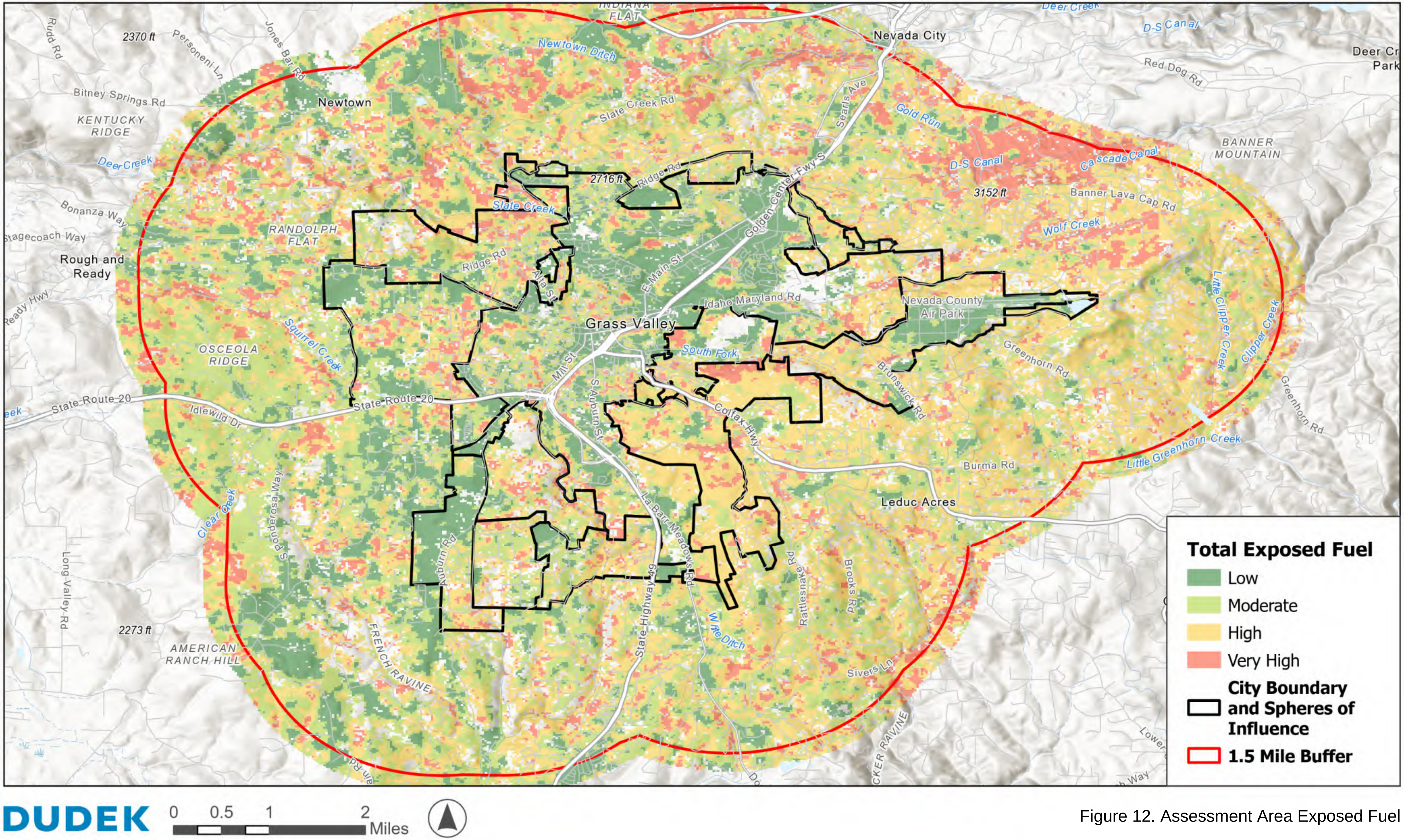

Figure 12. Assessment Area Exposed Fuel

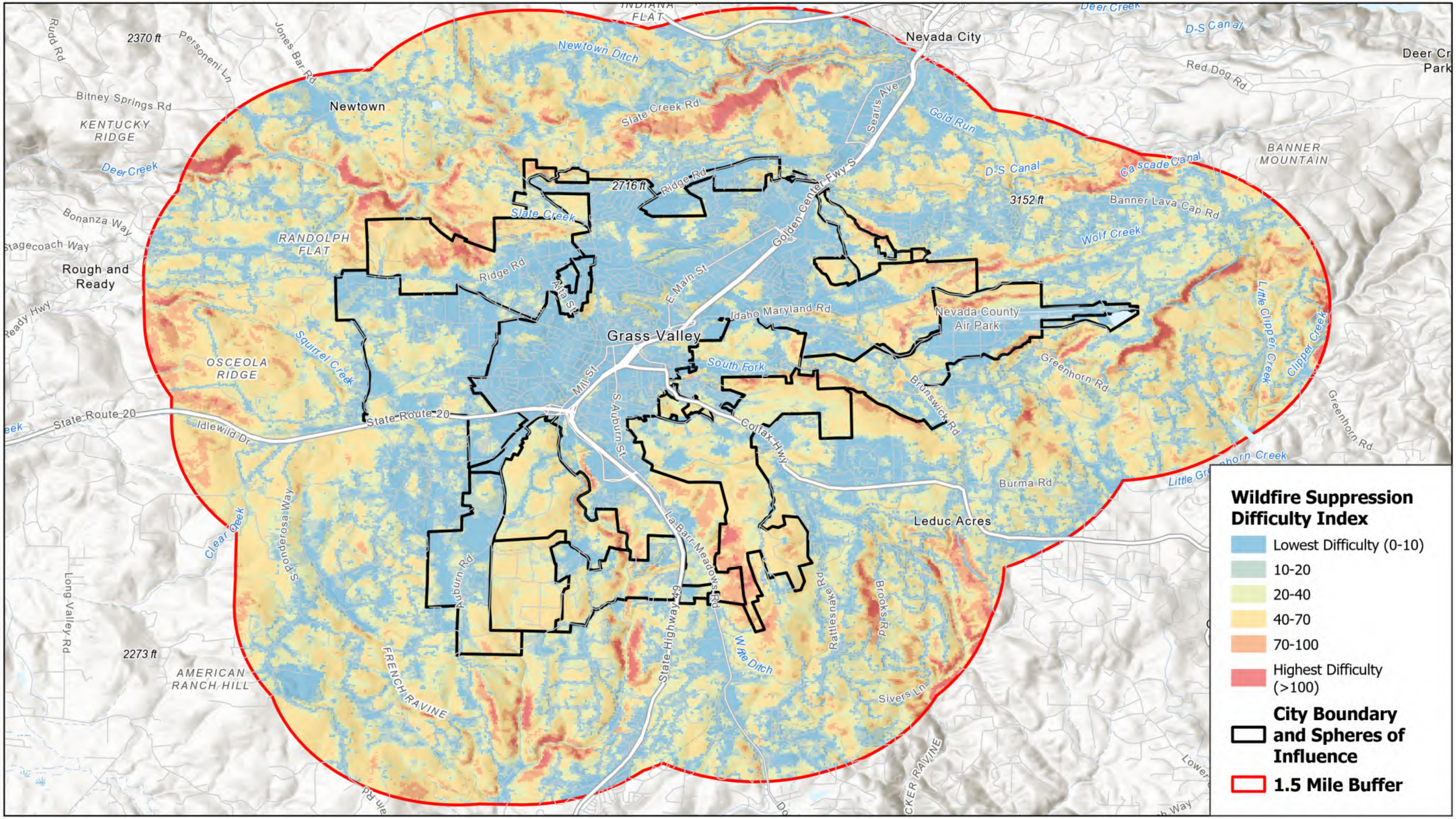

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Figure 13. Assessment Area Wildfire Suppression Difficulty

