Clark County

Connectivity Management Plan

Final
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Prepared for:
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Acronyms and Abbreviations

AADT	Average Annual Daily Traffic
ACEC	Area of Critical Environmental Concern
ADOT	Arizona Department of Transportation
AZGFD	Arizona Game and Fish Department
BLM	U.S. Bureau of Land Management
Caltrans	California Department of Transportation
CDFW	California Department of Fish and Wildlife
County	Clark County
DCP	Desert Conservation Program
DRECP	Desert Renewable Energy Conservation Plan
ESA	Endangered Species Act
GIS	geographic information system
GPS	Global Positioning System
I-11	Interstate 11
I-15	Interstate 15
MSHCP	Multiple Species Habitat Conservation Program
NDOT	Nevada Department of Transportation
NDOW	Nevada Department of Wildlife
OHV	off-highway vehicle
TCA	Tortoise Conservation Area
TDI	Terrestrial Disturbance Index
US-93	U.S. Highway 93
US-95	U.S. Highway 95
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Chapter 1 Introduction

1.1 Connectivity Management Plan Purpose

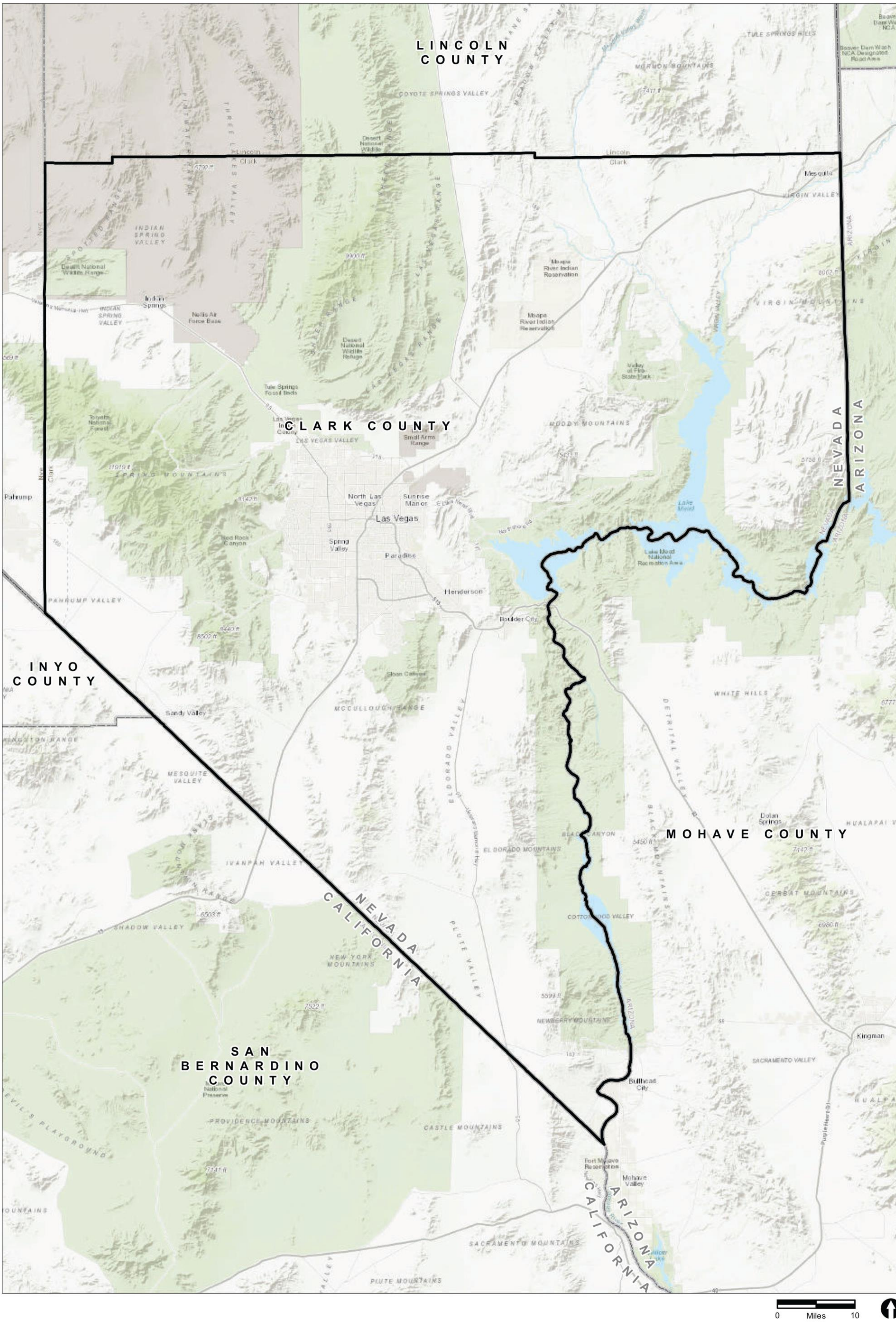
The Clark County (County) Desert Conservation Program (DCP) manages compliance of the Endangered Species Act of 1973 (ESA) on behalf of Clark County, Nevada and the cities of Boulder City, Henderson, Las Vegas, North Las Vegas, Mesquite, and the Nevada Department of Transportation (NDOT) (collectively, the Permittees). This is accomplished through implementation of the Clark County Multiple Species Habitat Conservation Plan (MSHCP) and associated Section 10(a)(1)(B) incidental take permit (Clark County DCP 2021).

The DCP was established in 1990 through a collaborative forum of local government representatives, public land managers, private landowners, interest groups, and individuals. Clark County serves as the implementing agent on behalf of the Permittees and the DCP is the Plan Administrator for the MSHCP. The DCP implements actions to ensure survivability of covered species in the wild. These actions include research, acquisition of sensitive habitats, habitat restoration, public information and education, the Wild Desert Tortoise Assistance Line, and installation and maintenance of fencing along roadways to reduce tortoise mortality.

In 2016, the DCP was awarded a Southern Nevada Public Lands Management Act grant, which is managed by the Bureau of Land Management (BLM) in Nevada. The grant was awarded to look at the current state of connectivity of a species covered under the MSHCP, the Mojave desert tortoise (*Gopherus agassizii*), throughout the County, investigate the threats and barriers to maintaining connectivity, and identify potential solutions the DCP can implement that will help conserve and/or restore connectivity of Mojave desert tortoise populations. As part of the grant, this DCP Connectivity Management Plan was prepared to address these objectives, synthesize the data collected over the course of the Southern Nevada Public Lands Management Act grant, and combine the data with previous work to develop a strategy to help maintain and/or enhance connectivity of tortoise populations across the County.

1.2 Connectivity Management Plan Planning Area

The Connectivity Management Plan's planning area consists of Clark County, which is located in the southernmost tip of Nevada (Figure 1-1) and is bordered on the north by Lincoln County, Nevada; on the east by Mohave County, Arizona; on the southwest by San Bernardino and Inyo counties, California; and on the west by Nye County, Nevada. The County covers approximately 7,890 square miles (approximately seven percent of Nevada's total area) and is Nevada's most populated county, with an estimated population of approximately 2.3 million (U.S. Census Bureau 2021).



Planning Area

FIGURE 1-1

Planning Area - Clark County, Nevada

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1.3 Connectivity Management Plan Guiding Documents: Clark County MSHCP and Incidental Take Permit

The Clark County MSHCP Section 10(a)(1)(B) incidental take permit covers all non-federal (private, municipal, and state) lands within Clark County and NDOT activities within Clark, Nye, Lincoln, and Esmeralda counties south of the 38th parallel and below 5,000 feet in elevation. The MSHCP Section 10(a)(1)(B) incidental take permit covers 78 species (14 reptiles, one amphibian, eight birds, four mammals, eight insects, two mollusks, and 41 plants) and of these, four are listed under the ESA: yellow-billed cuckoo (*Coccyzus americanus*, threatened), southwestern willow flycatcher (*Empidonax traillii extimus*, endangered), Mount Charleston blue butterfly (*Icaricia shasta charlestonensis*, endangered), and Mojave desert tortoise (U.S. Fish and Wildlife Service [USFWS] 2000).

The general measurable biological goals for each covered species are listed in Table 2.5, page 2.153 of the MSHCP (RECON Environmental, Inc. 2000). In summary, the goal for each covered species is no net unmitigated loss or fragmentation of habitat, primarily within Intensively Managed Areas and Less Intensively Managed Areas, or Multiple Use Managed Areas where a substantial proportion of the species habitat occurs within a Multiple Use Managed Areas. In addition, the MSHCP has a general goal of stabilizing or increasing populations of covered species (Clark County DCP 2015).

Measurable biological objectives broadly include (1) maintenance of the long-term net habitat value of the ecosystems in Clark County with a particular emphasis on Covered Species and (2) recovery of listed species and conservation of unlisted Covered Species. Appendices A and B of the MSHCP contain the evaluation of habitat values within each ecosystem and for each species (Clark County DCP 2015).

Chapter 2 Wildlife Connectivity Literature Review

2.1 Overview of Wildlife Habitat Connectivity Concepts

The connectivity of wildlife habitats within landscapes is an important ecological concept. Many species of plants and animals rely on connected habitat areas for maintaining territories, finding mates, reproduction, foraging, and cover/refugia. This section provides a broad overview of habitat connectivity, wildlife corridors, and habitat fragmentation concepts.

2.1.1 Habitat Connectivity

Wildlife require specific resources for survival, to ensure gene flow, and to establish territories. In addition, wildlife, large and small, require connectivity of landscapes with specific resources that allow for movement between areas and facilitate ecological processes. *Connectivity* is defined as "the degree to which the landscape facilitates or impedes movement between resource patches or habitats" (Ament et al. 2014; Taylor et al. 1993). This definition emphasizes that the types, amounts, and configuration of habitat or land use on the landscape influences movement and, ultimately, wildlife population dynamics and community structure (Taylor et al. 2006).

Connectivity is also defined as "the dispersal ability of a focal species and the ease of movement, or permeability, through the surrounding landscape" (Adriaensen et al. 2003). *Permeability* refers to the degree to which regional landscapes–encompassing a variety of natural, semi-natural, and developed land cover types–are conducive to wildlife movement and to sustain ecological processes.

There are two components of connectivity, structural and functional. *Structural connectivity* refers to the physical relationship between habitat patches or the spatial relationship (continuity and adjacency) between the structural elements of the landscape, which is independent of the ecological characteristics of species (Ament et al. 2014; Correa Ayram et al. 2016; Taylor et al. 2006). *Functional connectivity* describes the degree to which landscapes facilitate or impede the movement of organisms and processes between habitat patches and is specific to the species or process of interest (Ament et al. 2014; Correa Ayram et. al. 2016; Taylor et al. 2006). Structural and functional isolation of areas with high conservation value severely limits the capacity of the system to maintain ecological processes (Rudnick et al. 2012).

Connectivity can also be considered relative to demographic and genetic objectives. *Demographic connectivity* has been defined as the degree to which population growth rates and/or specific vital rates (such as survival and birth rates) are affected by dispersal (immigration or emigration) (Lowe and Allendorf 2010). Demographic connectivity is a function of the relative contribution of net immigration to total recruitment in a focal population (Lowe and Allendorf 2010). Low net immigration may represent a large proportion of total recruitment when populations are near extinction or when population growth rates are low (Lowe and Allendorf 2010). Demographic connectivity (such as large unfragmented habitats) is more important over a short-term temporal scale (such as within one generation) for support of populations, as compared to genetic connectivity, which is typically more important over a long-term temporal scale (several generations) (Averill-Murray et al. 2021; Kuo and Janzen 2004). *Genetic connectivity* has been defined as the degree to which gene flow affects evolutionary processes within sub populations (Lowe and

Allendorf 2010). Small amounts of gene flow may be sufficient to avoid the most harmful effects of genetic drift and inbreeding, which could lead to adaptive decline (Lowe and Allendorf 2010).

2.1.2 Wildlife Corridors

A *landscape matrix* may be a component of the landscape where habitat patches are embedded in a less hospitable matrix (Fahrig and Merriam 1994; Haddad et al. 2017; MacArthur and Wilson 1967). A matrix may be created from suitable habitat by altering its original state by human land use, which may vary in cover from human-dominated to semi-natural and in which habitat patches are embedded. The matrix may be anything from urban development to agricultural land to grassland or forest. Matrix lands have the potential to function along a continuum, ranging from potential habitat to complete barriers to movement (Brudvig et al. 2016; Meiklejohn et al. 2010).

Other terms that define the features of connectivity include corridors and linkages. A *corridor* is a distinct component of the landscape that provides connectivity (Ament et al. 2014) or landscape elements that provide physical links between habitat patches and facilitates movement of focal species between two or more habitat areas (Beier et al. 2008; Bennett 2003; Forman 1995 as cited in Correa Ayram 2016). *Wildlife corridors* specifically facilitate the movement of animals. Corridors provide movement opportunities for breeding adults, dispersing juveniles, surplus individuals seeking territories, and wandering individuals during daily movements and seasonal migrations, enabling genetic exchange between individuals from subpopulations (Soulé and Gilpin 1991 as cited in Boukall 2017). *Linkages* refer to broader regions of connectivity that are important to maintain ecological processes and facilitate the movement of multiple species (Ament et al. 2014).

Wildlife corridors are key landscape elements that serve to provide and increase connectivity between habitat patches, particularly in areas where permeability of the surrounding landscape matrix is relatively low (Beier and Noss 1998; Hennings and Soll 2010). Corridors provide the opportunity for wildlife to travel through habitats that may not be suitable for permanent residency or require days to generations to pass through (Beier and Loe 1992), to locate suitable habitat, find mates, provide dispersal for juveniles from natal areas, escape predation or other dangers, and access habitats needed for seasonal periods or at different life history stages (Beier 1995; Bennett and Mulongoy 2006; Hennings and Soll 2010). Wildlife corridors are important for linking areas of crucial habitat and facilitating movement, which reduce the negative impacts of fragmentation and allows wildlife greater flexibility to adapt to environmental stressors (Ament et al. 2014; Beier et al. 2008; Christie and Knowles 2015). Wildlife corridors should be considered wildlife habitat, generally containing native vegetation, which connects two or more larger areas of similar wildlife habitat. A wildlife corridor should allow movement between patches of habitat without significant impediments from disturbances or human land use (Boukall 2017).

Early definitions of habitat corridors described them as “linear” or “narrow”’ strips of land and often neglected behavioral processes such as habitat selection and movement paths (Chetkiewicz et al. 2006). However, the main rationale of corridors is that they have the capacity to facilitate movement, which typically occurs in different patterns and processes, and at different scales depending on the species or ecological process of interest. This means that habitat corridors will vary, may not be linear or narrow, and will depend on the wildlife species or process being targeted for conservation (Meiklejohn et al. 2010).

An updated definition of wildlife corridors is "components of the landscape that facilitate the movement of organisms and processes between areas of intact habitat." Implicit in the definition are two concepts: (1) corridors support the movement of both biotic processes (e.g., animal movement, plant propagation, genetic exchange) and abiotic processes (water, energy, materials); and (2) corridors are process- or species-specific (Jongman and Pungetti 2004 as cited in Meiklejohn et al. 2010). Three types of corridors that support biotic processes are typically used and are defined below.

Migration Corridor: Migration corridors are used by wildlife for annual migratory movements between resource areas (e.g., winter and summer habitat) (Jongman and Pungetti 2004 as cited in Meiklejohn et al. 2010). Migration is typically the predictable, periodic round-trip, or cyclic movement of groups of individuals among discrete areas not used at other times of the year (Ament et al 2014). An example of a migration corridor is the Path of the Pronghorn in Wyoming, the first federally designated migration corridor in the United States, which consists of an approximately 47,000-acre ungulate travel corridor between winter and summer habitat.

Dispersal Corridor: Dispersal corridors are used for one-way movements of individuals or populations from one resource area to another. Dispersal is critical to the maintenance of genetic diversity within populations and to the persistence of fragmented populations which may require regular immigration to avoid local extinction (Jongman and Pungetti 2004 as cited in Meiklejohn et al. 2010). Natal (or juvenile) dispersal is most common. Natal dispersal occurs when a species moves from its site of birth to a site in which it attempts to reproduce. Adult dispersal also occurs, typically at a lower rate than natal dispersal, and usually involves movement from one habitat patch to another (Croteau 2010). An example of a dispersal corridor is a riparian zone between mountain ranges that serves as a corridor for dispersal of young from one range to another.

Commuting Corridor: Commuting corridors link resource elements of species' home ranges to support daily movements including breeding, resting, and foraging. As such, commuting corridors facilitate localized movements throughout the landscape important to daily survival and reproduction (Jongman and Pungetti 2004 as cited in Meiklejohn et al. 2010). An example of commuting corridors is an area maintained or planted with specific vegetation (such as trees or hedges) outside bat roosting areas to maintain connectivity with local foraging areas.

As climate change accelerates, a fourth type of corridor will become increasingly important, namely corridors that will allow a species to shift its geographic range.

There are generally two types of wildlife corridor users, passage species and corridor dwellers (Beier and Loe 1992), described in more detail below.

Passage Species: As described in Beier and Loe (1992), passage species need corridors to allow individuals to pass directly between two areas for discrete events of brief duration, such as dispersal of juveniles, seasonal migration, or moving between parts of a large home range. Large herbivores and medium-to-large carnivores are typically passage species, as well as many migratory wildlife species. The passage corridor does not necessarily need to meet all of the species life cycle requirements; however, the corridor must at least provide conditions that motivate animals to enter and use the corridor.

Corridor Dwellers: As described in Beier and Loe (1992), corridor dweller species need several days to several generations to pass through the corridor. The majority of plants, reptiles, amphibians, insects, small mammals, and birds with limited dispersal ability are often corridor dwellers. These species must be able to live within the corridor for extended periods and possibly throughout their lifespans. The corridor must provide most or all of the species life-history requirements, including special needs related to reproduction, such as soil germination, denning areas, and other breeding adults.

2.1.3 Habitat Fragmentation

Habitat fragmentation is a landscape-level process in which a specific habitat is progressively sub-divided into smaller, geometrically altered, and more isolated fragments, which is often associated with, but not independent of, habitat loss (Fahrig 2003). Fragmentation involves changes in landscape composition, structure, and function at variable scales and occurs on a backdrop of a natural patch mosaic created by changing landforms and natural disturbances (McGarigal and McComb 1995). Fragmentation reduces permeability and may result in limited connectivity between habitat areas, or in isolated habitat patches where animals can become trapped or in danger if they leave the habitat patch (Hennings and Soll 2010). Fragmentation is widely recognized as an over-arching threat to wildlife and ecosystem health (Haddad et al. 2003; Hennings and Soll 2010) and is closely linked to habitat loss and spread of invasive species, which are both major threats (Hennings and Soll 2010).