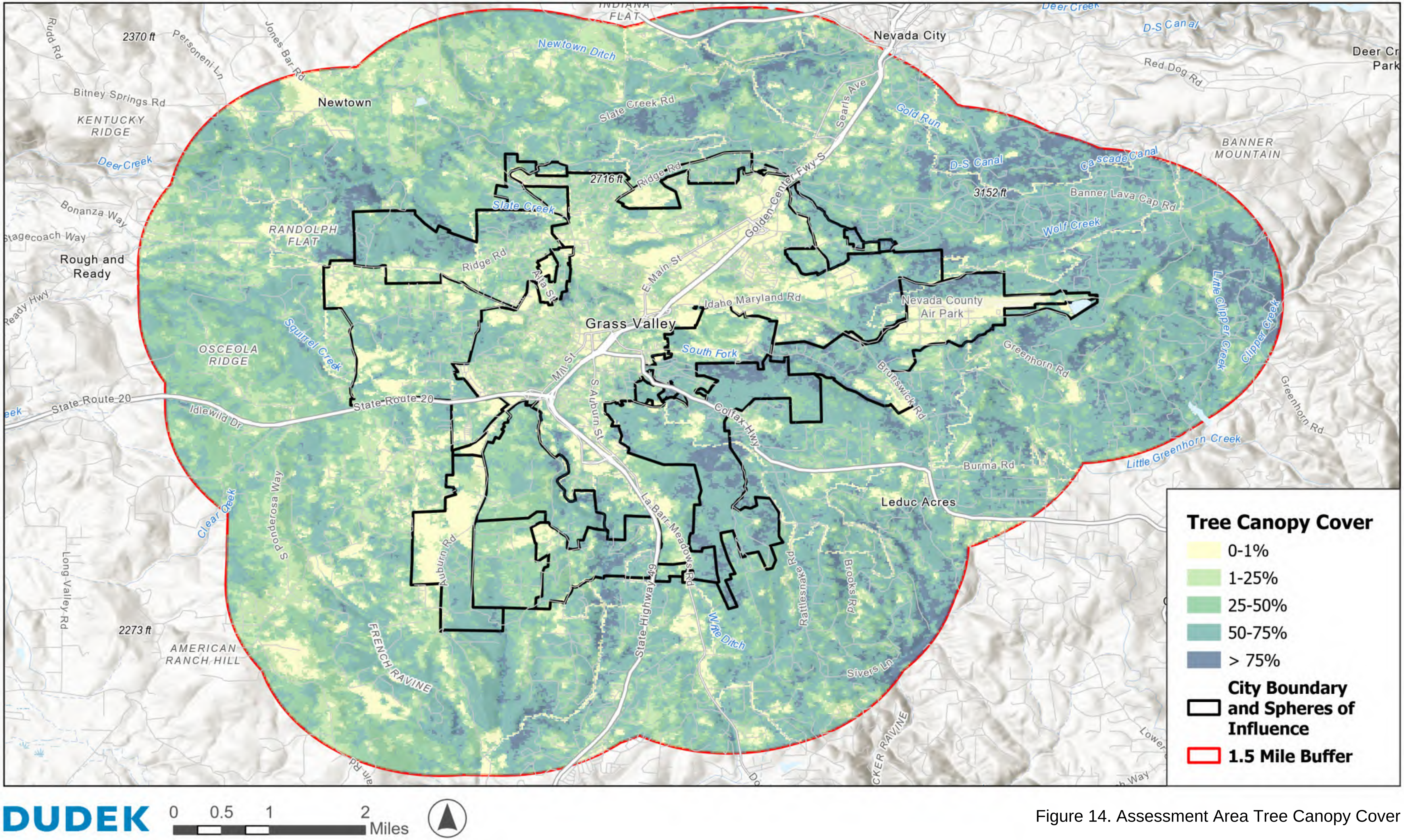

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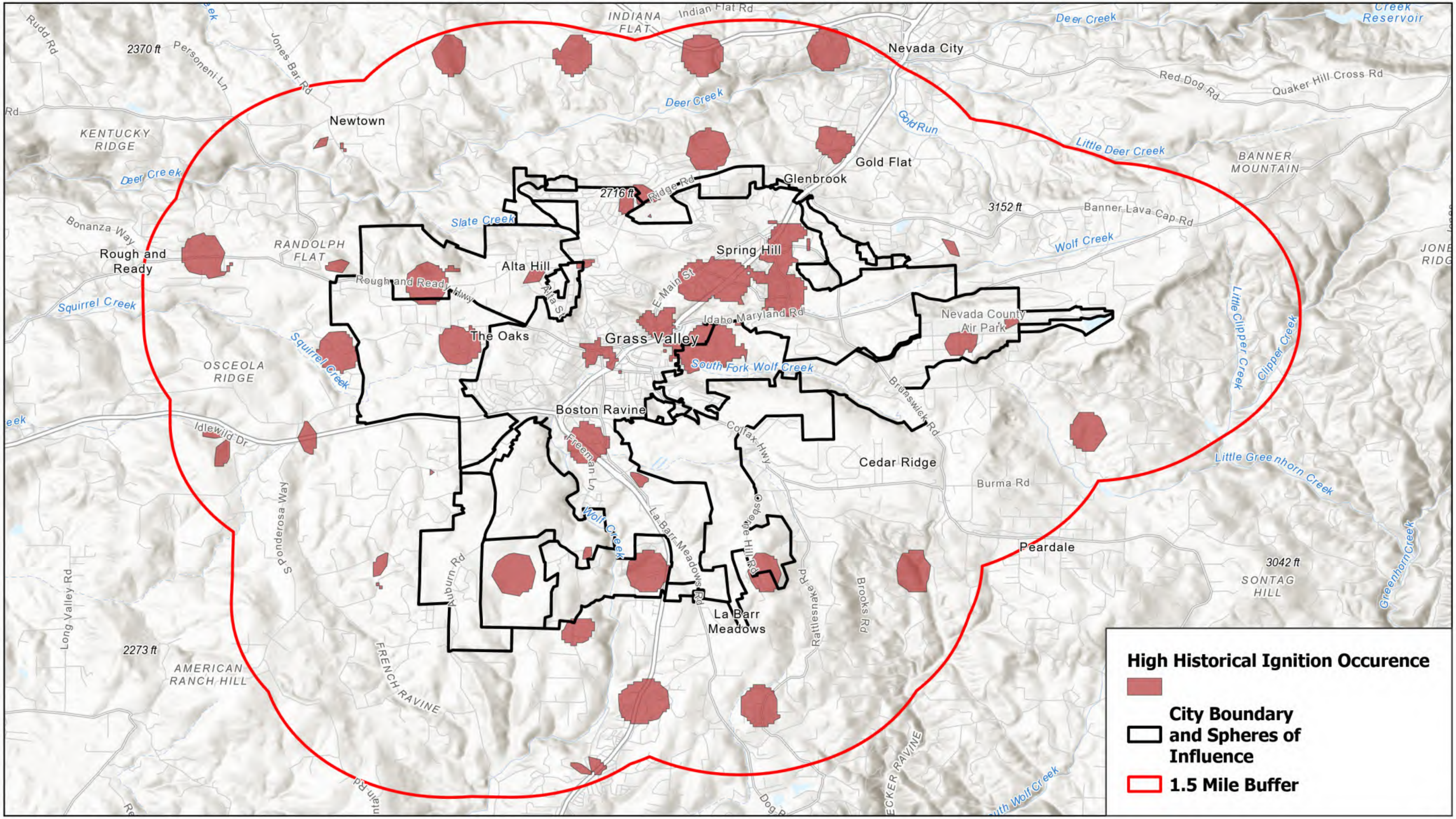
Figure 14. Assessment Area Tree Canopy Cover



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0 0.5 1 2 Miles

Figure 15. Assessment Area High Historical Ignition Locations

2.2 Risk Assessment

Wildfire risk for the assessment area focused on risk to developed areas, specifically, the area occupied by and adjacent to buildings (structures). To evaluate wildfire risk in the assessment area, the hazard input data sets (described above) were further analyzed and processed in GIS, as described below:

- The assessment area's development area (structure locations) was mapped and delineated.
- Hazard data set values were assigned a scale ranking value (between 1-4, where 1 represented lowest relative risk and 4 represented highest relative risk) to further refine their contribution to wildfire risk to developed areas (e.g., extreme fire behavior proximate to developed areas received a scale ranking of 4 and extreme fire behavior further from developed areas received a ranking of 1). A ranked GIS data layer was generated for each.
- Ranked hazard data set layers were assigned a weighting value of 1-4 (where 1 represented lowest relative risk to developed areas and 4 represented highest relative risk to developed areas). A weighted GIS data layer was generated for each.
- A GIS overlay analysis procedure was run on all the weighted GIS data layers to generate a single Composite Wildfire Risk layer for the assessment area. The Composite Wildfire Risk layer represents risk to developed areas and was categorized into five relative risk ratings. The risk ratings are relative, meaning the categories were assigned according to the maximum and minimum risk ratings observed throughout the assessment area.

2.2.1 Development Areas

Accurate mapping of developed areas was needed to effectively identify areas that are subject to risks from wildfire. Building footprint mapping data (Microsoft 2022) was used to determine the development area within the assessment area. This dataset is a collection of high-quality building footprints generated using AI and computer vision techniques. Building footprints were clipped to the assessment area boundary then visually compared with digital aerial imagery in a GIS to confirm data accuracy. No building footprint omissions or errors were observed during the visual assessment. Building footprints were then buffered by 300 feet using GIS tools to create the development area layer. The development area represents the area of land within 300 feet of structures, inclusive of building footprints. Development areas within the assessment area are presented in Figure 16.

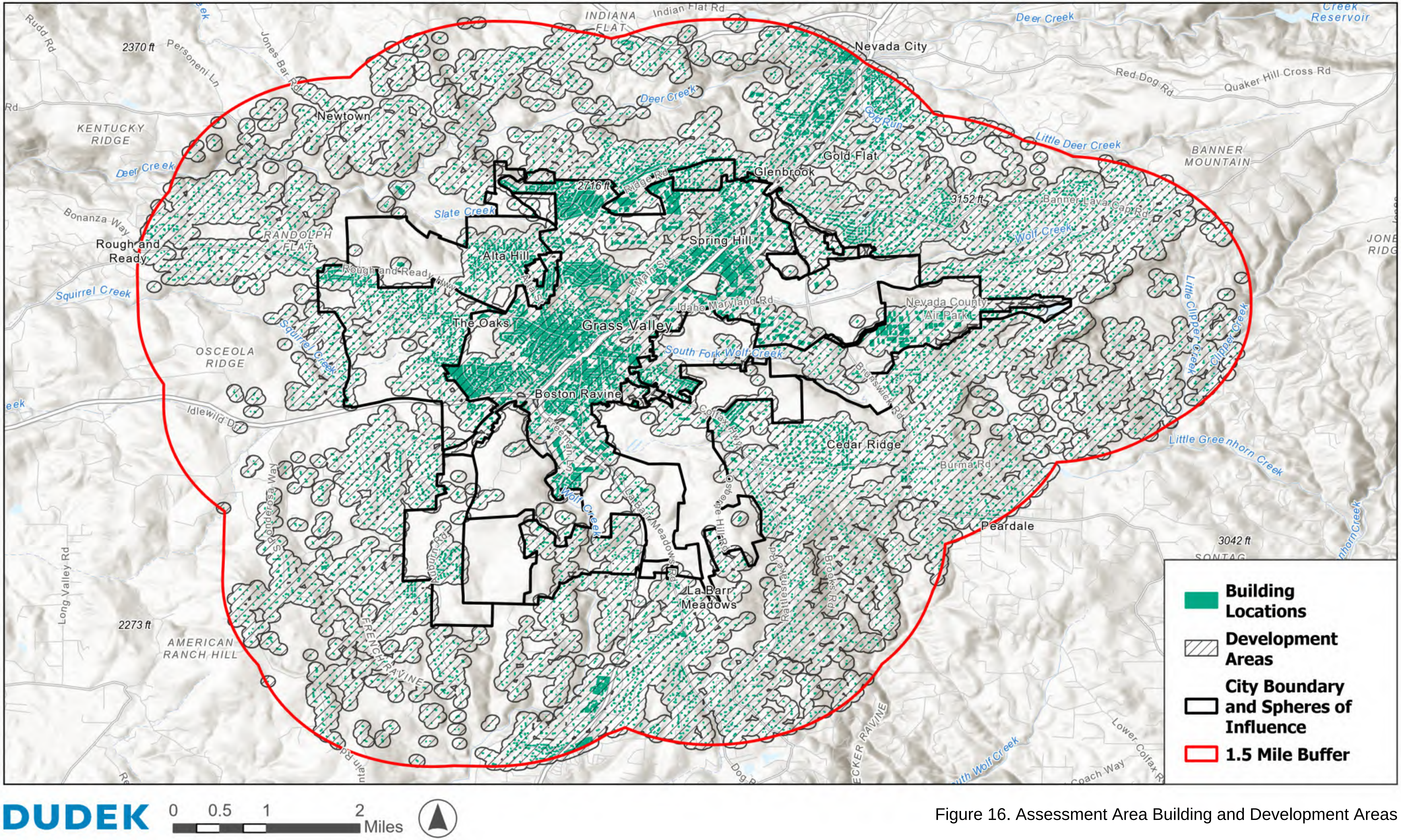

Figure 16. Assessment Area Building and Development Areas

2.2.2 Extreme Fire Behavior

Areas with modeled flame lengths greater than or equal to 8 feet were aggregated with areas where crown fires were modeled to create a GIS layer representing extreme fire behavior for the assessment area. The extreme fire behavior areas data was then buffered outward to 1,000 feet. Finally, this data was assigned a relative risk ranking value between 1 and 4 based on buffer distance and a new GIS layer (Proximity to Extreme Fire Behavior layer) was created. Table 9 presents the assigned relative risk ranking values.