Habitat fragmentation diminishes the landscape's capacity to sustain healthy native wildlife populations and may result in habitat loss, reduced habitat patch size, increased edge habitat, increased isolation of patches, and modification of disturbance events (an event that causes a pronounced ecosystem change). Fragmentation can benefit some species but is generally detrimental to wildlife. Fragmentation reduces the amount of and access to habitats needed to meet species' requirements, thereby lowering the number of individuals of a given species that can be supported, reducing population sizes, and increasing the likelihood of local extinctions (Hennings and Soll 2010). Populations in smaller habitat patches that may be fragmented are threatened by greater extinction risk than those in large well-connected networks (Hanski 1998).

Ecological processes may be disrupted by the cumulative effects of habitat isolation caused by fragmentation over time. Ecological processes play an essential part in maintaining ecosystem integrity and include the transport and cycling of water and nutrients, the flow of energy, and maintaining biodiversity (Folke et al. 2004). Ecological processes are present in all ecosystems and occur at various spatial scales (Hennings and Soll 2010).

Conservation efforts related to habitat fragmentation focus primarily on human activities, such as development of infrastructure (e.g., roads/highways, expanding urban areas, and utility infrastructure) which usually results in a progressive and permanent loss of habitat. Habitat loss results in habitat patches that become isolated from each other as they become embedded within developed and disturbed areas (McGarigal et al. 2005). Identifying important wildlife movement corridors and providing viable connectivity between remaining habitat patches can help reduce many of the ecological impacts of habitat fragmentation (Bennett and Mulongoy 2006; Hennings and Soll 2010; Soulé 1991 as cited in Hennings and Soll 2010).

2.2 Causes of Habitat Fragmentation

This section of the literature review will focus primarily on human activities that have caused habitat fragmentation, including urban expansion/development, agriculture, roads/highways and trails, and expansion of invasive species due to soil disturbance.

Human modifications have been described as the greatest drivers of habitat fragmentation over large spatial scales (Ewers and Didham 2006). Human modifications of the landscape often exceed natural rates of change reducing the time many species have to adapt within reduced areas of suitable and patchy habitat, thereby increasing extinction risk (Myers and Knoll 2001; Pimm et al. 1995; Rogan and Lacher 2018).

2.2.1 Urban Expansion and Development

Urbanization typically consists of nearly contiguous urban developments, including industrial, commercial, and residential structures and infrastructure, that cover large areas of land. Urban development results in loss of habitat and may fragment populations. Additionally, anthropogenic disturbance creates edge effects, altering habitat at the edges of development (Boarman 2002). Anthropogenic activities and disturbance from urbanization and development result in the alteration of the physical landscape, causing changes to functional connectivity of wildlife habitats. Urban infrastructure can result in increased distance between habitat patches and introduce barriers to movement, which reduces connectivity (Teitelbaum et al. 2020).

Habitat connectivity needed by many wildlife species for dispersal and migration is affected by habitat loss and fragmentation associated with urban areas. The loss or decrease of habitat connectivity due to urban expansion and development can alter wildlife behaviors, resulting in decreased dispersal success as well as impacts to other population processes such as migration, breeding, and growth rates (Bierwagen 2007).

2.2.2 Agriculture

Agricultural expansion within natural areas accounts for the greatest proportion of habitat loss and fragmentation in the United States (Tilman et al. 2017 as cited in Rogan and Lacher 2018). Agriculture affects wildlife habitat when natural areas are cleared for agricultural planting for food production or livestock use. Agricultural fields reduce the connectivity between areas of undisturbed native vegetation and changes the functional connectivity of wildlife habitats. Impacts of agricultural use are similar to urban development, particularly in large agricultural areas that are fenced, which result in barriers to movement.

2.2.3 Roads and Trails

Roads, highways, and trails (linear landscape features) have been found to be a significant contributor to habitat fragmentation, primarily by dividing large landscapes into smaller patches and converting interior habitat into edge habitat (McGarigal et al. 2005; Watson 2005). Habitat fragmentation caused by roads and other linear disturbances, such as trails and utility corridors, results in altered habitats and barriers to connectivity between unaltered habitat patches. Habitat fragmentation from roads can also increase the isolation of populations, leading to decreased genetic diversity, changes in vegetation beyond the roadway edge, as well as changes to the availability of cover, which can increase the potential for predation (Watson 2005).

The impact of roads, particularly wider multi-lane roadways (four to six lanes) has been researched for various wildlife species, from large mammals to small amphibians. Road effect zones are defined as the distance from a road at which effects to wildlife are detected (Forman and Alexander 1998). The size range of road effect zones can vary widely, from 300 feet to over 3,000 feet. Road effect zones increase the impacts to wildlife beyond the roadway, increasing habitat loss, edge effects, and habitat fragmentation (Dean et al. 2019).

Reptiles and amphibians can be particularly vulnerable to fragmentation of habitat by roads (Brehme et al. 2018; Jochimsen et al. 2004; McGarigal et al. 2005). Many reptiles and amphibians are slow moving, with limited dispersal ability, which can result in high vulnerability to habitat fragmentation from roads and can amplify the effects of habitat fragmentation and loss of connectivity to suitable habitat (Cushman 2006). Reptiles and amphibians are at great risk of mortality when moving across roads and through other inhospitable terrains, which depresses population growth rates (Carr and Fahrig 2001).

The use of off-highway vehicles (OHV) along recreational routes/trails has increased within public lands in the southwest. Along with this increase in OHV use, the density of recreational routes has also increased, resulting in degradation, loss, and fragmentation of desert tortoise habitat (Berry and Murphy 2019) through the loss of native vegetation within the OHV routes/trails and parking and staging/congregation areas. Berms along the more heavily used OHV routes and trails also create barriers between vegetated areas on either side of the routes. Erosion caused from use, wind, and rain can cause routes and trails to become deep depressions, which, along with berms at route and trail edges, can trap some species or cause exposure to extreme heat while attempting to cross the route, encountering berms, and seeking a passage area. The loss of native vegetation and barriers caused by OHV routes and trails as well as berms and depressions fragment habitat, particularly in areas with a higher abundance of routes and trails (Berry and Murphy 2019; Peaden et al. 2017).

2.2.4 Invasive Plant Species

Disturbances and process that fragment habitats for native species in turn provide opportunity for invasion of exotic and invasive species (Rudnick et al. 2012), which is affected by the extent to which landscapes are fragmented. Anthropogenic impacts such as, but not limited to, habitat disturbance, development, and recreation have resulted in the increasing invasion of non-native species (Berry et al. 2014; Nikolovska 2016). The introduction of invasive species can significantly change ecosystems and reduce native communities that have not evolved defenses against non-native species. The spread of invasive species results in the loss of native forage plants for wildlife, as well as the degradation of habitat features, such as cover (Esque et al. 2003).

Many species of wildlife avoid areas with a high volume of invasive plants due to the lack of forage and the alteration of habitat structure. Many invasive plant species can also increase the frequency of wildfire by providing more continuous fuels for fires, spreading fires to adjacent native plant communities. After wildfires burn, the invasive plants typically re-establish more rapidly than native plants, suppressing the recovery of the native plant communities, which can result in a range expansion for the invasive plants (USFWS 2014). The continued spread of invasive plants results in further loss of forage and habitat structure, which leads to larger fragmented areas and reduced connectivity.

2.3 Habitat Connectivity Strategies in the Southwest

This section focuses on habitat connectivity issues and strategies within the southwestern United States, specifically in Arizona, California, Nevada, and Utah. Within these states there remain relatively large areas of conserved wildlands that may be important to maintain in a connected network (Belote et al. 2016). However, habitat fragmentation has occurred throughout the southwest and many barriers on the landscape prevent interconnection of ecological systems.

The Desert Tortoise Transportation Ecology Task Force was recently formed as a range-wide effort led by the USFWS that is focused on issues related to installation of desert tortoise exclusion fencing along roadways and maintaining connectivity of habitats through culverts and other potential linkages. The task force is comprised of representatives from all four state transportation and wildlife agencies, and representatives from local, state, and federal agencies (Fairbank et al. 2021).

Below is a summary of the issues, research, and planning related to habitat connectivity and fragmentation within Arizona, California, Nevada, and Utah.

2.3.1 Arizona

Arizona has experienced extensive population growth in the last 20 years, which has also led to growth of infrastructure that presents challenges to maintaining natural ecosystems and wildlife populations (Nordhaugen et al. 2006). Of particular concern related to wildlife habitat connectivity in Arizona are roads/highways, urbanization, irrigation canals, railways, energy corridors, and activities related to border security operations that degrade habitat and increase isolation of wildlife populations.

To address these habitat connectivity issues, a working group was formed to assess wildlife linkages within the state, the Arizona Wildlife Linkages Workgroup (Workgroup), consisting of staff from the following agencies:

- Arizona Department of Transportation (ADOT), Natural Resources Management
- Group and Environmental Planning Group (Wildlife Connectivity; ADOT 2021)
- Arizona Game and Fish Department (AZGFD), Habitat Branch and Research Branch
- Northern Arizona University, School of Forestry
- U.S. Department of Agriculture Forest Service, Tonto National Forest
- Sky Island Alliance
- Federal Highway Administration
- USFWS

The Workgroup prepared the Arizona Wildlife Linkages Assessment which determined that the disturbances and barriers should be addressed cumulatively, not individually, to successfully maintain or restore wildlife linkages. The Workgroup's statewide assessment identified large blocks of protected habitat, potential wildlife movement corridors, and factors threatening to disrupt linkages.

The assessment also prioritized areas in need of further research (Nordhaugen et al. 2006). The assessment was intended to provide a starting point for detailed consultation and coordination among organizations and agencies that play a major role in maintaining habitat connectivity in Arizona (AZGFD 2021).

Using information developed from the Arizona Wildlife Linkages Assessment, a team of conservation biologists and geographic information system (GIS) analysts at Northern Arizona University created detailed linkage designs for 16 areas that were prioritized by the Workgroup. The plans identify and map multi-species corridors that will best maintain wildlife movement between wildland blocks and highlight specific planning as well as road mitigation measures required to maintain connectivity in priority areas. These 16 plans were developed in 2007 and 2008 (http://corridordesign.org/linkages/arizona).

The Arizona Wildlife Linkages Assessment also led to county-level efforts to assemble up-to-date knowledge of wildlife linkages and barriers to wildlife movement while helping build collaborative partnerships with local jurisdictions for implementation efforts (AZGFD 2021). Of the 14 counties in Arizona, seven have initiated workshops and assessments. The workshops for each county include a diverse range of participants with an interest in maintaining habitat connectivity to share their knowledge and outline general locations of wildlife linkages and movement barriers on large maps of each county. The maps have been digitized using GIS software to produce figures incorporated into the county-level assessments.

In addition to the county-level assessments, a statewide landscape integrity and wildlife connectivity assessment (Perkl 2013) has been used to support and complement existing wildlife conservation planning tools and models developed by the AZGFD. The statewide and county-level assessments will continue to be used to identify areas of highest concern at a landscape level, while also developing finer scale, GIS based wildlife corridor models and prioritize funding, research, and implementation efforts (AZGFD 2021).

ADOT has also developed a wildlife connectivity process that is aimed at streamlining project planning and delivery, increasing highway safety for both humans and wildlife, and connecting important habitats (ADOT 2021). ADOT has developed guidance and measures for wildlife connectivity in transportation planning, including Wildlife Connectivity Guidance, Wildlife Escape Measures, Wildlife Funnel Fencing, and a Wildlife Crossing Structure Handbook (ADOT 2021).

These statewide efforts have led to retrofitting of existing road structures to increase permeability to wildlife, the construction of new wildlife crossing structures, and fencing modifications that are “wildlife-friendly” to improve the utility of the linkage designs. Habitat restoration efforts have also been initiated to target the removal of invasive species.

2.3.2 California

Similar to other states in the southwest, California experienced extensive growth in the twentieth century (Public Policy Institute of California 2021). This growth has led to issues and threats that may adversely affect wildlife, habitats, and connectivity. The most widespread threats to wildlife habitat connectivity in California include statewide growth and development, water management conflicts, and the spread of invasive species (Bunn et al. 2007).

The California Department of Fish and Wildlife (CDFW) conducts habitat connectivity analysis throughout the state. Working closely with federal, tribal, state, and local agencies, the CDFW has developed three primary strategies to ensure habitat connectivity for wildlife (CDFW 2021):

- Protect connectivity while habitat is still intact, through permanent conservation and adaptive management. As part of this strategy, a workgroup of federal, tribal, state, and local agencies contributed to the California Essential Habitat Connectivity Project, which is a statewide assessment of large, intact blocks of natural habitat and "least-cost" modeling of connections between them. Agencies use this statewide model to collectively build course-scale networks of conserved lands.
- Avoid further fragmentation of habitat. Cluster urban development and site roads and other infrastructure projects where they are least likely to disrupt habitat connectivity. Conservation planning efforts are integrated with regional transportation and land use planning to both preserve connected habitat and allow development.
- Minimize or mediate the effects of existing barriers. Create wildlife crossings or fish passage structures. Transportation planning agencies are incorporating standard wildlife crossing designs into the planning process.

As part of habitat connectivity strategies, CDFW and California Department of Transportation (Caltrans) commissioned the California Essential Habitat Connectivity Project. The Essential Habitat Connectivity Report includes a statewide map of Essential Connectivity Areas, an assessment of these areas, and the lands that connect them. The report also describes strategies for maintaining and enhancing functional ecological connectivity through local and regional land-use and management plans, which assist agencies and organizations conducting land use and transportation planning, land management, and conservation in California (Spencer et al. 2010).

The information from the Essential Habitat Connectivity Report was intended to be used to comply with federal requirements to avoid, minimize, and mitigate impacts to habitat connectivity during transportation planning and to meet state requirements to map essential wildlife corridors and habitat linkages. It is also intended for use in the development and assessment of natural communities, habitat conservation, and habitat management plans, as well as land use planning within the state. Information from the report has been used to develop six ecoregional habitat connectivity analyses that have been prepared by federal, state, local, and non-profit agencies (CDFW 2021), as well as transportation planning and modeling efforts.

Caltrans has developed wildlife crossing guidance to meet regulatory requirements as well as guidance for biologists, environmental planners, transportation planners, and engineers engaged in efforts to reduce the environmental effects of California's highway infrastructure while improving public safety. The manuals describe procedures to identify wildlife crossing conflicts, choose effective avoidance, minimization, or compensatory mitigation strategies, and evaluate the results of mitigation actions (Brehme and Fisher 2021; Meese et al. 2009).

Caltrans is also working with partners to identify wildlife corridors and is adopting measures that attempt to direct wildlife under, over, or away from the threat of vehicle traffic. Some of the methods used to enhance wildlife passage include installing culverts under highways, wildlife overpasses, elevated road segments, shelves that allow wildlife to take temporary refuge during floods, directional fencing, escape ramps, permeable median barriers, and "jump-outs" for animals that may become trapped within the right-of-way. Caltrans is also conducting and sponsoring wildlife crossing and connectivity research to improve measures and guidance for planners (Caltrans 2019).

Within federally managed lands in California, the BLM developed the Desert Renewable Energy Conservation Plan (DRECP) and Land Use Plan Amendment (BLM 2016), which was a collaborative, interagency landscape-scale planning effort covering 22.5 million acres across seven California counties—Imperial, Inyo, Kern, Los Angeles, Riverside, San Bernardino, and San Diego. The plan was conceived and developed through a collaborative effort by the Renewable Energy Action Team Agencies (also known as the DRECP partner agencies), which consisted of the BLM, USFWS, California Energy Commission, and CDFW.

The DRECP's two primary goals were to: (1) provide a streamlined process for the development of utility-scale renewable energy generation and transmission in the deserts of Southern California consistent with federal and state renewable energy targets and policies and (2) provide for the long-term conservation and management of special-status species and desert vegetation communities, as well as other physical, cultural, scenic, and social resources within the DRECP Plan Area through the use of durable regulatory mechanisms. The DRECP identified conservation areas of high biological resource values and renewable energy development focus areas with low resource values. These designations, as well as other Land Use Plan Amendment decisions, will help conserve sensitive habitats and reduce renewable energy infrastructure impacts to wildlife corridors and habitat connections within the DRECP Planning Area (BLM 2016).

One result of the DRECP was a linkage network design commissioned by BLM (Penrod et al. 2012). This linkage network was designed to accommodate corridors for four focal species: Mojave desert tortoise, kit fox (*Vulpes macrotis*), bighorn sheep (*Ovis canadensis*), and American badger (*Taxidea taxus*).

2.3.3 Nevada

Within Nevada, the factors that have contributed to habitat and connectivity management issues include a long history of human land use that has altered natural habitats, recent intensive urban expansion and development, and the widespread occurrence of invasive species (Nevada Department of Wildlife [NDOW] 2012). The governor of Nevada signed Executive Order 2021-18, Creating the Nevada Habitat Conservation Framework, on August 23, 2021 (State of Nevada 2021). Sections of the order relevant to wildlife corridors and connectivity are listed below:

- Section 2: NDOW shall work with the relevant executive branch agencies in Nevada to further the following Framework goals:
    1) Conserving and propagating diverse and productive wildlife habitats;
    2) Addressing the priority threats to key habitats such as the wildfire and annual invasive grass cycle, and conifer encroachment; and
    3) Maintaining connectivity of habitats and corridors.

- Section 5: As a key supporting strategy of Goal 3 in the Framework, NDOW shall develop a statewide Nevada Wildlife Connectivity Plan (Connectivity Plan) that seeks to identify and conserve migratory corridors of wild ungulates and other key species NDOW may determine relevant. The Connectivity Plan shall be completed by December 31, 2023 and shall be reviewed for updates on a bi-annual basis.