Table 9. Development Area Proximity to Extreme Fire Behavior Ranking

Buffer Distance	Assigned Ranking Value
<200 feet	4
>200-350 feet	3
>350-1,000 feet	2
>1,000 feet	1

2.2.3 Ember Load

The Conditional Ember Load Index dataset was clipped to the development area boundary. This data was then assigned a relative risk ranking value between 1 and 4 based on the percent of maximum ember observed within development areas, and a new GIS layer (Ember Load layer) was created. Table 10 presents the assigned relative risk ranking values.

Table 10. Conditional Ember Load Index Ranking

Ember Load Classification	Assigned Ranking Value
Low (<25%)	1
Moderate (25-50%)	2
High (50-75%)	3
Very High (>75%)	4

2.2.4 Hazardous Fuels

This dataset was clipped to the assessment area and hazardous fuels ranked in the 75th percentile and greater were selected. The selected hazardous fuels data was then buffered outward to 1,000 feet. Finally, this data was assigned a relative risk ranking value between 1 and 4 based on buffer distance and a new GIS layer (Proximity to Hazardous Fuels layer) was created. Table 11 presents the assigned relative risk ranking values.

Table 11. Development Area Proximity to Hazardous Fuels Ranking

Buffer Distance	Assigned Ranking Value
<200 feet	1
>200-350 feet	2
>350-1,000 feet	3
>1,000 feet	4

2.2.5 Wildfire Suppression Difficulty

This dataset was clipped to the development area and relative risk ranking values between 1 and 4 were assigned based on the data set ranges. A new GIS layer (Wildfire Suppression Difficulty layer) was created. Table 12 presents the assigned relative risk ranking values.

Table 12. Wildfire Suppression Difficulty Ranking

Wildfire Suppression Difficulty Range	Assigned Ranking Value
0-20 (Lowest Difficulty)	1
>20-40	2
>40-100	3
>100 (Highest Difficulty)	4

2.2.6 Urban Tree Canopy Cover

This dataset was clipped to the development area and relative risk ranking values between 1 and 4 were assigned based canopy cover percentage. A new GIS layer (Urban Tree Canopy Cover layer) was created. Table 13 presents the assigned relative risk ranking values.

Table 13. Urban Tree Canopy Cover Ranking

Canopy Cover Percentage	Assigned Ranking Value
0-25%	1
>25-50%	2
>50-75%	3
>75-100%	4

2.2.7 Ignition Density

Areas representing higher historical ignition occurrences were extracted and assigned a ranking value of 4. All other areas were not assigned a risk score. A new GIS layer (Ignition Density layer) was created.

2.2.8 Composite Wildfire Risk

To develop the Composite Wildfire Risk layer for developed areas, the initial step was to assign weighting values to each ranked fire hazard layer (discussed in previous sections). As with the scale ranking, the weighting values used were between 1 and 4, where 1 represented lowest relative risk and 4 represented highest relative risk. Weighting value assignments for each ranked hazard data layer are presented in Table 14.

Table 14. Fire Hazard Data Layer Weighting Values

Ranked Hazard Data Layer	Weighting Value
Proximity to Extreme Fire Behavior	4
Ember Load	3
Proximity to Hazardous Fuels	2
Wildfire Suppression Difficulty	1.5
Urban Tree Canopy Cover	1
Ignition Likelihood	1

Following the assignment of weighting values, all six weighted data layers were overlayed in a GIS to create the Composite Wildfire Risk layer for developed areas. This layer was then classified into five Relative Risk Rating categories, as presented in Table 15.

Table 15. Composite Wildfire Risk Layer Classifications

Percent of Maximum	Relative Risk Rating
Minimum Value	Low
5th Percentile	Moderate
20th Percentile	High
60th Percentile	Very High
>60th Percentile	Extreme

It should be noted that the risk ratings presented in Table 15 are relative, and risk scores are assigned according to the maximum and minimum risk scores observed throughout the assessment area. For example, areas mapped as Low and Moderate risk may be subject to impacts from wildfire especially considering risk associated with airborne embers. However, these impacts were modeled to be less severe than those modeled and rated as High to Extreme. The Composite Wildfire Risk layer for developed areas within the entire assessment area is presented in Figure 17. Additionally, the Composite Wildfire Risk layer for developed areas was clipped to the City of Grass Valley and the City Sphere of Influence boundary. A map depicting this layer is presented in Figure 18. Finally, a map depicting the Composite Wildfire Risk layer for developed areas clipped to the City of Grass Valley and the City Sphere of Influence boundary and representing only Very High and Extreme relative risk ratings is presented in Figure 19.

2.3 Model Results

Relative wildfire risk results for developed areas within the entire assessment area are presented in Table 16. Areas of High, Very High, and Extreme relative risk cover 19,428 acres, or 77% of developed areas. Alone, areas classified as Extreme risk cover 9,124 acres, or 36% of developed areas. Low and Moderate risk areas encompass 1,835 acres, roughly 8% of the developed area.

Table 16. Relative Risk Ratings for Developed Areas within the Assessment Area

Relative Risk Rating	Acres	Percent of Assessment Area
Low	149	<1%
Moderate	1,686	7%
High	3,370	13%
Very High	6,934	28%
Extreme	9,124	36%
Non-developed Area	12,207	15%

Relative wildfire risk results for developed areas only within the City of Grass Valley and the City Sphere of Influence are presented in Table 17. Areas of High, Very High, and Extreme relative risk cover 527 acres, or 36% of development areas within the City and City Spheres of Influence. Areas classified as Extreme relative risk account for 1,613 acres, or 16% of development areas in this area. Low and Moderate risk areas encompass 1,405 acres, roughly 14% of this area.

Table 17. Relative Risk Ratings for Developed Areas within the City of Grass Valley and the City Sphere of Influence

Relative Risk Rating	Acres	Percent
Low	122	1%
Moderate	1,284	13%
High	1,071	11%
Very High	1,843	19%
Extreme	1,613	16%
Non-developed Area	3,924	40%

Generally, Low and Moderate relative risk areas exist within the urbanized core of the City, with higher risk areas commonly observed along the perimeter edges of the City. Areas of special concern within the City and the City Spheres of Influence include areas with high concentrations of Very High and Extreme relative wildfire risk. These areas are presented graphically in Figure 19 and listed below:

- Communities surrounding Condon Park
- The area near Doris Drive, Hill Street, Washington Street, and Bragg Avenue
- The Empire Mine State Historic Park area, including developed areas north and west of the park
- The Oaks community area
- Communities near East Bennett and Brunswick Roads
- Communities near Bubbling Wells Road
- The community north of Dorsey Drive and immediately east of Highway 20
- Communities near the Slate Creek drainage
- Communities near Crestview Drive, Smith Road, Elder Drive, near Ellens and Wolf Creek

- Communities near Manor Drive, Glenbrook Drive, and Apple Avenue

Wildfire hazard in the assessment area and its corresponding wildfire risk is dynamic and influenced by multiple factors, such as terrain, vegetation and fuels, weather conditions, and developed area proximity to areas presenting high wildfire hazard. Wildland urban interface/intermix areas exist extensively, covering 63% of the assessment area. These areas experience the highest relative risk from wildfire due to their proximity to vegetation conducive to wildfire ignition and spread. As described, extreme wildfire behavior is anticipated to occur in many areas throughout the assessment area, influenced by steep terrain and heavy fuel loads. Additionally, the assessment area is subject to frequent wildfire ignitions and has experienced several wildfires in recent years including the Bennett, Jones, and McCourtney Fires.