1) The Connectivity Plan shall include:
    a. The process for NDOW to identify and delineate migration corridors supported by existing and ongoing scientific research;
    b. Habitat definitions, conservation recommendations, and best management practices or measures that could be implemented at all levels of government planning and regulation for migratory habitats, based on best available science including but not limited to peer reviewed literature; and
    c. Migration corridor assessments that include a summary of knowledge regarding the migration, conservation threats, land tenure characteristics, and management recommendations that shall be provided to associated federal, state, county, and local land managers.
2) The Connectivity Plan shall be developed with input from counties, federal land management and state agencies, and other stakeholders. Stakeholder engagement should include, but not be limited to sportsmen's groups, conservation and environmental protection, farming and ranching, private landowners, rural communities, native tribal communities, outdoor recreation, real estate developers, transportation, mineral, and renewable energy developers, and linear infrastructure entities.
3) The Connectivity Plan shall be informed by public outreach and shall be publicly available on NDOW's website.

- Section 6: NDOW and NDOT shall enter into a Memorandum of Understanding that formalizes and sets expectations for collaboration on the implementation of this Connectivity Plan within 12 months of its completion. Collaboration may include:

    a. Identifying opportunities to protect and restore habitats and migratory corridors in new or existing NDOT policies, regulatory permitting processes, and planning processes to the greatest extent possible, including processes where such consideration is not currently formally required; and
    b. Identifying points where:
        - Key wildlife habitat, wildlife migration corridors, and highways intersect;
        - Identifying and implementing strategies to avoid, minimize, and mitigate wildlife-vehicle collisions; and
        - Prioritizing areas for implementation of wildlife crossings or other highway features to improve permeability for wildlife while maintaining highway user safety.

- Section 10: This Executive Order does not authorize any prescriptive actions on private lands; however, private landowners are encouraged to seek guidance from relevant agencies to minimize impacts inside of corridors designated within the Connectivity Plan, and any work with private landowners shall be voluntary. Private landowners may incorporate and implement strategies and principals consistent with the Framework, Sagebrush Habitat Plan, and Connectivity Plan by working within state or federal mechanisms to protect and enhance wildlife habitat.

Prior to this Executive Order, Nevada has been successful in funding research and wildlife-transportation infrastructure projects throughout the state, primarily through the collaboration of NDOT and NDOW. The two agencies have collaborated for over 20 years to improve habitat connectivity and wildlife corridors, particularly within northern Nevada, where large mammal-vehicle collisions have been substantial. Fencing, overpasses, underpasses, and roadway infrastructure modifications have increased over time. Public opinion of wildlife crossings and corridors has also improved. Landscape-scale approaches have also been completed, such as the Interstate 80 and U.S. Highway 93 (US-93) Pequop Crossing Network, located in rural northern Nevada. This project included a network of five overpasses and 10 underpasses that provide a corridor for mule deer (*Odocoileus hemionus*) migration, as well as other species (Maxwell et al. 2021).

Other projects that have been undertaken include retrofitting hydrologic culverts to improve Mojave desert tortoise safe passage (Maxwell et al. 2021), dispersal research (Smutko and Gautier 2020), research on priority wildlife-vehicle conflict areas (NDOT 2018), research on the effectiveness of wildlife crossings (NDOT 2015), and recently funded research and completed surveys on desert tortoise culvert use, as well as genetic connectivity (gene flow) research in areas with anthropogenic disturbance (Clark County 2021). Gate replacement and desert tortoise guard installation has also been completed at a local scale (Clark County 2021).

NDOW has several recent projects aimed at improving habitat connectivity. In 2019, NDOW received funding from the USFWS to enhance and improve the quality of big-game winter range and migration corridor habitat. Projects under this funding would also improve greater sage-grouse and other species habitat, primarily within sagebrush ecosystems (USFWS 2019).

The BLM Nevada State Office is currently in the process of gathering data for a proposed plan for roadway fencing to reduce Mojave desert tortoise mortality. The proposed action would provide for construction or installation of priority and programmatic fence segments as well as desert tortoise shade structures and cattle guards. These actions would occur within highway rights-of-way with fences installed at the edge of the rights-of-way. The planning process will take approximately two years prior to draft release to the public (BLM 2020).

2.3.4 Utah

As part of conservation actions under the Utah Wildlife Action Plan 2015-2025 (Utah Wildlife Resources Action Plan Joint Team 2015), in 2017 the Utah Division of Wildlife Resources started a statewide initiative to identify, preserver, and enhance movement corridors for both terrestrial and aquatic wildlife species in the state, called the Wildlife Migration Initiative. Global Positioning System (GPS) tracking technology is used under this initiative to track the movements of species in near real time. The initiative also produces maps of migration corridors, stopover sites, bottleneck areas, movement barriers, and the identification of mitigation needs, such as wildlife crossings over highways. Research and monitoring projects under the initiative have been conducted throughout the state for a variety of species, including mule deer, elk (*Cervus canadensis*), pronghorn (*Antilocapra americana*), mountain lion (*Felis concolor*), bighorn sheep, and desert tortoise (Wildlife Migration Initiative 2021).

In 2020, the Utah State Legislature passed the Concurrent Resolution Supporting the Protection and Restoration of Wildlife Corridors (House Concurrent Resolution 13; Utah State Legislature 2020). Highlighted provisions of the resolution acknowledge the following:

- healthy wildlife and landscapes are crucial to Utah's quality of life and economy;
- protecting fish and wildlife corridors will improve herd vitality of big game species and preserve connectivity of fisheries;
- wildlife-vehicle collisions pose a serious safety risk to motorists and wildlife and states, including Utah, that implement wildlife crossings to improve motorist safety and protect wildlife corridors have seen a decrease in wildlife vehicle collisions;
- current efforts to protect wildlife corridors and road safety;
- the need for the protection and restoration of migratory routes for wildlife through the Division of Wildlife Resources' Utah's Wildlife Migration Initiative;
- the federal government has initiated programs and awarded grants to protect wildlife corridors for big game animals; and
- the state's continued support for fish and wildlife corridors and road safety; and studies related to wildlife migration corridors within the state.

2.4 Desert Tortoise Habitat Connectivity Threats and Current Management Approaches

This section narrows the focus to connectivity for desert tortoise and focuses on connectivity issues and strategies specifically related to work and research that has been done regarding desert tortoise connectivity, including current approaches and major threats to maintaining connectivity of tortoise populations. The majority of literature reviewed is specific to the Mojave desert tortoise (at the time of listing it was considered a population but now considered a distinct species) but also includes relevant information on the Sonoran desert tortoise (*Gopherus morafkai*).

The Mojave desert tortoise range includes areas north and west of the Colorado River in Arizona, Utah, Nevada, and California. Mojave desert tortoise historic distribution was relatively continuous across its range, broken only by major topographic barriers, such as Death Valley, California, and the Spring Mountains, Nevada (Germano et al. 1994; Hagerty and Tracy 2010; Murphy et al. 2007; Nussear et al. 2009). Mojave desert tortoise conservation and recovery areas consist of 12 designated critical habitat units, National Park Service lands, and other conservation areas or easements managed for desert tortoise, also known as Tortoise Conservation Areas (TCAs) (USFWS 2011).

2.4.1 Major Threats to Mojave Desert Tortoise Habitat Connectivity

Estimates of Mojave desert tortoise regional and range-wide population trends have shown that this species is experiencing large, ongoing population declines and adult tortoise populations have decreased by over 50 percent in some recovery units since 2004 (Allison and McLuckie 2018). The primary causes of habitat loss and fragmentation, and tortoise population declines range-wide, have been shown to be human-related (USFWS 2011). Human-related causes of habitat loss and fragmentation include urbanization and agricultural use, utility corridors and renewable energy developments, transportation corridors, recreational route use, spread of invasive species, and wildfires (Boarman 2002; Esque et al. 2003; Tuma et al. 2016; USFWS 2011). Below is additional detail on these causes of habitat loss and fragmentation.

2.4.1.1 Urbanization and Agricultural Use

Urbanization

The impacts of urbanization and infrastructure development on wildlife habitat connectivity, as discussed in Section 2.2.1, are similar for desert tortoise habitat connectivity, including loss and fragmentation of habitat, edge effects, alteration of functional connectivity, and barriers to movement. A recent study by Carter et al. (2020) quantified the level of development within desert tortoise habitat and found that relatively high urban development levels occur in some areas protected for Mojave desert tortoise. The study found that combined encounter rates1 for live and dead tortoise decreased significantly as development increased. This study analyzed 13 years of desert tortoise monitoring data and found that the majority of desert tortoise observations were at sites in which five percent or less of the surrounding landscape within one kilometer was developed (Carter et. al. 2020). This indicates that desert tortoises do not tolerate developed areas and habitat connectivity corridors in geographic proximity to developed areas result in diminished use by tortoises or possible abandonment of the corridor. The results of this study can be helpful in identifying tortoise habitat in areas with five percent or less of the surrounding landscape within one kilometer of development. Connectivity between these areas could also be determined based on distance from development. It should be noted that the habitat with five percent development may not necessarily provide the resources needed to maintain tortoise population sizes for both demographic and functional connectivity and a lower threshold of development should be considered (Averill-Murray et al. 2021).

Agricultural Use

Within the Mojave Desert, large portions of desert valleys that once supported high densities of tortoises have been developed into urban, ex-urban, agricultural, and industrial uses, which has reduced habitat at the margins and fragmented the interior of historic tortoise geographical ranges (Berry and Murphy 2019). As an example, agricultural development between 1992 and 2001 resulted in the loss of approximately 1.8 square miles of desert tortoise critical habitat (Berry and Murphy 2019). When tortoise habitat is converted for agricultural use, it becomes unusable for foraging or burrowing (Boarman 2002) and connectivity between habitat areas can be lost. Undeveloped native vegetation communities between agricultural fields could potentially serve as corridors for tortoises; however, agricultural use and activities have been shown to result in the spread of invasive plant species in adjacent areas. The spread of invasive plants within corridors reduces forage availability and can reduce tortoise use of the corridor (Boarman 2002).

Agricultural fields also result in indirect impacts to surrounding tortoise habitat by causing fugitive dust that reduces native plant production, possible introduction of toxic chemicals, and introduction

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[1] Encounter rates were used for detection of both live and dead Mojave desert tortoise combined, and proximity of human development levels inside and outside of tortoise protective designation areas. Encounter rates are a widely used metric for desert tortoise populations.

of invasive plants along edges (Boarman 2002), further expanding tortoise habitat degradation and fragmenting the landscape.

2.4.1.2 Utility Corridors and Renewable Energy

Since 2000, development of renewable energy and utility corridors has resulted in the loss of approximately 9.6 square miles of high value tortoise habitat (but not critical habitat) in the northeastern Mojave Desert (Berry and Murphy 2019). In 2013, modeling showed that approximately 270 square miles of desert tortoise habitat in the Mojave Desert may be at risk of permanent habitat loss from the development of solar energy (Averill-Murray et al. 2013). Utility corridors have one or more access roads, often dirt with berms, and the roads have increased in length and area with development of renewable energy facilities on public and private lands (Berry and Murphy 2019). Renewable energy developments, utility corridors, and associated access roads result in the loss and potential fragmentation of tortoise habitat, often within high value habitat areas (Lovich and Ennen 2011). Access roads and utility corridors may also result in habitat conversions during early stages of post-construction succession that may suppress regular use by tortoise and could function to reduce dispersal across the corridor, which may fragment a previously intact population (this view is speculative) (Boarman 2002).

Renewable energy developments, particularly solar developments, fence the area surrounding the facilities for security purposes, which can create gaps between solar facility developed areas that may function as tortoise corridors. The majority of fencing surrounding solar facilities does not allow tortoise passage. Tortoise that encounter fencing have been shown to pace along the fence line seeking habitat and resources previously accessible. Although fences create corridors between habitats, it is unclear how the fence lines may be influencing tortoise ecology and movements. Further research is needed to determine if tortoise habitat corridors between fenced solar facilities provide sufficient resources for population residency and transgenerational connectivity (Hromada et al. 2020).

Within more recent solar developments, approaches to solar installations only include temporary fencing during construction, raising the panels above the ground surface, and leaving vegetation relatively intact with the aim of encouraging wildlife, particularly desert tortoise, to reoccupy the landscape once construction is complete. However, there is currently no monitoring data on desert tortoise use of these type of solar development areas.

2.4.1.3 Transportation Corridors and Recreational Routes

A large portion of Mojave desert tortoise habitat is intersected by transportation corridors, including highways, railroads, roadways, and recreational routes (USFWS 2011). The majority of desert tortoise TCAs are divided internally or separated from adjacent units by major roads and highways (Averill-Murray et al. 2021). The desert tortoise is a slow-moving species, making them more susceptible to transportation corridor impacts such as injury and mortality from being hit by vehicles (Berry et al. 2020a). Mortality from highways may reduce tortoise abundance up to two miles or more away (von Seckendorff Hoff and Marlow 1997). Transportation corridors alter the movement paths and behaviors of individuals (Hromada et al. 2020; Peaden et al. 2017), as well as serving as conduits for predators such as ravens and increasing the potential spread of invasive plant species, which result in diminished corridor habitat quality and decreased use by tortoises (Boarman et al. 1997). Road effect zones are areas of habitat loss that extend beyond the linear feature and result in reduced tortoise abundance at greater distances from the road with increased traffic volume (within a range of 220 to 5,000 average daily traffic) (Nafus et al. 2013; Peaden et al. 2015; von Seckendorff Hoff and Marlow 2002). There is a clear negative impact of unfenced roads on desert tortoises and high-volume roadways (e.g., highways with higher traffic levels) that significantly degrade the capacity of suitable habitat to support viable tortoise populations (Nafus et al. 2013; Peaden et al. 2015; von Seckendorff Hoff and Marlow 2002). Mojave desert tortoises are more likely to move among activity centers when the potential movement areas are further from minor roads and when adjacent roadways have barrier fencing (Sadoti et al. 2017). Transportation corridors within the geographic range of the desert tortoise can result in lost and degraded habitat and reduced connectivity (Berry and Murphy 2019; Dutcher et al. 2020).

Recreational route linear disturbance, consisting primarily of 2- and 4-wheel track roads, are found throughout desert tortoise habitat and TCAs. These recreational routes are not typically as wide as transportation corridors and have lower traffic levels. However, the density of recreational routes has increased in the Mojave Desert and resulted in degradation, loss, and potential fragmentation of desert tortoise habitat (Berry and Murphy 2019). Recreational use of routes can lead to vegetation disturbance and loss, soil compaction, and increased erosion. These factors lead to an increase of denuded areas and invasive plant species, which further deteriorate desert tortoise habitat and corridors between habitats. These changes result in the loss of shrub cover and burrow sites, reduction in preferred food plants, and a greater exposure to predators and extreme temperatures (Berry et al. 2020b).

High densities of invasive plant species also increase the likelihood of wildfires. Wildfires, in turn, burn and destroy native species and result in the continued spread of invasive plants (Boarman 2002; Esque et al. 2003; USFWS 2021a), which affect both habitat and corridors between habitats. Fires fragment tortoise habitat by creating patches of unusable habitat, at least over the short term (Boarman 2002) and can result in the loss of connectivity between remaining suitable habitat patches, depending on the size of the burned areas. Drake et al. (2016) found that during years six and seven after wildfires, the movements of desert tortoises into burned areas declined relative to the reduction in live cover of a perennial forage plant that rapidly colonize burned areas.

2.4.2 Current Management Approaches for Desert Tortoise Habitat Connectivity

2.4.2.1 Mojave Desert Tortoise Recovery Plan: Connectivity Related Recovery Actions

The Desert Tortoise (Mojave Population) Recovery Plan published in 1994 described a strategy for recovering the Mojave desert tortoise and included the identification of six recovery units, recommendations for a system of Desert Wildlife Management Areas within the recovery units, and development and implementation of specific recovery actions (USFWS 1994). A Revised Recovery Plan was published in 2011 (USFWS 2011) to build on the foundation of the 1994 Recovery Plan by emphasizing partnerships to direct and maintain focus on implementing recovery actions and a system to track implementation and effectiveness of recovery actions. The Recovery Plan (USFWS 2011) includes the following actions specific to connectivity, corridor, and habitat fragmentation:

- Recovery Action 2: Protect Existing Populations and Habitat
  - Restrict, Designate, Close, and Fence Roads (Recovery Action 2.5): Paved highways, unpaved and paved roads, trails, and tracks have significant impacts on desert tortoise populations and habitat. In addition to providing many opportunities for accidental mortality, they also provide access to remote areas for collectors, vandals, poachers, and people who do not follow vehicle-use regulations. Substantial numbers of desert tortoise are killed on paved roads. Roads also fragment habitat and facilitate invasion of non-native vegetation. Collectively, the actions described below are of relatively high priority in all recovery units.
    - Establishment of new roads should be avoided to the extent practicable within desert tortoise habitat within tortoise conservation areas; tortoise conservation areas should have a minimum goal of "no net gain" of roads.
    - Existing roads should be designated as open, closed, or limited. This action is especially pertinent for closed or limited designations, which can help mitigate impacts mentioned above. Maintenance of route designation signs may also be required due to vandalism. Route designation is a particularly high priority in all recovery units except Upper Virgin River (moderate priority).
    - Non-essential or redundant routes should be closed, especially within tortoise conservation areas. Emergency closures of dirt roads and routes may also be needed to reduce human access and disturbance in areas where human-caused mortality of desert tortoise is a problem. Road closures are a particularly high priority in all recovery units except Upper Virgin River (moderate priority).
    - Tortoise-barrier fencing should be installed, according to specifications provided in Appendix C (of the Recovery Plan), and maintained along highways in desert tortoise habitat. In particular, all highways and paved roads within or adjacent to tortoise conservation areas should be fenced with appropriate modification to avoid population fragmentation. Fencing projects need to be completely implemented and maintained to ensure effectiveness. A list of priority roads is provided in the Recovery Plan.

      Alternatives to fencing may be investigated in areas of high-maintenance (e.g., subject to flash flooding) or viewshed concern. Culverts and underpasses should be incorporated into road-fencing projects as well as any state or federal road or highway improvement/expansion to minimize the fragmenting effects of the road (2.11).

  - Secure Lands/Habitat for Conservation (Recovery Action 2.9): This action is of moderate priority in all recovery units. It counters habitat loss and protects tortoise, provided secured lands are suitable habitat (discussed under Action 2.1 of the Recovery Plan) or can serve as corridors or buffers. Given the vast amount of desert tortoise habitat already under federal management or primary conservation use, land acquisition should be strategic, focusing on particularly sensitive areas that would connect functional habitat or improve management capability of the surrounding area. For example, some tortoise conservation areas have significant inholdings of private land on which development and associated access roads would threaten the conservation value of these areas. Land acquisitions should include surface and subsurface mineral rights whenever possible.