As discussed, 77% of development areas within the assessment area were classified as either High, Very High, or Extreme relative wildfire risk. Therefore, it is recommended that the community take a proactive approach to wildfire risk reduction, especially those located in the areas identified above. A list of potential wildfire risk reduction approaches is also provided in Section 3.

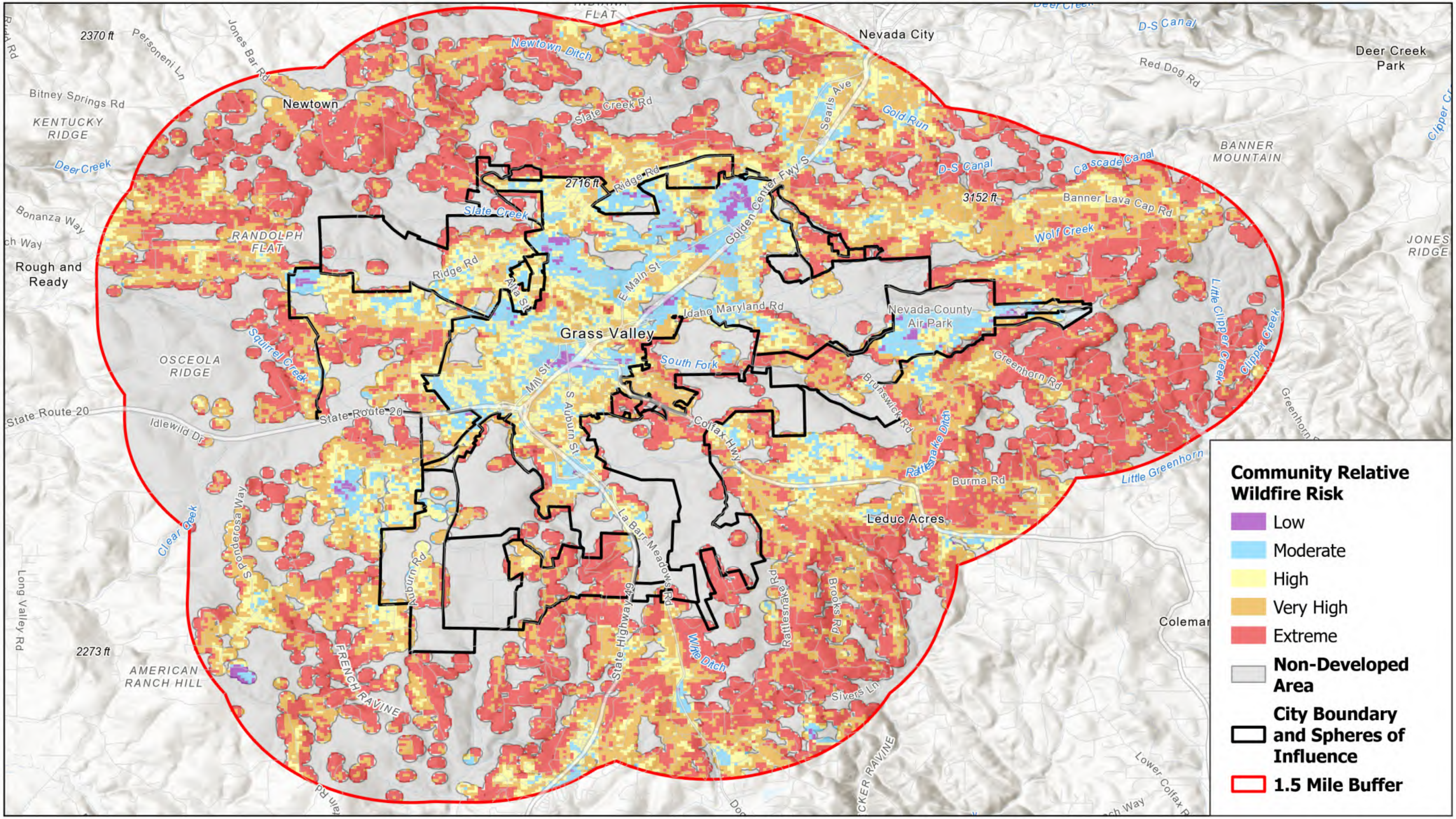

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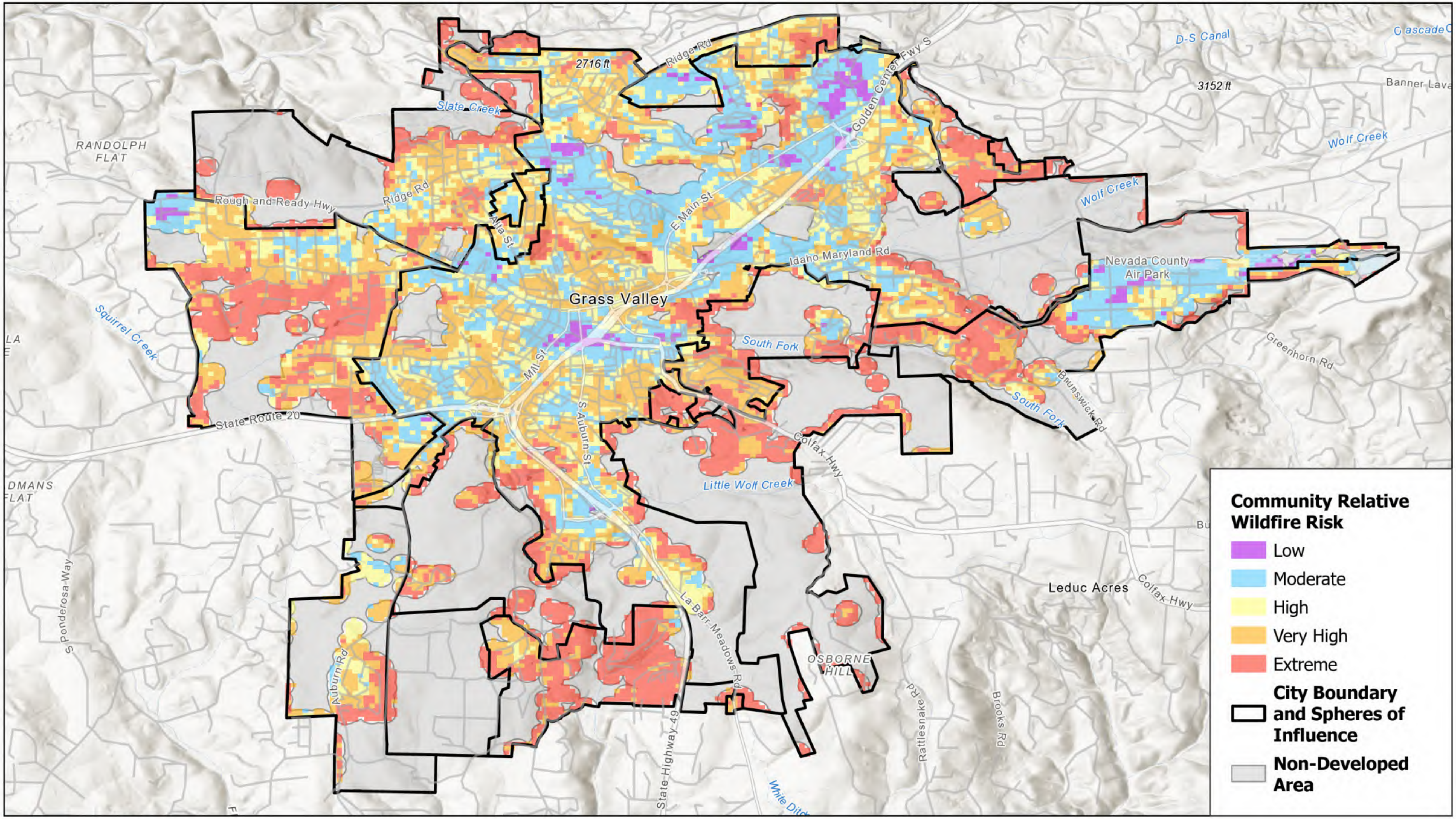
Figure 17. Assessment Area Community Relative Wildfire Risk