Conservation agreements and other private-landowner incentives could also be developed to protect desert tortoise habitat in such areas.

Land managers should coordinate with the Department of Defense on efforts such as the Readiness and Environmental Preparedness Initiative and the Army Compatibility Use Buffer program to acquire lands that would serve a dual purpose of preventing encroachment on military installations and conserving desert tortoise habitat.

Areas of particular emphasis noted by managers for this recovery action include the Western Mojave Recovery Unit and inholdings within National Parks. In addition, consolidating private lands within the Red Cliffs Desert Reserve is important for habitat connectivity.

  - Connect Functional Habitat (Recovery Action 2.11): Connecting fragmented habitat helps to maintain gene flow between isolated populations. This action improves species fitness (ability to maintain or increase its numbers in succeeding generations) by maintaining diversity, allowing populations to interbreed, and providing access to larger habitats (Forman et al. 2003). Roads and urban areas form barriers to movement and tend to create small, local populations which are much more susceptible to extinction than large, connected populations (Wilcox and Murphy 1985).

    This action is of consistently moderate priority among recovery units. It entails connecting isolated blocks of desert tortoise habitat, particularly through corridors of natural habitat for large-scale connectivity (e.g., habitat corridor around the north end of the Spring Mountains, Nevada), as well as culverts for smaller-scale connectivity across fenced roads and railroads.

- Recovery Action 5: Conduct Applied Research and Modeling in Support of Recovery Efforts Within a Strategic Framework.
  - Determine the Importance of Corridors and Physical Barriers to Desert Tortoise Distribution and Gene Flow (Recovery Action 5.5): Determining the importance of corridors and barriers will allow population models to be made spatially explicit relative to current land management (e.g., population and habitat fragmentation due to roads, urbanization, and energy development) and potential distributional shifts resulting from climate change.

2.4.2.2 Connectivity Related Federal Land Management: BLM

The BLM manages the largest area, approximately 54 percent, of Mojave desert tortoise habitat area in Nevada. Within southern Nevada, the BLM has designated several Areas of Critical Environmental Concern (ACECs) for the protection of desert tortoise. BLM management goals for the desert tortoise include, but are not limited to, the following:

- Manage a sufficient quality and quantity of desert tortoise habitat, which in combination with tortoise habitat on other federal, state, and private lands, will meet recovery plan criteria.

- Maintain functional corridors of habitat between ACECs to increase the chance of long-term persistence of desert tortoise populations within the recovery unit.
- Implement inventory, monitoring, and research projects dealing with management issues within desert tortoise habitat and ACECs. Research is being conducted on disease, livestock grazing, predator-prey relationships, genetics, tortoise translocation/relocation, and habitat restoration.

The BLM is part of the Desert Tortoise Management Oversight Group, established in 1998 after the Mojave population of the desert tortoise was listed under the ESA. The group is charged with ensuring that data analysis procedures are standardized, establishing funding and research priorities, ensuring that various reports are prepared, and reviewing existing and new laws and plans relating to the desert tortoise.

2.4.2.3 Habitat Restoration for Connectivity

Desert tortoise habitat conservation, enhancement, and restoration were emphasized in the Revised Recovery Plan as priority recovery actions (USFWS 2011). Many native habitat restoration and improvement techniques have been proposed but most have not been tested for their effectiveness as recovery actions for the desert tortoise (Abella and Berry 2016). Habitat restoration efforts that help improve connectivity include ground surface treatment, reducing non-native plants, such as invasive grasses, and decommissioning backcountry roads to improve desert tortoise forage quality and increase forage availability.

Habitat Restoration Methods

Habitat restoration methods that have been used to restore degraded areas that can serve as connectivity corridors for the desert tortoise include the following:

- Outplanting: Transplant of native plants from a nursery bed, greenhouse, or other location to an outside area to restore habitat.
- Transplanting: Moving plants living in the wild from one site to another (possibly with an intervening period of residence in a greenhouse or nursery) or back to the same site after a period of time. Plant salvage can be considered as a type of transplanting.
- Seeding: methods include broadcasting seed over an unprepared or prepared (e.g., by ripping or contouring soils) surface, drilling (inserting seeds into the ground), hydro (combining seeds with a slurry of water and other materials), and pelleting (encasing seeds with soil or other particles). An advantage of seeding for agencies is that seeds can be amassed during high production years and then used to produce container plants or for direct application at restoration sites (Weigand and Rodgers 2009).
- Ground Surface Treatments: Ground surface treatments are used as part of restoration in areas that have significant loss of vegetation, soil compaction and erosion, and to hide previous disturbance (such as trails and other linear disturbances). Ground surface treatments can include soil treatments such as decompaction and erosion control, and mulching (vertical and horizontal).

Reduction of Non-Native Invasive Plants

The priorities for decreasing the impacts of non-native invasive plants within habitat corridors are to reduce the abundance of existing non-native plants and limit the establishment of new non-native plants. Reduction of invasive plants would also reduce the probability of non-native grass fueled fires that result in the mortality of native plants, which further degrade and fragment desert tortoise habitat (Abella and Berry 2016).

Early detection of non-native invasive species along with removal as soon as possible after detection has been shown to be less expensive and more effective than attempts to manage populations that have been established over a longer period of time.

Non-native invasive species can be reduced in a variety of ways, including, but not limited to, mechanical control, biological control, and chemical control. Within the Mojave Desert, mechanical and chemical control are the most common treatment methods.

Decommission Backcountry Roads

Backcountry unpaved roads, primarily used for recreation, are found throughout the Southwest. Many of these roads are duplicative, leading to the same location, and can be deemed unnecessary. Removing duplicative and unnecessary unpaved roads from use (decommissioning roads) and restoring the disturbed areas can result in improved soil and vegetation community health within desert tortoise habitat. Most backcountry recreational roads are typically disturbed areas with minimal vegetation and compacted soils. Decommissioning unnecessary roads within desert tortoise habitat could serve to improve forage availability and reduce habitat fragmentation. Two main best practices have been highlighted for decommissioning backcountry unpaved roads: ameliorate topographic and soil surface alterations; and limit post-restoration vehicle incursions (Abella and Berry 2016).

2.4.2.4 Fencing and Culverts for Connectivity

Roads have been shown to be an important factor in the decline of the desert tortoise across its range (Boarman et al. 1997; Nafus et al. 2013; Peaden et al. 2015; Peaden et al. 2017; von Seckendorff Hoff and Marlow 2002). To mitigate road mortality, roadside tortoise exclusion fences have been constructed along several major roads and highways in the Mojave Desert. Studies have shown that mortality can be prevented by fencing roadways to prevent tortoises from crossing, and that fencing tied in with culverts can allow safe passage (Peaden et al. 2015; Ruby et al. 1994).

In order to reduce the potential for habitat fragmentation and improve connectivity, fencing can be connected to culverts (drainage features) generally along desert dry washes designed to allow safe passage of tortoises under roadways. Studies have shown that desert tortoises exhibit a strong preference for use of dry washes during movements within or between habitats (Boarman et al. 1997; Peaden et al. 2017). However, fencing along newly constructed roads may also result in tortoise pacing along the fence line and increased carapace temperatures due to longer-term exposure. Fencing is considered a valuable tool to mitigate road mortality, but placement of fencing should be thoroughly evaluated, and shading should be considered as part of the mitigation strategy (Peaden et al. 2017).

Fencing can also assist in restoration of desert tortoise habitat, including connectivity corridors. Fencing can be used to exclude livestock and recreational vehicle use, which leads to improved perennial plant cover as well as an increase in the amount and quality of annual plant forage for desert tortoises (Abella and Berry 2016).

2.4.2.5 Connectivity Modeling

Mojave Desert tortoise management can be informed by various models that describe, predict, or produce maps of habitat suitability, levels of development or disturbance, landscape genetics, tortoise habitat linkages and connectivity, genetic connectivity effects of land use and climate change, dispersal patterns, and demography. Modeling can address a variety of management issues and act as an important tool in developing management approaches for preserving tortoise habitat, restoration efforts, and maintaining connectivity. Models can also help agencies coordinate on the range-wide conservation strategy for the desert tortoise (U.S. Geological Survey [USGS] 2019). The most relevant desert tortoise models are listed below.

U.S. Geological Survey Habitat Model

The USGS Habitat Model (Nussear et al. 2009) is a quantitative, spatial habitat model for the Mojave desert tortoise north and west of the Colorado River. The model incorporates environmental variables such as precipitation, geology, vegetation, and slope and uses occurrence data of desert tortoise from sources spanning more than 80 years, including data from the 2001 to 2008 range-wide monitoring surveys. The model predicts the relative potential for desert tortoise to be present in any given location, given the combination of habitat variables at that location in relation to areas of known occupancy throughout the range. This model does not account for anthropogenic effects to habitat and represents potential desert tortoise occupancy without inclusion of anthropogenic effects (USFWS 2021a). The model is based on the correlation of the following:

- Tortoise presence points
- Statistically derived pseudo-absences (where presence data are not available)
- A variety of habitat variables

Applications of this model include the following:

- Project proponent planning
- Establishing survey requirements
- Evaluating reports on tortoises
- Base for subsequent models
- Modeling layers can be applied to many other problems

The model assumptions, limitations, and caveats include the following:

- Model assumes pristine habitat status (it does not consider or factor in the influence of human land uses such as roads, urbanization, solar arrays, powerlines, or degradation from invasive plants and fire in the distribution).
- The one-kilometer-square resolution may be relevant to tortoise movement but finer resolution may be desired for some applications.

Gene Flow Model

The Gene Flow Model (Hagerty et al. 2010) addresses the factors that have contributed to the population genetic structure of the desert tortoise across the Mojave Desert. Three main factors were investigated for the model that influence landscape connectivity:

1. Geographic distance (Hagerty and Tracy 2010; Murphy et al 2007)
2. Natural barriers to dispersal
3. Landscape friction/permeability (a habitat's resistance to the movement of individuals taken as the inverse of habitat suitability from Nussear et al. 2009)

The model assumptions, limitations, and caveats for genetic connectivity include the following:

- Habitat suitability is an appropriate estimate of habitat friction/permeability to dispersal.
- Landscape influences migration rates per generation across a large geographic area (not individual dispersers among habitat patches).
- Modeling does not address recent barriers to gene flow for the Mojave desert tortoise.

A review of this model (USGS 2019) suggested that habitat suitability values were not effective approximations of landscape friction. Modeling results showed geographic distance and dispersal barriers were dominant factors associated with genetic structure, while landscape friction had little to no influence. Results also indicated that when more than one pathway was available to desert tortoises to traverse the landscape, or the size of the path increased, resistance to desert tortoise movement decreased. The model also indicated that habitat for the Mojave desert tortoise was historically connected (USGS 2019).

USFWS Linkage Model

The USFWS Linkage Model (Averill-Murray et al. 2013) identified linkages between TCAs using least-cost corridors based on an underlying habitat suitability model (Nussear et al. 2009), while accounting for highly disturbed areas such as military training areas and off-highway open areas. The model components include the following:

1. Habitat Suitability Model base
2. National Landcover Dataset developed areas layer (Fry et al. 2011)
3. The Nature Conservancy's "Highly Converted Areas" for the Mojave ecoregion (Randall et al. 2010)
4. Conservation Category D (developed) areas for the Sonoran ecoregion (Conservation Biology Institute 2009)

This model requires refinement at the local level and questions remain about the ultimate ability of a conservation network based on this model to support viable tortoise populations and accommodate climate change (Averill-Murray et al. 2013).

Omnidirectional Connectivity Model

The Omnidirectional Connectivity Model (Gray et al. 2019) is a range-wide model of contemporary, omnidirectional (being in or involving all directions) connectivity for the Mojave desert tortoise. The objectives of this model were as follows:

- Use telemetry data to develop an empirical, range-wide model of landscape conductance, or movement habitat potential for the Mojave desert tortoise.
- Create a model relevant to the scale of movement.
- Derive a range-wide estimate of potential connectivity that does not rely on the delineation of discrete habitat or population cores.

The methods used for the model are as follows:

- Brownian Bridge Movement models were used to estimate probabilities of movement between locations. Movement data were obtained from telemetered desert tortoises.
- Habitat covariates were used to describe the presence of desert washes, distance to minor roads, vegetation, and 30-year average temperatures.

The model results differentiated habitat movement quality from factors associated with other life history requirements (e.g., precipitation, food plant availability). New spatial layers within the model have application for many future analyses (e.g., wash spatial layer). The noncentralized approach of this model identifies the value of desert tortoise connectivity corridors.

Intactness or Terrestrial Disturbance Index Model

The Intactness or Terrestrial Disturbance Index Model (Carter et al. 2020) connected landscape approaches and species-level conservation to quantify development. The modeling methods included the following:

- Mapping of potential desert tortoise habitat.
- Development of a generalized terrestrial development index that included agriculture, energy development, surface mines and quarries, pipelines and transmission lines, and transportation infrastructure.
- Determination of levels of development relevant to desert tortoises (disturbance proportion of the pixels equaled the Terrestrial Disturbance Index [TDI]).
- Evaluation of threats from existing development to potential habitat (the relationship between the TDI and desert tortoise abundance [live versus dead] from distance sampling results analyzed at multiple spatial scales).
- Frequency distribution of the TDI was mapped and sorted by land administration.
- Areas with no development within one kilometer were defined as undeveloped areas or areas least impacted by development.

The model indicated that live tortoise encounter rates were near zero as the TDI values increased above ten percent. Lower TDI values did not have a clear threshold for disturbance responses. Protected lands showed a stronger correlation with higher numbers of live tortoises (e.g., BLM ACECs benefit tortoises). The model predicted there are substantial undeveloped areas of desert tortoise habitat that would benefit from protection. There is potential to use the model to identify habitat corridors and determine where more intensive management might increase the value of desert tortoise habitat.

New Models

New models that focus on habitat connectivity include the following:

- The impacts of land use and urban growth on range-wide Mojave desert tortoise gene flow and corridor functionality (Nussear et al. 2021): The objectives of this model are to predict how land use will impact Mojave desert tortoise demographic connectivity within the context of landscape connectivity.
- Connectivity Modeling (Dutcher et al. 2019): This modeling effort used individually-based, spatially-explicit, forward-in-time simulations to predict genetic connectivity in no disturbance and disturbance scenarios. The simulations used a corridor success index (adapted from Gregory and Beier 2013), based on genetic differentiation, to forecast the maintenance of gene flow over time, and translated the metric into structural landscape patterns. This modeling predicted desert tortoise genetic diversity, population genetic structure, and number of individuals relative to anthropogenic disturbance.
- Desert tortoise dispersal (Hromada et al. 2020): Modeling of dispersal patterns that lead to better predictions of how habitat development and climate change may influence connectivity. The goal of this modeling effort was to develop an updated Mojave desert tortoise connectivity model that explicitly and statistically considers the impact of terrain and slope on movement probability and habitat connectivity. The connectivity map highlights the areas that, based on the data and covariates used to fit model movement suitability, are most important for maintaining overall connectivity for the desert tortoise in Clark County.
- Demographics (Shoemaker et al. 2020): Building models of tortoise vital rates (age-structured survival and fecundity) as functions of environmental and climatic covariates to assess local behavioral and physiological adaptations and quantify the range of environmental change that populations can withstand in the absence of natural selection or long-distance movements to more suitable habitats.

These modeling efforts have provided additional evidence for:

- Habitat suitability in the absence of anthropogenic disturbance.
- Historically well-connected range-wide desert tortoise population structure influenced by topographic features.
- Reduced movement and gene flow across linear barriers (highways and railroads).
- Loss of genetic diversity and increased isolation with urbanization.
- Reduced tortoise observations in areas with anthropogenic disturbance.

For these models, surface disturbance was derived from nationally available datasets and does not necessarily include temporary disturbance.

Chapter 3 Existing Conditions in the Planning Area Related to Mojave Desert Tortoise Connectivity

3.1 Land Ownership/Management in the Planning Area

Clark County consists of approximately 5.2 million acres located in southern Nevada. Several federal agencies manage lands within Clark County, as detailed in Table 3-1 below and shown in Figure 3-1.

Table 3-1
Federal Land Management Within Clark County, Nevada

Federal Agency	Acres
Bureau of Land Management	2.9 million
National Park Service	587,000
U.S. Fish and Wildlife Service	493,000
U.S. Air Force/Department of Defense	340,500
U.S. Forest Service	252,000
Bureau of Reclamation	50,700
Source: Clark County Comprehensive Planning Department 2021	

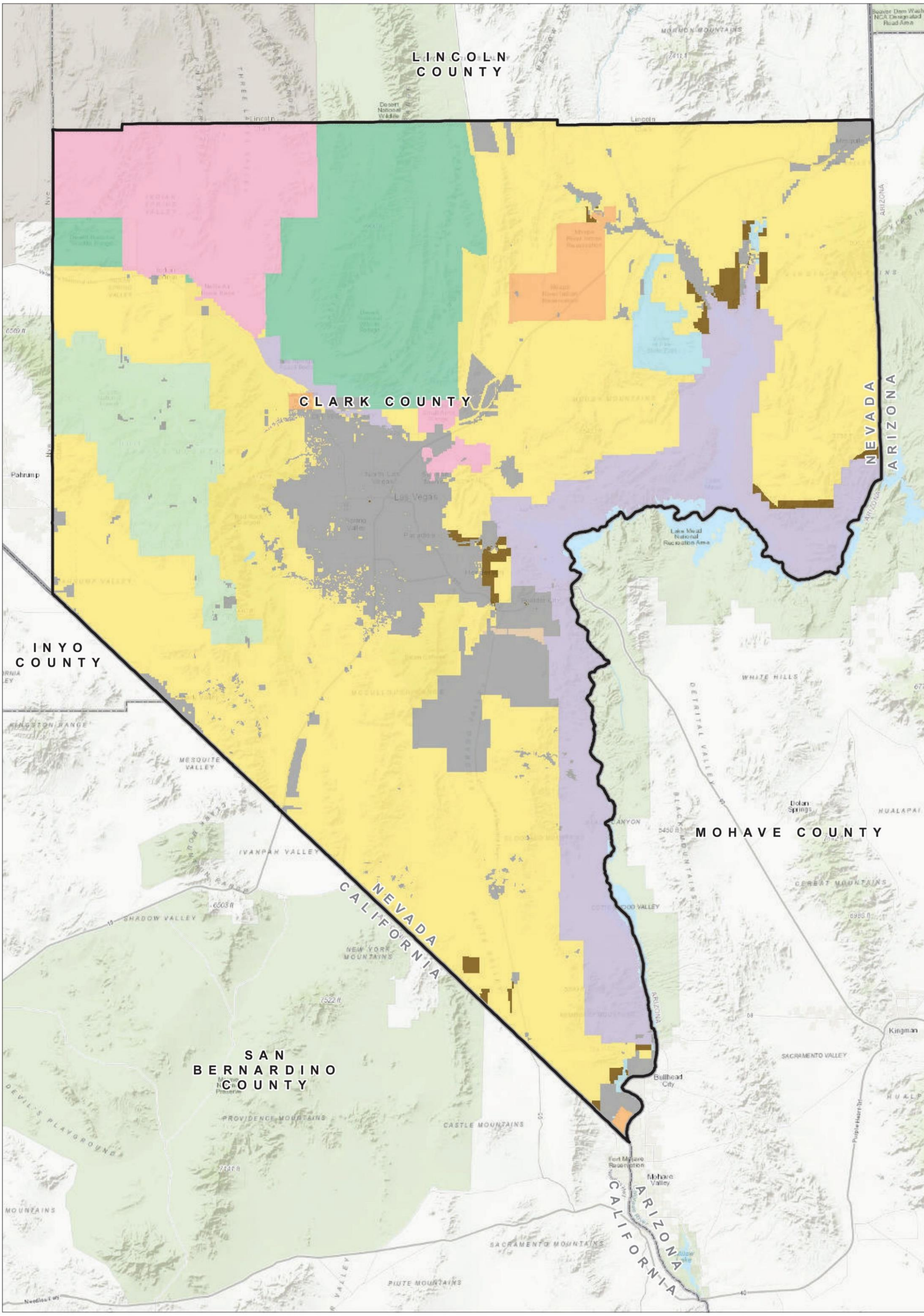
As shown in Table 3-1, the majority of land within Clark County is managed by federal agencies, approximately 89 percent. The BLM manages the largest area within the County with approximately 56 percent. Because of the large land area managed by federal agencies within the County, agency activities have a significant impact on wildlife habitat management, including management related to habitat connectivity.