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0 0.5 1 2 Miles

Figure 18. Grass Valley and Spheres of Influence Community Relative Wildfire Risk

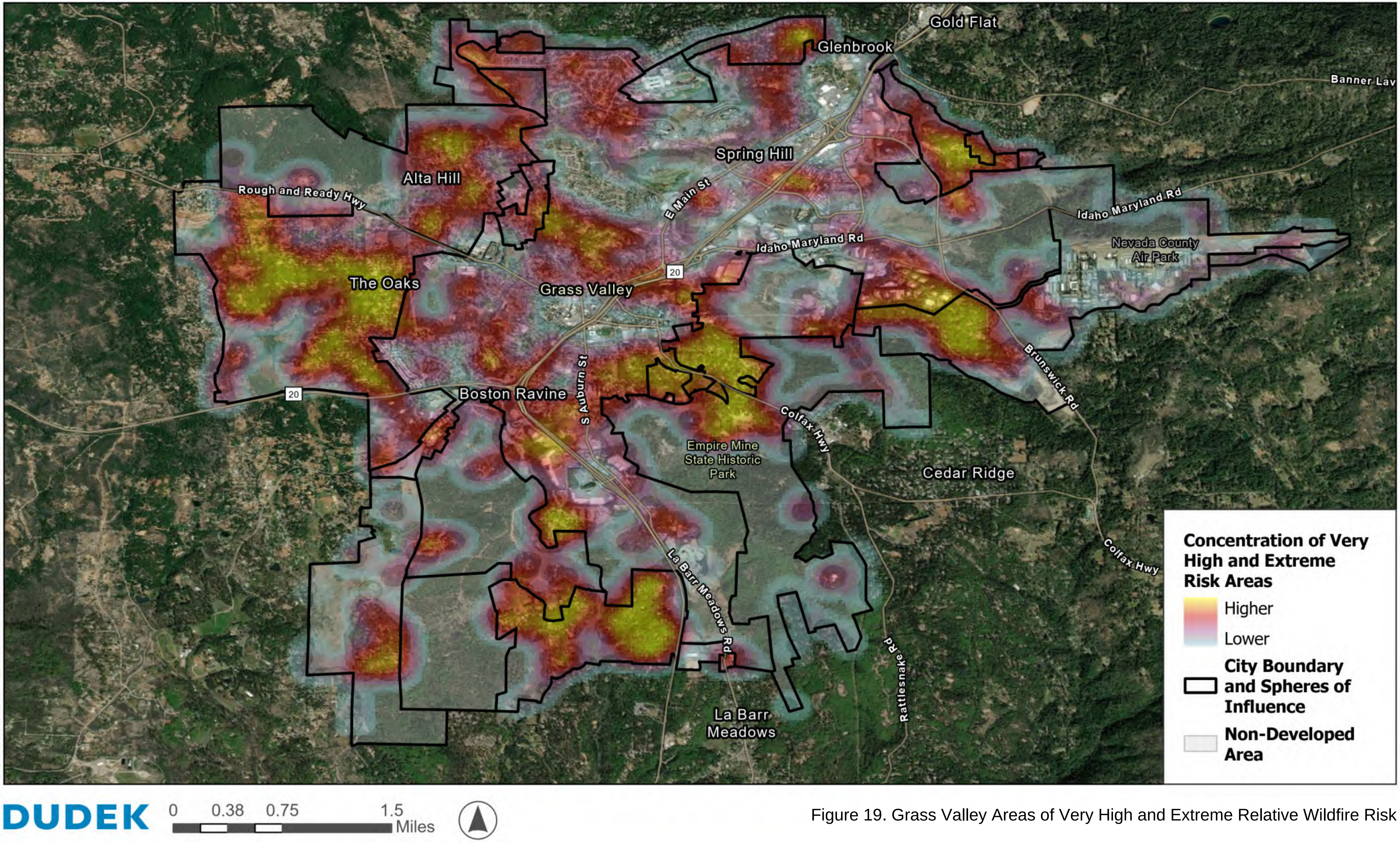

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Figure 19. Grass Valley Areas of Very High and Extreme Relative Wildfire Risk

3 Potential Wildfire Risk Reduction Approaches

The following sections identify potential approaches that can be implemented to reduce wildfire risk to the community. Further analysis and detailed planning, permitting, environmental review, and community outreach regarding specific projects may be necessary.

3.1 Reducing Structural Ignitability

Terrain, vegetation, and climatic conditions in the assessment area combine to create a unique situation capable of supporting large-scale, high-intensity, and sometimes damaging wildfires. There are two main components to reducing structural ignitability: structural hardening and defensible space. The following sections identify actions that can be implemented by homeowners on private properties to reduce the potential for structure ignitions.

3.1.1 Structural Hardening

The main way in which structures ignite is via direct fire exposure (flame impingement, convection, radiation) or via ember exposure (Maranghides et al. 2022). To reduce structural ignitability, efforts need to address direct fire and ember exposure (Maranghides et al. 2022). Addressing structural ignition potential is an effective mitigation strategy for preventing wildfires and increasing WUI ignition resistance (Zhou 2013). Research has found that structural characteristics, especially roofing, play a significant role in reducing structural vulnerability to fire and the likelihood of burning (Bracmort and Gorte 2012; Kolden and Henson 2019; Manzello et al. 2011; Zhou 2013). Further, reducing a structure's likelihood of ignitions reduces the risk for individual homeowners and the risk associated with fire spreading to other homes and wildland areas (Mockrin et al. 2020).

Although fire-resistant construction standards are mandatory for new buildings in the assessment area, hardening of existing structures is voluntary. Hardening of the homes and other structures to enhance survivability during a wildfire would include retrofitting the most vulnerable home features, including roofs, vents, eaves and soffits, windows, walls, decks, rain gutters, patio covers, chimneys, garages, and fences. Adopting mandatory home hardening provisions of building and fire codes is problematic because existing, nonconforming structures were typically approved and built to the codes in effect at the time of construction. A burning structure contributes to wildfire spread via radiant heat generation (to nearby structures) and ember generation (to downwind structures). Retrofits to existing structures can reduce fire risk, and some cost-sharing and grant programs are available to offset costs. Resources for hardening structures can be found on the following websites:

- Wildfire Home Retrofit Guide
- Protect Your Property from Wildfire
- Prepare for Wildfire
- Low Cost Retrofit List
- Preparing Your Home

3.1.2 Defensible Space

Reducing structure exposure to wildfire is also achieved via vegetation management in defensible space areas. The following three zones are identified for defensible space areas. Recommendations for management actions that can be taken by homeowners in each of these zones can be found on Grass Valley's website at https://www.cityofgrassvalley.com/post/defensible-space.