Under Section 7 of the ESA, all federal agencies must use their authorities to conserve endangered and threatened species in consultation with the USFWS. Within Clark County, the Mojave desert tortoise, listed as threatened under the ESA, is identified as a priority species for both federal agencies and under the Clark County MSHCP. The County coordinates with federal agencies for the management of the desert tortoise, including management of habitat corridors.

3.2 Physical Setting of the Planning Area

3.2.1 Topography

Within Clark County, elevations range from 450 feet above mean sea level along the Colorado River at the southeastern boundary to 11,918 feet at Charleston Peak (Figure 3-2). Clark County is located within the Basin and Range physiographic province, which is characterized by a series of rugged, generally north-south-trending mountain ranges separated by wide valleys, or basins. Most mountain ranges within the County are steep and cut by deep ravines and canyons. Mountain ranges in the County are divided into four geographic areas, generally bounded by major highways that radiate from Las Vegas (see Figure 3-2) (Clark County Comprehensive Planning Department 2017).



Planning Area

Land Management

- Bureau of Land Management (BLM)
- Bureau of Reclamation
- US Forest Service (USFS)
- National Park Service (NPS)
- US Fish and Wildlife (USFW)
- Indian Reservation (IR)
- US Air Force/Department of Defense
- Other Federal
- State
- Private Lands

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FIGURE 3-1
Planning Area Land Management

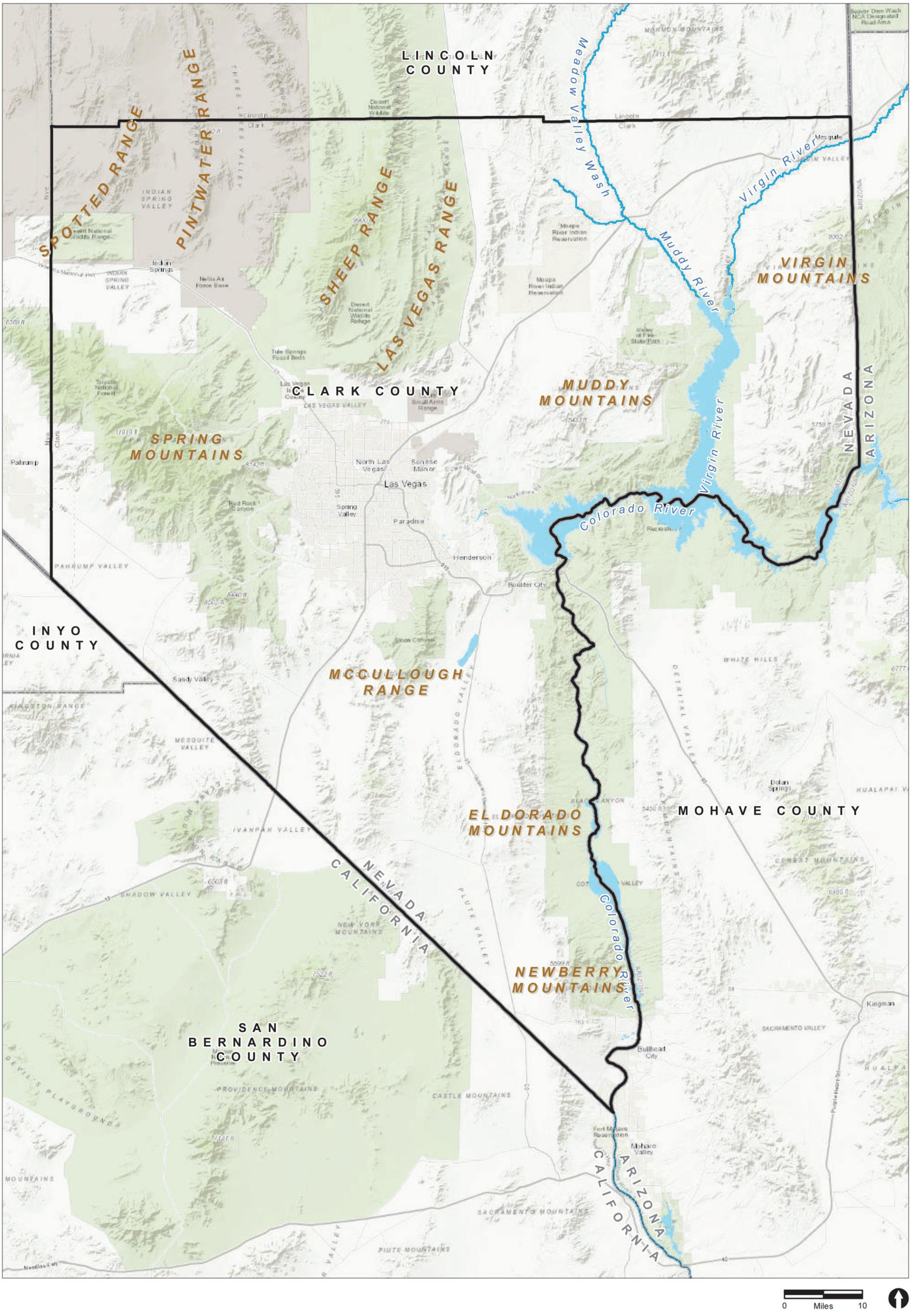

FIGURE 3-2

Mountain Ranges and Rivers in the Planning Area

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Valleys between the mountain ranges within Clark County typically consist of central basins surrounded by gentle slopes leading down from the steep range fronts. Many of the basins are internally drained, with large dry lake beds (playas) in the lowest areas. Broad alluvial aprons are found between the level lowlands of the valley floors and the surrounding mountains (Clark County Comprehensive Planning Department 2017). There are three major rivers within Clark County: Colorado River, Muddy River, and Virgin River (see Figure 3-2). Meadow Valley Wash is a large stream located in the Moapa Valley that flows into the Muddy River (see Figure 3-2). The stream is intermittent with dense riparian vegetation in many segments that can be a barrier to desert tortoise movement.

Topographic features important to the Mojave desert tortoise within Clark County, and throughout its range, include a variety of habitats from sandy flats to rocky foothills, as well as alluvial fans, washes and canyons where suitable soils for den construction might be found. Mojave desert tortoises are found from near sea level to over 3,500 feet in elevation (USFWS 2021b). Topographic features related to Mojave desert tortoise movement include desert washes and ephemeral streambeds. These landscape features are important in desert tortoise ecology, both as foraging areas and potentially as movement corridors (Hromada 2020). Desert tortoises are reluctant to move through areas of high slope and show a preference for higher vegetation cover and desert wash characteristics, with movement habitat quality steeply falling as slope increases (Hromada 2020).

3.2.2 Vegetation Communities

Vegetation communities within Clark County range from alpine and mixed conifer within mountain ranges to desert scrub within lower desert elevations (Figure 3-3). The Mojave desert scrub and blackbrush communities cover the majority of Clark County, approximately 65 and 20 percent, respectively (Table 3-2).

Table 3-2
Vegetation Communities Within Clark County, Nevada

Vegetation Community	Acres	Percentage of Clark County
Alpine	306	<0.01
Bristlecone Pine	18,962	0.4
Mixed Conifer	67,556	1.3
Pinyon-Juniper	286,400	5.6
Sagebrush	11,632	0.2
Blackbrush	1,027,144	20.0
Salt Desert Scrub	204,329	4.0
Mojave Desert Scrub	3,377,939	65.5
Mesquite/Acacia	50,008	1.0
Desert Riparian Perennial	27,717	0.5
Playa	19,180	0.4
Disturbed (i.e., developed, agriculture, etc.). Note: As estimated in 2011	278,042	5.5
Total Acres	5,369,215	

Source: Heaton et al. 2011

Figure 3-3 Vegetation Communities in the Planning Area

Within southern Nevada, the majority of invasive plant species that dominate areas outside of riparian zones consist of annuals. Annual invasive species are well suited to arid conditions by remaining dormant as seeds in the seedbank and germinate when conditions are favorable (typically from winter to spring). The major species of concern include cheatgrass (*Bromus tectorum*), red brome (*Bromus rubens*), buffelgrass (*Cenchrus ciliaris*), Mediterranean split-grass (*Schismus barbatus, Schismus arabicus*), red-stemmed filaree (*Erodium cicutarium*), and various mustard species (*Brassica tournefortii, Hirshfeldia incana, Sisymbrium irio, Sisymbrium altissimum, Malcomia Africana*) (Brooks et al. 2013a).

3.3 Desert Tortoise Habitat within Clark County

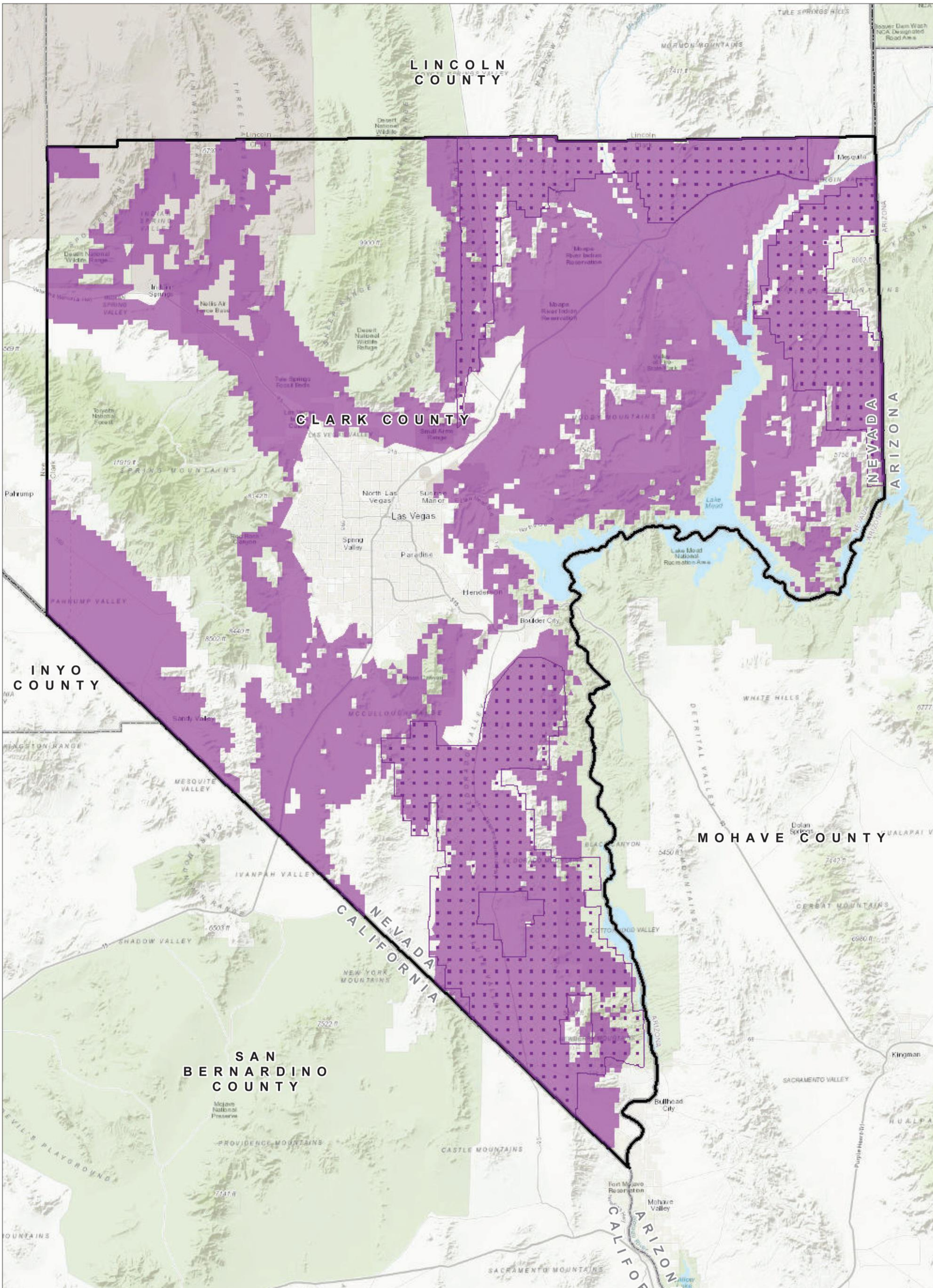
Typical habitat for Mojave desert tortoise is creosote bush (*Larrea tridentata*) scrub in association with white bursage (*Ambrosia dumosa*); however, desert tortoise may also be found in Joshua tree (*Yucca brevifolia*) woodland, blackbrush (*Coleogyne ramosissima*) scrub, microphyll woodlands, shadscale (*Atriplex confertifolia*) scrub, saltbush (*Atriplex* spp.) scrub, cactus scrub, and warm season grassland (Germano et al. 1994; Nussear et al. 2009). Mojave desert tortoise typically inhabit areas that include deeply incised washes, sandstone outcrops, rugged rocky canyons, and basalt-capped ridges interspersed with sandy valleys but most commonly occur in areas with gentle slopes, sufficient shrub cover, and friable soils to allow burrow construction (Allison and McLuckie 2018).

Mojave desert tortoise critical habitat and probable habitat within Clark County is shown in Figure 3-4. There are approximately 958,000 acres of critical habitat and over 2.8 million acres of probable habitat within the County.

3.4 Desert Tortoise Habitat Connectivity Threats in Clark County

3.4.1 Urban Development

Within southern Nevada, the primary threats to desert tortoise habitat connectivity include loss of habitat from construction projects such as roads, urban development and expansion, and energy developments, including renewable energy and transmission. Urban sprawl in the Las Vegas Valley and renewable energy and other large-scale developments in the Ivanpah Valley have created significant barriers to desert tortoise movement and reduced occupancy or fragmented habitat patches within linkages between TCAs. Within Clark County, the human population has increased significantly from approximately 756,000 in 1990 to a population of approximately 2.3 million in 2020 (University of Nevada Center for Economic Development 2022). The increase in population and tourism since the 1970s lead to a large urban expansion within the Las Vegas Valley, which consists of approximately 600 square miles and contains the major cities of Las Vegas, North Las Vegas, and Henderson. This urban sprawl has resulted in the loss of desert tortoise habitat and habitat fragmentation within and at the edges of development. Based on historical trends, growth forecasts, and planned development, the urban footprint will continue to expand along the edges of existing development and to the east of the I-15 corridor south of the Las Vegas Valley within Clark County.