- **Zone 0 (0–5 feet):** Zone Zero, sometimes referred to as the "Ember Resistant Zone," is the area nearest the house and includes the surfaces of the structure itself, vegetation, equipment, outdoor furniture, toys, or anything else that can be ignited by embers. No vegetation or combustible items are recommended within this zone to avoid ignitions from windblown embers landing on or near the structure. Clear soil, rocks, gravel, or concrete should be used instead of landscape mulch or wood chips. This area is especially crucial since research from the Insurance Institute for Business and Home Safety (IBHS) shows that the first 0 to 5 feet around the house has the greatest impact on reducing the risk of losing a home to wildfire.
- **Zone 1 (5–30 feet):** Zone 1, sometimes referred to as the "Home Protection Zone," extends from 5 feet from the structure to 30 feet. This zone should be designed to create and maintain a landscape that, if ignited, will not transmit fire to the home. This includes having a minimum planting zone with low density planting to medium density planting as you move farther away from the structure. Depending upon the type of wildland vegetation in the area and the steepness of the slope, this zone should have an area at least 30 feet wide (50 feet for slopes above 20%) that is lean, clean, and green. Trees should be spaced to allow minimum 10' clearance to structure at full maturity.
- **Zone 2 (30–100 feet):** Zone 2, sometimes referred to as the "Reduced Fuel/Thinning Zone," extends from 30 feet to at least 100 feet. This zone also serves as a connection to the natural environment in promoting habitat restoration while eliminating continuous, dense vegetation, to decrease the energy and speed of a wildfire. To help with this function, vegetation should not be removed to the bare soil, and use of heavy equipment on hillsides should be avoided as they can cause soil erosion and mudslides.

3.2 Vegetation Management

Vegetation management actions outside of defensible space areas may be conducted by fire and land management agencies for the purposes of wildfire risk reduction. A list of potential vegetation management practices is provided below. Project type (e.g., roadside fuel reduction, shaded fuel break, invasive species treatment), location, and treatment prescriptions would need to be determined and planned to meet overall project objectives. Coordination with agencies and landowners and completion of environmental review and agency permitting would also be necessary.

- **Grazing.** Grazing is a method of using livestock to reduce fine fuel loading of live herbaceous growth, shrubs, and new growth of trees. Livestock, such as goats or sheep, browse on grasses, forbs, shrubs, and fresh growth of young trees, thereby removing vegetation from the overall fine fuel load of the site. Grazing is effective in managing fine fuels and preventing the expansion of brush into grasslands. Livestock have different grazing habits, and not all livestock are ideally suited for grazing treatments. Most livestock, with the exception of goats, do not consume live or dead, tough, woody plant material in significant quantity because this material is generally unpalatable. Additionally, livestock does not effectively create fuel breaks, but is well-suited to initiate access to a site for hand crews or to maintain new annual growth.

- **Manual Treatments.** Manual techniques involve pruning, cutting, or removing trees or other forest vegetation by hand or manual equipment. Manual treatments involve removing dead wood, piling material, lopping and scattering, and spreading chips/mulch. Lopping and scattering is the process of breaking down vegetative material into smaller pieces, usually with a chainsaw, and scattering (as opposed to concentrating) the material across the treatment area. Manual treatment is most effective in small treatment areas or areas with difficult access where using heavy equipment is infeasible. Manual treatment also allows for selective management or targeted vegetation removal and is typically used in conjunction with other techniques. Proper hand crew training and supervision is necessary to reduce danger to workers using sharp tools on steep and/or unstable terrain, or where other environmental hazards exist. Hand tools include chain saws, shovels, Pulaski hoes, McLeod fire tools, line trimmers, weed wrenches, pruning shears, and loppers. Personal protection equipment typically includes long pants and long-sleeved shirts, gloves, safety goggles, hard hats, chaps, and sturdy boots.
- **Mechanical Treatments.** Mechanical practices include all methods employing motorized heavy equipment to remove or alter vegetation. Mechanical practices rearrange vegetation structures; compact or chip material; and move material to landings, staging areas, or burn piles. Mechanical equipment typically uses rubber tires or tracks, although skids and cables are also used. In some instances, two or more pieces of equipment work in concert to achieve a management standard. Mechanical equipment includes masticators, tractors, skid-steers, chippers, mowers, grinders, crushers, and skidders. Mechanical treatments are commonly used to create fuel breaks, which are wide strips of land where vegetation management has occurred so that wildfires burning into them can be more easily controlled. Fuel breaks are not intended to stop fire spread, especially where embers can be transported via strong winds over the fuel break, but rather to modify fire behavior and enhance firefighting capabilities.
- **Prescribed Fire.** Prescribed fires reduce fuel volume through combustion and are permitted under specific regulations when conditions permit adequate combustion and fire control. Prescribed fires use planned activities with low- to moderate-intensity fire and defined goals. Prescribed fires are performed in conjunction with specific land management objectives, such as reducing fuel loads, increasing overall forest or habitat health, and/or protecting communities from wildfire (USDA 2022). Prescribed fires can accomplish land management objectives to control undesirable vegetation, prepare sites for harvesting/seeding, control plant pathogens and pests, improve wildlife habitat, improve plant production or quality, remove debris, restore ecological sites, and maintain native plans diversity and composition. Prescribed fires can occur in small, designated areas or over larger expanses. Two types of prescribed fire, pile burning and broadcast burning, are often implemented in conjunction with manual treatment and mechanical treatment methods as a means of treating vegetative debris, or to enhance effectiveness in advance of an herbicide treatment.
- **Chemical Techniques.** Chemical applications use herbicides to kill vegetation or prevent growth and are typically used in combination with other fuel reduction treatments. Herbicides do not remove vegetation from treatment areas; therefore, dead plant material remains without further treatment (except in cases where pre-emergent herbicides are used to control annual plants). Herbicide application is typically performed by hand and may include sponging, spraying, or dusting chemicals onto undesirable vegetation. Hand application provides flexibility and is ideally suited for small treatment areas. Roadside herbicide application may employ a boom affixed to or towed behind a vehicle. Herbicide application requires specific storage, training, and licensing to ensure safe use.