Planning Area

Mojave Desert Tortoise Critical Habitat

Mojave Desert Tortoise Probable Habitat

FIGURE 3-4
Mojave Desert Tortoise Critical Habitat and Probable Habitat within the Planning Area

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3.4.2 Major Highways and Adjacent Connectivity Barriers

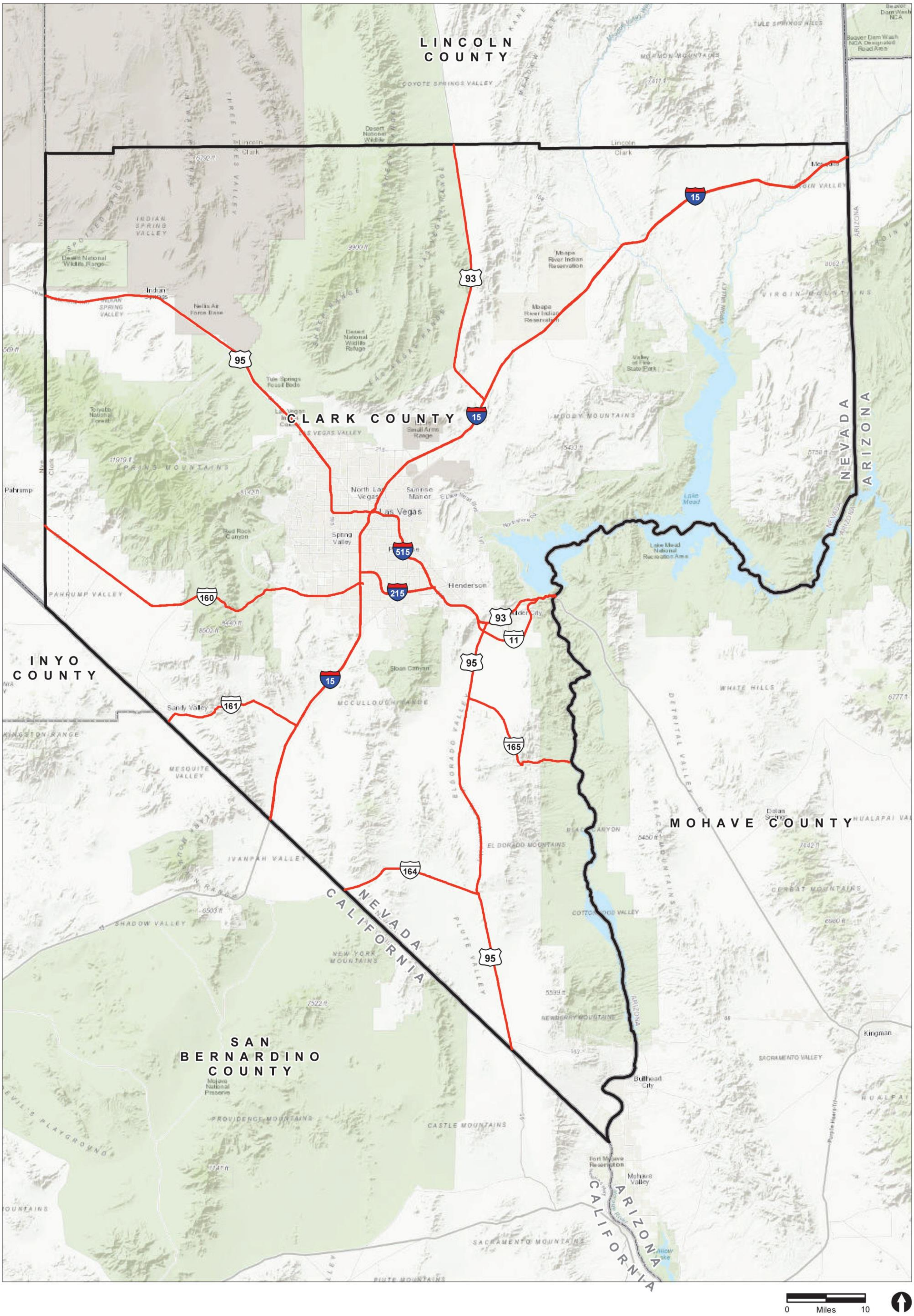
The major highways within Clark County include Interstate 15 (I-15), U.S. Highway 95 (US-95), US-93, State Highway 160, State Highway 161, State Highway 164, State Highway 165, and the new Interstate 11 (I-11) (Figure 3-5). Major highways and roadways within desert tortoise habitat have been shown to be barriers to desert tortoise movement and habitat connectivity (Peaden et al. 2017). These highways are described in more detail below.

I-15: I-15 from the California-Nevada border through the Ivanpah Valley (passing through the communities of Primm and Jean) to the Las Vegas metropolitan area is a six-lane divided highway with an average annual daily traffic (AADT) count in 2020 of approximately 44,000 vehicles (NDOT 2021). North of the Las Vegas metropolitan area, I-15 continues as a four-lane divided highway through the communities of Moapa and Mesquite before reaching the Utah state border. Concrete barriers have been added to the majority of I-15 in the Ivanpah Valley as well as desert tortoise exclusion fencing along the majority of I-15. Because I-15 is a divided highway, areas crossed by washes require two sets of culverts, one for each portion of the divided highway with an open area between the culverts, which creates an additional barrier to tortoise movement. The divided highway, concrete barriers, fencing, as well as high vehicle use and speeds, act as a significant barrier to desert tortoise movement within the Ivanpah Valley (Peaden et al. 2017). Along the portion of I-15 located within the Ivanpah Valley, south of Las Vegas, studies have shown a significant decrease in connectivity. Desert tortoise connectivity modeling results (Dutcher et al. 2019) showed disturbance scenarios in the Ivanpah Valley are expected to result in an almost complete loss of connectivity and isolated tortoise population clusters.

Other barriers and large developments that impact tortoise connectivity within the Ivanpah Valley and areas north of Las Vegas include large-scale solar development, large transmission lines (that include access roads), and the Union Pacific railroad. Additional solar developments are proposed, as well as the Southern Nevada Supplemental Airport near Primm, Nevada, and a proposed new high speed rail line (Brightline West) that would travel from California through the Ivanpah Valley to Las Vegas.

I-11: I-11 is an east-west highway that was created to bypass the Hoover Dam to facilitate travel between Arizona and the Las Vegas area. I-11 is currently approximately 23 miles long between the Arizona state line and Henderson, Nevada. I-11 is a 4-lane divided highway with concrete barriers. The AADT count in 2020 was approximately 13,200 vehicles (NDOT 2021). Culverts are primarily undivided, meaning they consist of one culvert that is not split, allowing tortoises to pass through from one side to the other without open space between openings, reducing the threat from predators (such as ravens) or potential for entering the roadway between openings, as may occur with divided culverts, if there is no tortoise fencing.

Other barriers and large developments adjacent to I-11 include large transmission lines, large transmission substation, recreational routes and activities, sand and gravel mining, and expanding urban development in the Henderson area.



Planning Area

Major Highways

FIGURE 3-5

Major Highways in the Planning Area

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US-95: US-95 within Clark County traverses from the California-Nevada border to the south through the communities Cal-Nev-Ari and Searchlight, and north to Las Vegas. North of Las Vegas, US-95 continues north-northwest past the community of Indian Springs. Outside of Las Vegas. US-95 is primarily a 4-lane divided highway. The AADT count in southern Clark County near Cal-Nev-Ari in 2020 was approximately 7,240 vehicles (NDOT 2021). Near Indian Springs in northern Clark County, the AADT count was 4,100 vehicles (NDOT 2021). Culverts along some portions of US-95 span the width of the divided highway (one culvert). North of Las Vegas, culverts span the width of each side of the highway and are open in the median, with tortoise exclusion fencing that keeps tortoises from accessing the highway from the median and keeps them funneled between the culvert sections. Desert tortoise exclusion fencing has been placed along portions of US-95.

Other barriers and large developments adjacent to US-95 in southern Clark County include large scale solar energy fields south of Railroad Pass, recreational routes and activities, and large transmission lines. To the north of Las Vegas, barriers and large developments include large correctional facilities, a golf course, large transmission lines, and planned solar developments.

US-93: US-93 within Clark County traverses from east of Boulder City into Las Vegas, where it is primarily a 4-lane undivided roadway. North of Las Vegas, US-93 is primarily a two-lane north-south highway passing through the community of Coyote Springs in northern Clark County. The AADT count near Boulder City was approximately 3,050 vehicles and near the junction with I-15 north of Las Vegas the AADT count in 2020 was approximately 3,500 vehicles (NDOT 2021). Culverts along US-93 span the width of the highway (one culvert). Desert tortoise exclusion fencing has been placed along portions of US-93.

Other barriers and large developments adjacent to US-93 to the east of Las Vegas include expansion of urban development between Boulder City and Las Vegas, recreational routes and activities, golf course, as well as railroad tracks. To the north of Las Vegas, there are several large solar fields near the US-93 and I-15 junction, large transmission lines, and a large golf course in Coyote Springs.

State Highway 160: State Highway 160 is an east-west highway that enters Clark County from the west near Pahrump, passes through the community of Mountain Spring, and ends in west Las Vegas at the junction with I-15. State Highway 160 is a 2-lane undivided highway. The AADT count in 2020 was approximately 8,750 vehicles in the western portion of Clark County (NDOT 2021). Culverts along State Highway 160 span the width of the highway (one culvert).

Other barriers and large developments adjacent to State Highway 160 include urban expansion west of Las Vegas.

State Highway 161: State Highway 161 is an east-west highway that enters Clark County at the Nevada-California border near Sandy Valley and ends at the junction with I-15 in Jean, Nevada. State Highway 160 is a 2-lane undivided highway. The AADT count in 2020 was approximately 3,250 vehicles (NDOT 2021). Culverts along State Highway 161 span the width of the highway (one culvert).

Other barriers and large developments adjacent to State Highway 161 include recreational routes and activities and large transmission lines.

State Highway 164: State Highway 164 is an east-west highway that enters Clark County at the Nevada-California border east of Nipton, California and ends at the junction with US-95 in Searchlight, Nevada. State Highway 164 is a 2-lane undivided highway. The AADT count in 2020 was approximately 960 vehicles (NDOT 2021). Culverts along State Highway 164 span the width of the highway (one culvert). Desert tortoise exclusion fencing has been placed along portions of State Highway 164.

Other barriers and large developments adjacent to State Highway 164 include recreational routes and activities and large transmission lines.

State Highway 165: State Highway 165 is an east-west highway that traverses from US-95 to the Colorado River in eastern Clark County. State Highway 165 is a 2-lane undivided highway. The AADT count in 2020 was approximately 390 vehicles (NDOT 2021). Culverts along State Highway 165 span the width of the highway (one culvert).

Other barriers adjacent to State Highway 165 include mining and recreational routes and activities.

3.4.3 Off-Highway Vehicle Recreation

Recreational activities, primarily OHV recreation, within Clark County and southern Nevada have resulted in degraded and fragmented desert tortoise habitats from trails and high use areas. There are thousands of miles of OHV routes/trails within Clark County. OHV recreation includes individual use as well as race events. OHV recreation has increased significantly in Clark County as the population in the surrounding areas has increased, leading to an increase in the density of recreational routes in the Mojave Desert that has resulted in degradation, loss, and potential fragmentation of desert tortoise habitat (Berry and Murphy 2019).

3.4.4 Wildfires

Wildfires within Clark County have resulted in threats to desert tortoise and habitat connectivity (Berry and Murphy 2019). Within the BLM Southern Nevada District, which includes Clark County, wildfires have burned approximately 377,270 acres in the last 20 years (BLM 2021). The majority of these fires were caused by lightning. The presence and spread of fine fuels from non-native annual grasses and other invasive species has resulted in larger and hotter fires within Mojave Desert vegetation communities, where fires were historically less frequent (Berry and Murphy 2019; Brooks et al. 2013b). Wildfires result in the loss of vegetative cover used by tortoises (Esque et al. 2003). Wildfires can destroy perennial plants that are important resources for desert tortoise forage and cover, and may also destroy burrow sites (BLM 2017). In areas that have experienced multiple fires due to increases on non-native grasses, native vegetation can be converted into non-native grasslands over time (Meyer 2008). Factors that may contribute to desert tortoise avoidance of burned areas include inhibited movement, increased fire-induced mortality, and reduced availability of shelter sites and diverse forage (Meyer 2008). Loss of native vegetative cover, forage, and burrow/shelter sites result in habitat fragmentation and can change connectivity between habitats.

3.5 Desert Conservation Program Desert Tortoise Connectivity Studies

3.5.1 Clark County Highway Culvert Evaluation

The DCP contracted a study to comprehensively evaluate the culverts beneath the highways connected to tortoise-proof fencing in Clark County that could theoretically be used by desert tortoises. The data gathered could be used to map the existing passageways for tortoises and to help in planning improvements for existing infrastructure to facilitate more usable culvert corridors efficiently and strategically (NewFields 2021).

The relevant highways included in the study are I-15, US-95, US-93, State Highway 160, State Highway 161, State Highway 164, State Highway 165, and the new I-11 (see Figure 3-5). Approximately 99 percent of the culverts along these highways were located, and a scoring rubric (grading) was used to distinguish desert tortoise usability of each culvert visited (NewFields 2021). An example of the data collected is shown in Table 3-3 below.

Table 3-3
Clark County Culvert Data Point Inspection Grades (2014)

Grade/Desert Tortoise Usability	Number of Culverts
Grade 1 / Easily Passable	225
Grade 2 / Passable with Light Effort	112
Grade 3 / Passable to Some Tortoise	112
Grade 4 / Would Require Some Culvert Intervention	109
Grade 5 / Would Require Major Culvert Improvement	165
Grade 1 or 2 with Attached Tortoise Fence	51

Source: NewFields 2021

The culvert dataset from this study has been used in combination with desert tortoise habitat connectivity modeling to identify gaps in passable culverts available as well as to prioritize culverts in need of changes to improve usability (NewFields 2021).

3.5.2 Mapping Potential Desert Tortoise Habitat Connectivity in Clark County

The DCP contracted a study to develop an updated Mojave desert tortoise connectivity model that explicitly and statistically considered the impact of terrain on movement probability as well as habitat connectivity. This model is an update to the Omnidirectional Connectivity Model (Gray et al. 2019). The modeling workflow consisted of the following (Conservation Science Partners 2021):

1. For each pixel in a rasterized representation of the landscape, generate a movement probability model to allow prediction of the relative probability that the pixel is suitable for movement.
2. Use the movement probability model to generate a “conductance surface” in which each pixel is assigned a value proportional to the ease with which a tortoise could traverse it.
3. Use the conductance surface to model omni-directional landscape connectivity and generate a map of landscape connectivity.

Modeling results showed that connectivity is most constrained around Las Vegas (black areas), which was expected (Figure 3-6). In general, the model predicted that movement intensity is consistently high in southern Clark County (yellow and red areas); while in the northeast and northwestern portions of the County, current flow was predicted to be moderate to low (blue areas), despite high conductance values for those regions. This suggests that these regions may have more path redundancy than the rest of the County (Conservation Science Partners 2021).

The analysis of this connectivity modeling led to recommendations for future research priorities, including the following (Conservation Science Partners 2021):

- It will be critically important to validate these model results in the field.
- Additional monitoring, particularly in the highest flow areas, should be done to re-evaluate how functional the model is in predicting tortoise movement and/or occurrence.
- Collection of more tortoise movement data across Clark County, for validation of existing models and use in future movement and connectivity modeling.
- Collection of data across a larger gradient of terrain, vegetation, and climate characteristics to improve inference in future models.
- For future data to be useful for Brownian bridge movement modeling, it is critical that location data are collected frequently (ideally, at least every 24 hours).

The movement suitability model has helped more fully understand how terrain affects tortoise movements and serves to provide additional support for the accuracy of the final connectivity model from Gray et al. (2019), as well as providing quantitative estimates of the influence of slope and terrain ruggedness on tortoise movement. Results of this model suggest that slope and terrain ruggedness may be particularly valuable for predicting tortoise movement suitability. The connectivity map that resulted from modeling highlights the areas that are most important for maintaining overall connectivity for Mojave desert tortoise in Clark County (areas in yellow in Figure 3-6). With validation of the connectivity model, the areas identified as most important for maintaining overall connectivity could be the focus of conservation efforts for the Mojave desert tortoise in Clark County.

3.5.3 Desert Tortoise Connectivity Across Roadways

The DCP contracted a study to collect data to estimate Mojave desert tortoise population densities and examine tortoise movement in relation to culverts along portions of US-93 and US-95 north of Las Vegas, Nevada. The purpose of the study was to collect data to assist with determining desert tortoise population densities near highway culverts and to determine the number of observed highway crossings per estimated tortoises in the area (Ecocentric 2021).

Mark-recapture surveys were conducted to help assess desert tortoise population densities near highway culvert crossings and to provide information on the potential effectiveness of culverts as population connectors. Surveyors encountered a total of 183 unique tortoises, 89 of which were recaptured during subsequent survey passes. More than twice as many tortoises were encountered on US-93 plots than on US-95 plots. Crews observed 2,745 tortoise burrows, 139 tortoise carcasses (five of which had ID tags from a previous project), 78 pieces of tortoise scat, 49 piles of tortoise bone/scute fragments, and 13 locations with tortoise eggshells. Recorded tortoise sign on US-93 plots was more than triple that recorded on US-95 (Ecocentric 2021).

Map Source: Conservation Science Partners 2021 Mapping Potential Desert Tortoise Habitat Connectivity in Clark County, NV

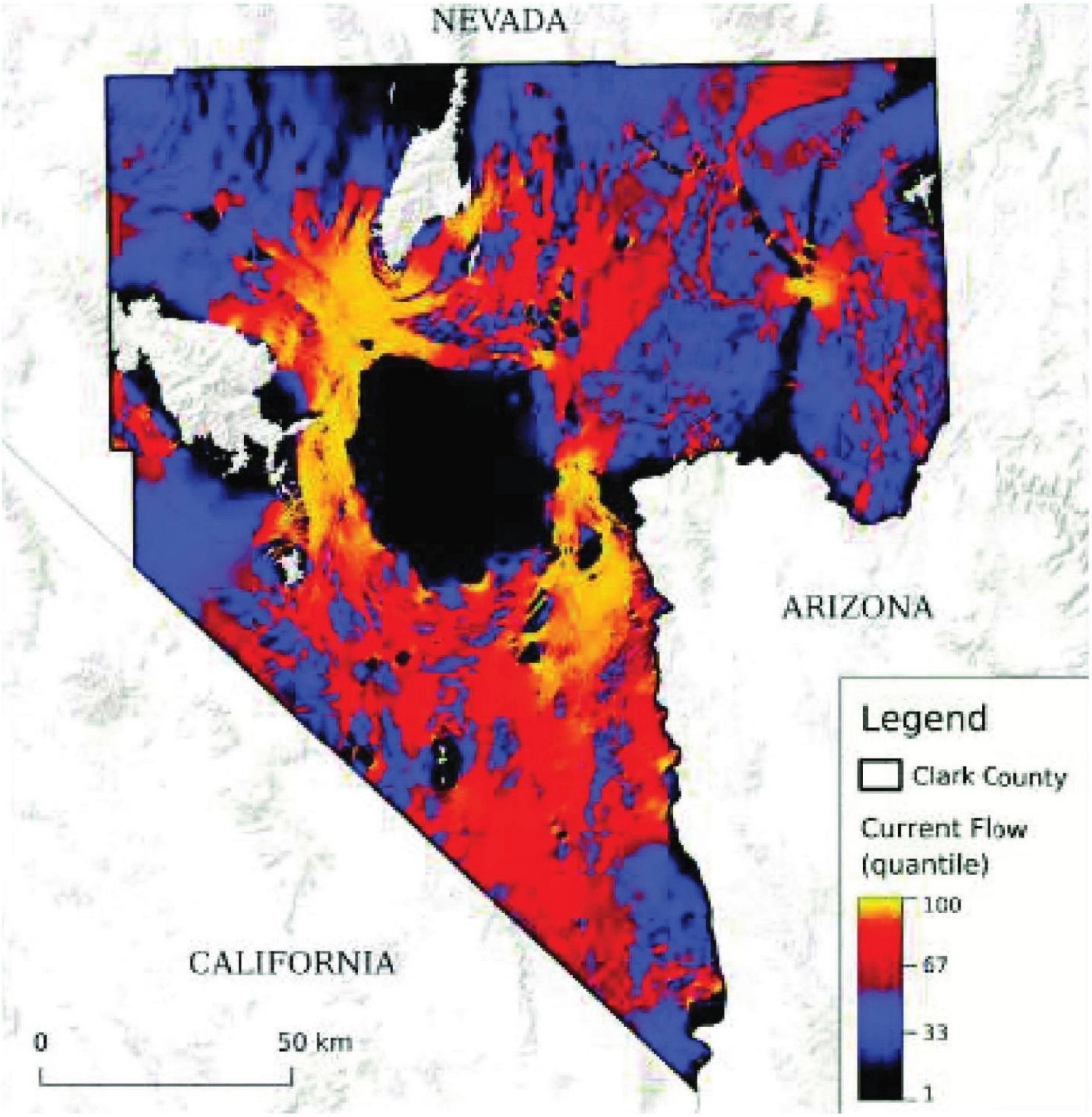

FIGURE 3-6
Omni-Directional Connectivity
Output in the Planning Area

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The data on desert tortoise locations, including tortoise sign, will be used in future analysis to determine relative abundance as well as contribute to ongoing federal and state agency efforts to gain a better understanding of tortoise population connectivity throughout the range. In addition, the project resulted in 14 tortoises receiving radio transmitters and these tortoises have been included in the ongoing Desert Tortoise Telemetry Around Culverts project (Ecocentric 2021).

Study recommendations include examination of factors that may contribute to the difference in the density of tortoise populations between US-93 and US-95, such as topography, vegetation, soil characteristics, highway noise, and annual precipitation. Future studies might also examine variables that influence tortoise movement through or near culverts such as culvert type, vegetation cover near culverts, or ease of accessing culvert entrances. These data could inform design and placement of culverts in tortoise habitat and increase safety for animals using the crossings (Ecocentric 2021).

3.5.4 Mojave Desert Tortoise Connectivity Data Analysis

The DCP contracted a study that incorporated data and results from the Mojave Desert Tortoise Connectivity Data Analysis study (Ecocentric 2021), along with unpublished camera crossing data (prepared by S. Cambrin with Clark County DCP, BLM, and USFWS) to better understand the direct use of culverts and the indirect effects of a fenced highway and connectivity culverts on a tortoise population. The study area consists of US-93 and US-95 in northern Clark County (Heron Ecological 2022).

The key results of the data analysis are summarized below (Heron Ecological 2022):

- Abundance of tortoises differed markedly on either side of highway culverts. Plots along US-95 that have large box culverts had desert tortoise abundance consistently and significantly higher on the south side of the highway than the north side, for all plots that had tortoises. Plots along US-93 that have cylindrical culverts had no consistent variation of desert tortoise abundance along or on either side of the highway.
- Culverts did not appear to equalize tortoise abundance across the highway.
- Culverts did function as connectivity conduits, supported by camera and GPS data.
- The connectivity benefit of culverts was positively related to disparity in abundance on either side of the highway, suggesting benefits related to dispersal rather than regular movement.
- Tortoises were more likely to switch to, and stay in, resting states when nearer to the highway.
- Behavioral state switching (between movement and resting) and maintenance may be a mechanical effect behind the indirect impact of highways on tortoise populations.
- Future culverts would be best placed in locations with disparate abundances on either side of the road, with the recognition that indirect road effects may reduce, but not eliminate, the connectivity benefits of culverts.

3.5.5 Desert Tortoise Connectivity Modeling

The DCP contracted a study to predict Mojave desert tortoise genetic connectivity in Clark County, Nevada. The study used forward-in-time simulation within an individually-based framework and three landscape scenarios: (1) no habitat disturbance, (2) current levels of habitat disturbance, and (3) future projections of habitat disturbance given by development scenarios currently under consideration. The study quantified the genetic effects of current and planned habitat disturbance on populations through time and searched for what constitutes corridor success by investigating the shared characteristics of corridors expected to maintain genetic connectivity for tortoises into the future (Dutcher et al. 2019).

Below is a summary list of the primary study results (Dutcher et al. 2019):

- Connectivity improves with corridors and higher desert tortoise densities.
- Anthropogenic disturbance reduces gene flow and population size.
- Corridor success is dependent on landscape.

Results of the study indicate that current and planned activities related to economic and urban growth will result in desert tortoise population declines and loss of genetic connectivity (Dutcher et al. 2019).

A summary of management recommendations from the study are listed below (Dutcher et al. 2019):

- Conduct more critical evaluation of proposed developments and reduction of anthropogenic disturbance in Mojave desert tortoise habitat.
- Prioritize landscapes with high levels of genetic connectivity for conservation to ensure additional habitat is not lost.
- Consider strategically restoring habitat and connectivity linkages in landscapes with intermediate genetic connectivity.
- Consider major reductions in planned development and improvements to habitat in already disturbed areas in landscape scenarios that fail to maintain genetic connectivity.

3.5.6 Desert Tortoise Connectivity Simulations

The DCP contracted a study to use movement data from local GPS-tagged desert tortoises to populate multi-state random walk models to approximate tortoise movements. The study used connectivity layers as the basis for movement simulations to understand the potential for long-term use of culverts under US-95 in northwest Clark County. Movement paths of hypothetical desert tortoises were simulated across a heterogeneous landscape resistant to movement and in relation to an impermeable (fenced) highway with permeable corridors (culverts) (Alta Science and Engineering 2022).

As part of the study, 15 adult resident tortoises (9 males and 6 females) were captured and GPS-tagged. Measurements of each tortoise were taken and movement patterns were tracked. Data were used to estimate the number of simulated tortoises and their movements. Simulations were repeated 1,000 times and results were evaluated based on the number of times a tortoise crossed the road under two densities of culverts, the existing density (7 culverts, 0.56 culverts per mile) and a higher density (28 culverts, 2.58 culverts per mile). Two culvert widths were also evaluated, 24-inch culverts (smallest within the study area) and 72-inch (largest within the study area). The number of culverts and culvert sizes resulted in four crossing scenarios (Alta Science and Engineering 2022):

1) Seven 24-inch culverts
2) Seven 72-inch culverts
3) Twenty-eight 24-inch culverts
4) Twenty-eight 72-inch culverts

Below is a summary list of the primary study results (Alta Science and Engineering 2022):

- One GPS-tagged tortoise of the 15 captured used a single culvert as a connectivity pathway across US-95 (crossing once and returned a month and a half later). Most GPS-tagged tortoises did not approach within 500 meters of a culvert, and those that approached within 500 meters did not approach within 150 meters.
- Simulated tortoises crossed the highway at lower rates compared to GPS-tagged tortoises (simulated tortoises were randomly started within the same 800-meter plots as captured tortoise).
- Simulated tortoises crossed a combination of high-density (28 culverts) wide culverts (72 inches) 150 percent more times than the combinations of twenty-eight 24-inch culverts, seven 72-inch culverts, or seven 24-inch culverts. Simulations showed that increasing culvert density and/or width would increase culvert use under a random walk scenario.
- The lack of crossing of culverts by GPS-tagged tortoises demonstrated that culvert use is not likely a random event, as random wandering of simulated tortoises did not result in as many encounters or increased culvert use.
- Desert tortoise use of culverts is likely related to other cues than simple random walking within a heterogeneous landscape. It is possible that large-scale tortoise movements (e.g., exploration, territory defense, or mate seeking) may drive encounters with the highway and subsequent use of the culverts, beyond what was captured in the stimulated local heterogeneous landscape.

A summary of management implications from the study are listed below (Alta Science and Engineering 2022):

- When planning for infrastructure and conservation of desert tortoise populations, transportation planners and wildlife managers should consider the densities and widths of culverts used in road improvements projects.
- Higher culvert densities and wider culverts were associated with higher crossing rates of simulated tortoises, indicating that connectivity across highways for desert tortoises would benefit from increasing the density and/or width of under-highway culverts. Transportation retrofits are recommended to seek to maximize culvert densities and sizes where possible.
- Transportation retrofits or enhancements of existing culverts should include installing new culverts of increased size, placing additional culverts at key locations where good habitat for crossing occurs (e.g., along desert washes), or locating culverts at more frequent intervals based on the home range size of tortoises.
- More research is needed to determine the optimum number and effective width of culverts from both an economic and biological standpoint, which would facilitate safe, cost-efficient crossings while minimizing the potential for habitat fragmentation and population isolation and loss.

3.5.7 Desert Tortoise Connectivity Solutions Modeling

The DCP contracted a study that used individual (also known as agent-based) modeling to attempt to provide a more realistic approach to understanding the potential for the Mojave desert tortoise to maintain connectivity in light of disturbance on the landscape associated with urbanization and other anthropogenic impacts and features on the landscape. The study modeled connectivity of tortoise populations within areas of fragmented habitat to better understand the possible influences of anthropogenic disturbance on genetic connectivity and population demographics within areas of Clark County differentially impacted by anthropogenic activities and barriers to movement by modeling movement, mating, mortality, and population genetics (Nussear et al. 2022).

This study simulated gene flow across complex landscapes using resistance surfaces from large areas of Clark County to evaluate multiple barrier scenarios. Areas predicted to fail to maintain genetic connectivity based on low connectivity index scores determined by previous studies (Dutcher et al. 2019) were incorporated. Simulations were run forward-in-time for 100 years using overlapping generations and realistic parameters for tortoise movement, mating, and mortality derived from empirical studies. Demographic and genetic patterns were predicted from simulation output to better understand the consequences of specific actions. The studies overarching goals were as follows (Nussear et al. 2022):

- Develop a model suitable for appropriate landscape scale analysis.
- Use the model to discern which factors most affect connectivity at specific locations and which available solutions best alleviate the stress of human land use disturbances.

The study identified six areas for analysis across Clark County, which were chosen to achieve maximal areas of relatively discrete tortoise habitat that likely have minimal gene flow between them, based on hydrological units, and that were also tenable for analysis given computational limitations. The six study areas are listed below (Nussear et al. 2022) and shown on Figure 3-7:

- Ivanpah Valley
- Lake Mead Area
- North Area
- Northwest Area
- Pahrump/Trout Canyon Area
- Piute-Eldorado Valleys

The simulation scenarios evaluated for each study area included the following (Nussear et al. 2022):

- No Barrier: landscape with no anthropogenic disturbance based only on the habitat model to create a 100-year reference for an unimpeded landscape.
- Simple Barrier: Roadways, solar facilities, and railways were considered to be barriers to movement with all available culverts closed; however, unintended barrier crossovers were infrequent, but possible.
- Culvert 1: Roadways and railways were considered barriers relative to traffic loads with culverts assigned values from zero to 80 percent passable.
- Culvert 2: Roadways, railways, and culvert values followed Culvert 1 scenario except in the Ivanpah Valley where culverts along a section of I-15 were given values of 80 percent passable.
- Culvert 3: Roadways and railways followed culvert 1 scenario, but were ranked based on their current state (e.g. many are not tied into the fencing and are otherwise impassable) current and predicted urbanization and solar development were included.
- Open culverts: Roadways and railways were considered barriers relative to traffic loads with all culverts assigned a value of 80 percent passable.

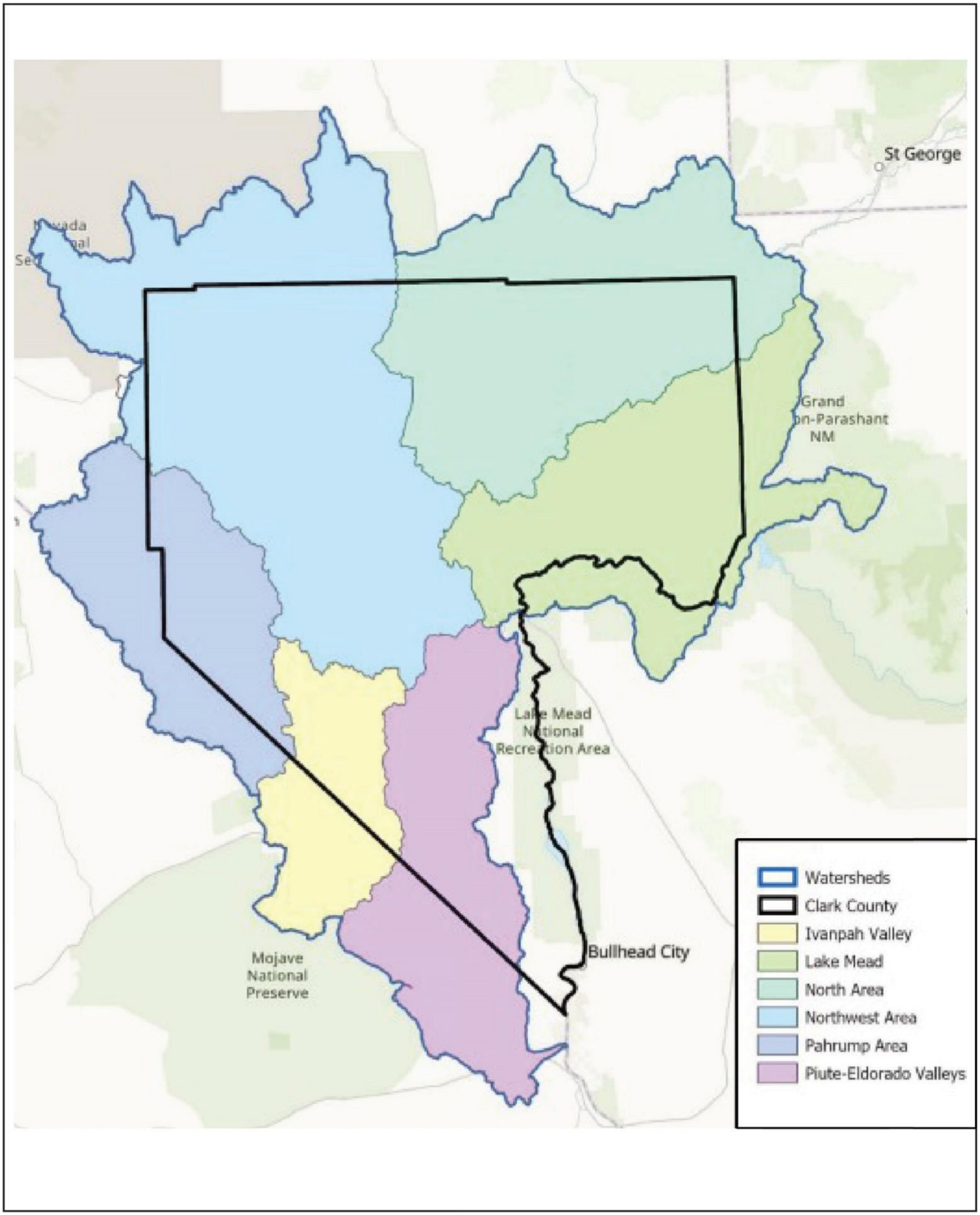

FIGURE 3-7
Six Study Areas within Clark County from the Desert Tortoise Connectivity Solutions Modeling Project (Nussear et al. 2022)

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The key takeaways for each area are summarized below (Nussear et al. 2022; Scott Cambrin, DCP Senior Biologist, personal communication March 9, 2022).

Ivanpah Valley Area: Within this area, the results indicated that habitat loss may have a greater impact on desert tortoise connectivity than linear features on the landscape. Results also indicated that when populations in isolated zones become small enough, genetic differentiation was detectable within the scope of 100-year simulations. I-15 and railroad tracks create a barrier that limits east to west movement of desert tortoises in the northern portion of the Ivanpah Valley. The number of culverts tortoises would need to cross to facilitate movement is probably more than is feasible over time and none of the scenarios modeled showed much movement in these areas outside of the null/no barrier model. In addition, the expansion of urbanization with the planned airport and surrounding development south of Las Vegas would remove some of the opportunities for tortoise connectivity, even though connectivity is currently extremely low to nonexistent in the current state. However, there is a possibility to restore north-south connectivity through Ivanpah Valley by increasing movement corridors across some of the smaller roads in the area and reconnecting the desert tortoise Large Scale Translocation Site to the surrounding area.

Lake Mead Area: Within this area, urban growth was predicted to be minimal and primarily affect the northern portion of the area. The results for this area indicate that urbanization and linear barrier effects are relatively small but weakly apparent. The majority of barriers to tortoise movement in the Lake Mead area are natural barriers in the form of rivers which limit the need for actions to reconnect connectivity as it was limited in the first place. The one exception to this is Northshore Drive, which does not currently have tortoise fencing, allowing tortoises to move freely across the road but are subject to mortality on the road. Fencing will reduce some connectivity over time but may reduce mortality as well. Northshore Drive is a two-lane highway, however, the scenarios for tortoise population sizes did not differ noticeably between culvert and null scenarios. Given the effects of roads seen elsewhere, fencing of Northshore Drive would likely reduce tortoise mortality in the future.

North Area: Within this area, I-15 is a substantial barrier to desert tortoise movement and genetic exchange between the west and east sides of the interstate. The Muddy River is also a barrier to movement and genetic exchange east of I-15. The barrier scenarios showed significant reductions in connectivity that were most evident between the Mormon Mountains and Mesquite zones. Fencing remains a big issue in this section of Clark County with highways 168 and 169, and portions of I-15 and US-93, lacking fencing. These areas would see a potential increase in tortoise movement if the culverts were connected, with the exception of the Moapa area where I-15 on the northwest and the Muddy River on the northeast create barriers that significantly limit potential crossings. The Virgin River at the more northeast end of the area where it parallels I-15 may also provide a significant barrier to movement as well as the Muddy River and Meadow Valley Wash north of I-15.

Northwest Corridor Area: Within this area, there is substantial development predicted within the 100-year modeling scenario, with the zones closest to the Las Vegas metropolitan area showing the largest impacts, including reductions in tortoise population size. The study showed that connectivity would continue to be significantly reduced in the areas nearest to urbanization resulting in the complete isolation of some zones from one another and offspring from parents in adjacent zones decreasing with time. Large portions of the southern part of this section (Lake Las Vegas, Sloan, Blue

Diamond, East Las Vegas, and Spring Mountains) are either currently urbanized or are planned for current or future disposal by the BLM. This makes connectivity extremely limited under all but the no barriers scenario for the southern portion of this area. However, some room exists on the west side of Las Vegas to facilitate minimal connectivity going forward. There are many areas where fencing could be installed and all culverts should be checked to ensure they are connected to fencing to improve movement at the northern most portion of the Northwest Corridor area.