3.3 Community Outreach and Education

Community outreach and education is an important component in community wildfire hazard reduction efforts. Such efforts increase the community's knowledge and awareness of wildland fire, can assist in prevention and preparedness efforts, and are an important component in planning and implementing vegetation management projects. Following are examples of community outreach programs:

- **Ready, Set, Go!:** The Ready Nevada County website (https://readynevadacounty.org/) breaks down wildfire preparedness into three actions—Ready, Set, Go—with resources provided for approaching each action. The County provides a handbook of these actions at:

  https://www.nevadacountyca.gov/DocumentCenter/View/44617/2022-Ready-Nevada-County-Handbook-PDF
- **City of Grass Valley Emergency Preparedness Guide:** This brochure provides general guides and best practices for emergency preparedness, particularly wildfire emergencies. Topics covered include emergency planning, defensible space and vegetation management, and evacuation planning. This educational brochure can be downloaded at the following link:

  https://www.cityofgrassvalley.com/sites/main/files/file-attachments/emergency_prep_brochure_2019_grs_v.5.pdf?1582814072
- **Nevada County Emergency Preparedness Toolkit:** The County compiled a toolkit that residents may visit to find educational resources related to wildfire preparedness topics: Emergency Preparedness, Emergency Alerts, Defensible Space Resources, Wildfire Research Fact Sheets, and a YouTube playlist of informational videos from Ready Nevada County. https://www.nevadacountyca.gov/2792/Preparedness-Toolkit
- **Ready Nevada County Dashboard**: This dashboard an interactive informational tool to be used before, during and after a major event. This tool provides real time updates on Red Flag Warnings, Evacuation Warning & Order Areas, Community Reverse 911 messages, weather, Public Safety Power Shutoff information and more:

  https://nevcounty.maps.arcgis.com/apps/MapSeries/index.html?appid=dfae8e3b36e3455bbf9dcc865349e72e
- **CodeRED:** CodeRED is an opt-in notification system used by the County of Nevada to notify residents in an emergency. These alerts may be received as text, email, landline, cell phone, and TTY. Message and data rates may apply to sent and/or received texts. Interested residents may opt-in at:

  https://public.coderedweb.com/CNE/en-US/CA8B57E20D17.
- **Genasys Protect (formerly Zonehaven):** The City of Grass Valley and Nevada County adopted Genasys Protect (formerly Zonehaven) to provide specific, timely and accurate information regarding evacuations. Genasys Protect divides geographic regions into smaller zones, based on several factors, and is accessible online. CodeRED is Nevada County's Emergency Alert System and has the capacity to relay evacuation information during a wildfire event. Community members can access Genasys Protect online to view current evacuation orders by zone using the interactive map feature accessible at the following link:

  https://protect.genasys.com/zones/US-CA-XNE-GRS-E222?z=13.184711644240117&latlon=39.22087118546949%2C-121.04232317608148
- **Defensible Space Inspection Request**—The County and Ready Nevada County jointly administer the County's Defensible Space Inspection Program to educate residents on defensible space requirements and home hardening principles. Embers are the number one cause of structure ignition during wildfire, and a

coupled approach of creating effective defensible space with focused home hardening retrofits can increase a structures likelihood of surviving a wildfire. Property owners or occupants can request a defensible space inspection by going to https://nevadacounty.jotform.com/231176343180046

- **Red Flag Warnings.** A Red Flag Warning means that critical fire weather conditions are either occurring now or will shortly. A combination of strong winds, low relative humidity, and warm temperatures can create extreme fire behavior. The National Weather Service provides daily fire weather forecasts in coordination with local fire agencies. The Red Flag Warning program enables firefighting agencies to manage critical resources and prepare appropriate suppression responses for protecting life and property. Red Flag Warnings are typically issued within 24 hours of an impending critical fire weather event. Residents can sign up for Sever Weather Alerts at:

  https://www.weather.gov/enterprise/

- **Firewise Communities.** The Firewise USA recognition program,[1] administered by the National Fire Protection Association, promotes collaboration within communities to organize and improve the ignition resistance of homes and communities. Communities can receive a Firewise Community designation through the California Office of the State Fire Marshal's Community Wildfire and Preparedness and Mitigation Division. In addition to financial support for conducting risk reduction projects, homeowners living within a Firewise Community are qualified to receive insurance discounts with the California Fair Plan. Thirteen Firewise Communities existing within or partially within the City or the City Sphere of Influence.

3.4 Additional Wildfire Risk Reduction Approaches

The following techniques may minimize ignition potential, reduce risks to assessment area assets and resources, and/or alter vegetation conditions within suitable areas identified in this assessment as demonstrating high fire probability:

- **Post-Fire Vegetation Management**: Treatment in burned areas to promote forest canopy re-growth. Work may include removal or treatment of dead/dying trees, brush, and exotic or invasive weeds or other vegetation.
- **Reforestation/Tree Planting**: Planting trees or shrubs to achieve management goals may include restoration of degraded areas, wind flow alteration, ember defense, and increased ground surface shading.
- **Invasive Species Removal**: Removal and treatment of invasive plants that displace native species and/or increase fire hazards via high fuel loading rates or increased ignitability and flammability.
- **Fire Road Maintenance**: Minor grading or natural material resurfacing to ensure fire agency apparatus can drive on existing fire access roads.
- **Roadside fuel management:** vegetation management along key roadways that may be needed during evacuations and are exposed to natural fuel beds should be treated to reduce the potential that the roadway is compromised by fire. Thinning and selective plant removal, from 50 to 100 feet wide on both edges of key evacuation routes in high fire burn probability areas is prudent.
- **Ignition and Spread Prevention:** Modifications including flashy fuel treatment, restoration, ignition-resistant mat installation, and use restrictions (e.g., no parking).

1 https://www.nfpa.org/Public-Education/Fire-causes-and-risks/Wildfire/Firewise-USA

- Structural Hardening: Efforts to reduce structure ignition via radiant heat, direct flame impingement, or ember intrusion (e.g., installation of dual-pane windows, replacement of combustible roof materials, installation of ember-resistant attic vents).
- Community Outreach: Public education and engagement to raise wildfire risk awareness and encourage wildfire risk reduction efforts (e.g., maintenance of defensible space, participation in chipper programs).
- Utility Hardening/Undergrounding: Moving overhead powerlines below ground, or retrofitting overhead power line networks to minimize arcing, conductor contact, and other hazards.
- Patrols: Patrolling fire hazard areas to deter, detect, and report fire starts.
- Inspection/Monitoring: Conducting defensible space or structural hardening inspections or monitoring open space areas for trespass or fire activity.
- Chipper Program: Providing chippers to incentivize fuels reduction and defensible space maintenance work on residential properties.
- Infrastructure: Equipment purchase, installation, permitting, and maintenance intended to alert the communities about wildfires (e.g., fire detection cameras), or provide data to fire managers (e.g., remote automated weather stations).

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Appendix A
Photograph Log

Photo 1. Brush and ladder fuels within a portion of Condon Park.

Photo 2. Brush and ladder fuels within a portion of Condon Park, near adjacent structures.

Photo 3. Dense forest adjacent to the Grass Valley Wastewater Treatment Plant, a critical City facility.

Photo 4. Thinned/treated forest on the opposite side of Allison Ranch Road from the Grass Valley Wastewater Treatment Plant.

Photo 5. Standing dead trees resulting from the 2016 Auburn Fire (from South Auburn Street).

Photo 6. Heavy roadside vegetation along East Empire Street, across from Empire Mine State Historic Park.

Photo 7. Standing dead trees resulting from the 2021 Bennett Fire (from East Bennett Road).

Photo 8. Standing dead trees resulting from the 2021 Bennett Fire (from Whispering Pines Lane).

Photo 9. Ladder fuels on undeveloped parcels along Whispering Pines Lane.

Photo 10. Dense roadside vegetation along Glenwood Road.

Photo 11. Vegetation behind houses in the Morgan Ranch neighborhood.

Photo 12. Dense and dying vegetation in the drainage below houses on Jan Road and Hill Street.