Pahrump/Trout Canyon Area: Within this area, the study showed that the Pahrump West zone (southern portion of the area) had increasing isolation from the Trout Canyon zone (northeast portion of the area) that could result in genetic isolation over time due to urban growth. Results indicate that maintaining connected culverts as safe passageways for desert tortoises across linear barriers in this area may be beneficial for connectivity. The biggest threat to tortoises in this area is large-scale solar, which could affect both overall numbers and connectivity. This area is under consideration to be converted to a Special Management Area under an amendment to the Clark County MSHCP, which could alleviate some of the pressure to the area related to solar development. Remaining connectivity would need to be restored by attaching culverts to tortoise exclusion fencing.

Piute-Eldorado Valley Area: Within this area, urban growth was predicted to be minimal. Existing roadways and barriers were shown in culvert scenarios to reduce connectivity among tortoise populations, which could indicate that maintaining passable culverts and minimizing development in the northern portion of the area may be most beneficial for connectivity. Scenarios showed that development has minimal impact on connectivity in this area, with the majority of development occurring in the northern most sections, primarily related to solar and energy development. It is possible that development could limit connectivity between the Piute-Eldorado, Northwest Corridor, and Lake Mead areas, therefore, connectivity monitoring over the long-term would be beneficial. Lower priority tortoise exclusion fence installations may help in some areas; however, the majority of connectivity would be helped by ensuring culverts are attached to tortoise exclusion fencing.

Chapter 4 Management Recommendations for the Desert Conservation Program

The goals and management recommendations in this DCP Connectivity Management Plan were derived or adapted from the Revised Recovery Plan for the Mojave Population of the Desert Tortoise (USFWS 2011), studies conducted for the DCP specific to desert tortoise connectivity, and other desert tortoise connectivity related research. Many of the management recommendations would require cooperation/coordination with NDOT prior to implementation.

Studies conducted for the DCP specific to desert tortoise connectivity also provide information on road segments modeled to improve connectivity and genetic diversity (Nussear et al. 2022).

The Desert Tortoise Transportation Ecology Task Force is working on a final report that will provide new and refined recommendations related to tortoise connectivity. The final report is due to be completed at the end of 2022 (Fairbank et al. 2021).

4.1 Install and Improve Culverts for Desert Tortoise Habitat Connectivity

4.1.1 Goal

The goal of improving existing culverts and installing culverts during road construction is to provide increased connectivity for Mojave desert tortoise within Clark County along major roadways. This management goal would also meet the USFWS Revised Mojave Desert Tortoise Recovery Plan (2011) recommendation of connecting functional habitat (Recovery Action 2.11).

4.1.2 Culvert Management Recommendations

Culvert-1: Maintain or modify existing connected culverts to ensure safe Mojave desert tortoise access (Averill-Murray et al. 2021). Specific maintenance and modification processes that may be used have been developed by the BLM Las Vegas Field Office (BLM 2022) and include the following:

- Annual inspection/monitoring of culverts for factors that could cause blockage during flooding and potentially lead to entrapment of desert tortoises.
- Repair of culverts where sedimentation, erosion, rip-rap, or other characteristics resulting in openings that are not accessible for tortoises or other wildlife. Modifications include the addition of concrete to place the bottom of culvert outlets level with the ground if they have become "perched" by erosion.
- Make culvert openings accessible to tortoises by ensuring adjacent portions of washes are passible. Rip-rap is a major obstacle (tortoises cannot traverse through rip-rap). Solutions include inserting locally sourced, smaller gravel/pebble infill between rip-rap boulders which would create a safe place for tortoises to traverse without becoming entrapped in crevices.

Culvert-2: Ensure tortoise exclusionary fencing is properly attached to culverts at the following locations starting by attaching all grade 1-3 culverts in the following preferred order (Nussear et al. 2022; Scott Cambrin, DCP Senior Biologist, personal communication March 9, 2022):

1. Piute-Eldorado Valley: US 95, State Hwy 164 (Nipton Rd), and Hwy 163
2. North Area: US 93, I-15, and the Union Pacific Railroad
3. Northwest Area: US 95
4. Ivanpah Area: State Highway 164 (Nipton Rd) and Good Springs rd
5. Trout Canyon Area: State Highway 160

Culvert-3: Fix passability issues associated with the grade 4-5 culverts associated with the locations called out in recommendation Culvert-2 above and attach to fencing where possible (Nussear et al. 2022; Scott Cambrin, DCP Senior Biologist, personal communication March 9, 2022).

Culvert-4: Focus culvert modification or construct new culverts specific for desert tortoise in areas modeled to improve connectivity and genetic diversity (Alta Science and Engineering 2022; Heron Ecological 2022):

- Consider culvert width and density (interval frequency). Higher culvert densities and wider culverts were associated with higher crossing rates of simulated tortoise (Alta Science and Engineering 2022).
- Consider different types of culvert installation, such as trenchless (e.g., pipe ramming, horizontal boring) or more traditional trench and cover techniques (which would depend on contracting, NDOT specifications, cost, etc.).

Culvert-5: Conduct herbicide or mechanical invasive vegetation treatments at culverts in areas that block tortoise access to culvert openings.

- Remove excess invasive vegetation, particularly Russian thistle (*Salsola tragus*), from existing culverts to make them passable for tortoises. Dead or live invasive plant material can be removed by hand and loaded into trash bags, a dumpster, or other container for transportation to a landfill. Once problem areas are identified by monitoring, herbicide treatments would be used to reduce the build-up of invasive vegetation at culvert openings.
- Attempt to restore native vegetation, such as hardy perennials, in areas treated for invasive species.

Culvert-6: Coordinate culvert and fencing management and monitoring with NDOT and BLM.

Culvert-7: Work with USFWS and NDOT to develop construction standards that are consistent with hydrologic/erosion management goals, which would also maximize the potential for tortoise survival and passage and make the standards widely available (Averill-Murray et al. 2021). The Desert Tortoise Transportation Ecology Task Force is currently working on this effort.

4.2 Install and Improve Desert Tortoise Fencing

4.2.1 Goal

The goal of installing and improving tortoise roadside barrier fencing is to connect or reconnect tortoise habitat to facilitate safe road passage at culvert entrances and exits. This management goal would also meet the USFWS Revised Mojave Desert Tortoise Recovery Plan (2011) recommendation of installing tortoise barrier fencing (Recovery Action 2.5). Focus areas would be areas modeled to improve connectivity and genetic diversity.

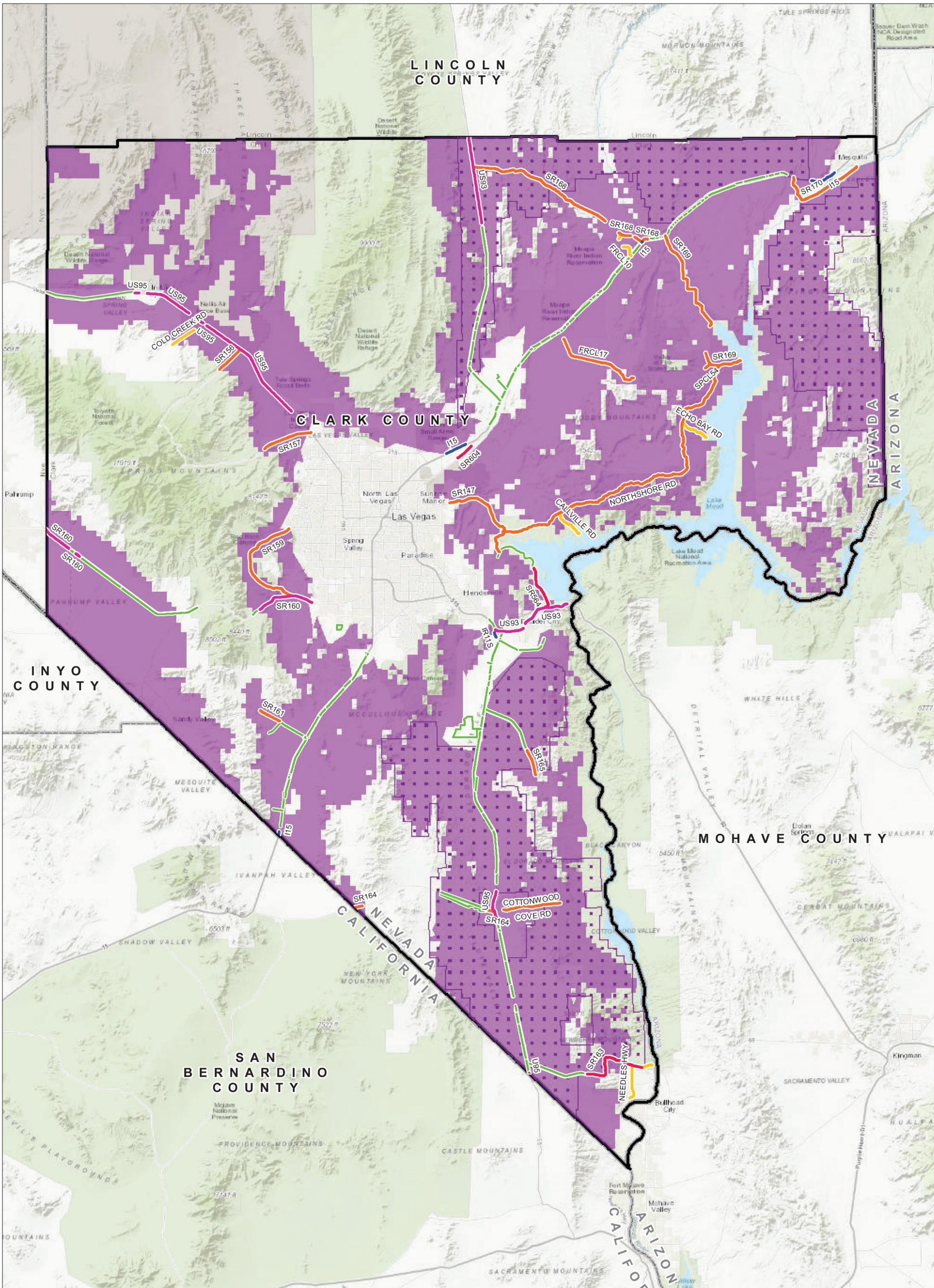
4.2.2 Fencing Management Recommendations

Fence-1: In coordination with NDOT, install roadside barrier fencing (tortoise exclusionary fencing) and ensure all fencing is connected to culverts to facilitate safe passage underneath roadways in areas identified as most important for maintaining connectivity and genetic diversity. The USFWS recommends extending existing tortoise exclusion fencing within Clark County along the roadways shown on Figure 4-1 and listed in Table 4-1 below.

Priority areas for fence extension/completion recommended by modeling (Nussear et al. 2022; Scott Cambrin, DCP Senior Biologist, personal communication March 9, 2022) include the following:

- State Highway 161 (Goodsprings Road) on the north and south side of the road to the town of Goodsprings in the Eldorado Valley Area
- State Highway 164 (Nipton Road) in the Ivanpah Valley Area
- Northshore Drive within the Lake Mead National Recreation Area in the Lake Mead Area
- Fenceless stretches of I-15 in the North Area
- US-95 to the border with Lincoln County in the North Area
- State Highway 168 and State Highway 169 within tortoise habitat in the North Area
- US-95 from Las Vegas to Indian Springs in the Northwest Corridor Area
- Unfenced portions of State Highways 156, 157, 159, and 160 in the Northwest Corridor Area
- US-93 and State Highways 163, 164 (east and west of Searchlight), and 165 that are not currently fenced but are within tortoise habitat in the Piute-Eldorado Valley Area

Fence-2: Install intermittent shade structures along the habitat side of fences to limit overheating of tortoises that may pace the fence (Averill-Murray et al. 2021; Peaden et al. 2017).



Planning Area

Existing Tortoise Fencing

Mojave Desert Tortoise Critical Habitat

Mojave Desert Tortoise Probable Habitat

USFWS Roadway Fencing Projects by Priority Ranking

- 1
- 3
- 4
- 5
- 6

FIGURE 4-1

U.S. Fish and Wildlife Service Recommended Roadway Fencing Project Areas

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Table 4-1 Roadways Recommended for Tortoise Exclusion Fencing by the USFWS by Priority Ranking		
Roadway Name	Fence Miles	Location within Clark County
Priority 1		
I-15	6.20	Four segments: Northeastern Clark County north of State Highway 170; Northern Clark County at State Highway 168; Central Clark County north of Las Vegas; Southern Clark County near California border
I-11 South	0.61	Central Clark County south of US-93
Priority 3		
State Highway 160	11.62	Three Segments: Two segments in western Clark County near Nye County border; West-central Clark County west of Las Vegas
US-93	20.52	Three segments: Northern Clark County south of Lincoln County border; Two segments in Eastern Clark County east of Las Vegas near Arizona border
US-95	26.29	Six segments: Four segments in northwestern Clark County; Southern Clark County near Searchlight; Southern Clark County at California border
Priority 4		
State Highway 163	9.26	Southern Clark County
State Highway 564	5.59	Eastern Clark County east of Las Vegas north of US-93
State Highway 604	2.21	Central Clark County north of Las Vegas
Priority 5		
Cottonwood Cove Road	7.05	Southern Clark County
FRCL17	11.03	Northeastern Clark County
Northshore Road	44.58	Eastern Clark County east of Las Vegas
State Park Route/Clark County 54	0.78	Eastern Clark County north of State Highway 169
State Highway 147	9.62	Central Clark County east of Las Vegas
State Highway 156	3.62	Western Clark County south of US-95
State Highway 157	6.18	Western Clark County north of Las Vegas
State Highway 159	14.32	West-central Clark County west of Las Vegas
State Highway 161	2.68	Southwestern Clark County east of Goodsprings
State Highway 164	2.05	Two segments: Southern Clark County near Searchlight; Southwestern Clark County at California border
State Highway 165	3.17	Southeastern Clark County east of US-95
State Highway 168	22.05	Three segments: Northern Clark County east of US-93; Two segments in Northeastern Clark County west of I-15
State Highway 169	19.55	Northeastern Clark County east of I-15
State Highway 170	11.24	Northeastern Clark County south of I-15 west of Arizona border
Priority 6		
Callville Road	3.73	West of Las Vegas
Cold Creek Road	3.23	Northwestern Clark County
Davis Dam Road	1.21	Southeastern Clark County
Echo Bay Road	3.64	Northeastern Clark County
Frontage Road/Clark County (FRCL) 10	1.89	Northern Clark County
Hidden Valley Road	0.62	Northern Clark County south of State Highway 168
Needles Highway	4.31	Southern Clark County south of State Highway 163
Source: Kerry Holcomb, USFWS personal communication		

Fence-3: Ensure that land inside tortoise-exclusion fences is not so degraded that it leads to degradation of tortoise habitat outside the exclusion areas (Averill-Murray et al. 2021).

- Encourage recolonization of native vegetation within and adjacent to fenced culverts.
- Where feasible, mow invasive plants inside road rights-of-way or treat with wildlife safe herbicide to limit the spread into adjacent tortoise habitat and minimize risk of wildfire (Averill-Murray et al. 2021).

Fence-4: Develop agreements with NDOT and other partners to contribute to the monitoring, repair, and maintenance of tortoise fencing along major road rights-of-way within Clark County.

- The USFWS Desert Tortoise Recovery Office is the lead in coordinating efforts throughout the range of the desert tortoise to identify and address tortoise/wildlife fence issues. These efforts include the establishment of interagency working groups that are developing new technical, fiscal, and cooperative approaches to fence management using information from new research in the field of transportation ecology.

4.3 Fire Prevention/Management in Desert Tortoise Habitat

4.3.1 Goal

The goal of fire prevention and management is to prevent the alteration of habitat and connectivity (especially reduced capacity to support tortoises that would compromise occupancy and viability of conservation areas and occupancy of linkages between conservation areas [i.e., as corridor dwellers]), reduce the spread of invasive plant species, and restore connectivity post-fire. This management goal would also meet the USFWS Revised Mojave Desert Tortoise Recovery Plan (2011) recommendation of connecting functional habitat (Recovery Action 2.11).

4.3.2 Fire Management Recommendations

Fire-1: Prepare a Fire Management Plan, which may include the following:

- Fire management goals and objectives
- Hazardous fuels monitoring
- Fire occurrence mapping
- Assessing fire effects
- Monitoring effectiveness of fuel treatments
- Coordination with federal, state, and local agencies related to wildfire management

4.4 Additional Modeling and Research Studies

4.4.1 Goal

The goal of additional modeling and research related to desert tortoise connectivity is to build upon and refine the research and modeling conducted to date as well as develop new models.

4.4.2 Additional Modeling and Research Studies Recommendations

Study-1: Conduct studies to examine variables that influence tortoise movement through or near culverts. These data could inform design and placement of culverts in tortoise habitat and increase safety for animals using the crossings (Ecocentric 2021). Studies may include analysis of the following variables:

- Culvert type
- Culvert width
- Culvert interval (density of culverts along a roadway)
- Vegetation cover near culverts
- Ease of accessing culvert entrances for tortoises

Study-2: Conduct studies to validate recent connectivity model results in the field. Validation studies could include the following (Conservation Science Partners 2021):

- Collection of tortoise movement data across Clark County for validation of existing models and use in future modeling efforts.
- Collection of data across larger gradients of terrain, vegetation, and climate characteristics to improve inference in future models.

Study-3: Conduct a study on the factors that may contribute to the difference in the density of desert tortoise populations between highways US-93 and US-95, such as topography, vegetation, soil characteristics, highway noise, and annual precipitation (Ecocentric 2021).

Study-4: Conduct a study to determine the optimum number and effective width of culverts from both an economic and biological standpoint, which would facilitate safe cost-efficient crossings while minimizing the potential for habitat fragmentation and population isolation and loss (Alta Science and Engineering 2022; Averill-Murray et al. 2021).

Study-5: Conduct a study on the effects climate change on desert tortoise habitat, distribution, and population connectivity (Averill-Murray et al. 2021).

Study-6: Conduct a study on the effects of large-scale fires, particularly within repeatedly burned habitat, on desert tortoise distribution and population connectivity (Averill-Murray et al. 2021).

Study-7: Conduct a study on the ability of solar energy facilities or similar developments to support tortoise movement and presence by leaving washes intact, leaving native vegetation intact whenever possible, managing weeds, and allowing tortoises to occupy the sites (Averill-Murray et al. 2021).

Study-8: Conduct a study that examines new proposed linear disturbances prior to and after development to determine effects to tortoise movements and how tortoise incorporate crossing structures post-development.

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