ARIZONA MISSING LINKAGES

Rincon – Santa Rita – Whetstone Linkage Design

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NORTHERN ARIZONA UNIVERSITY

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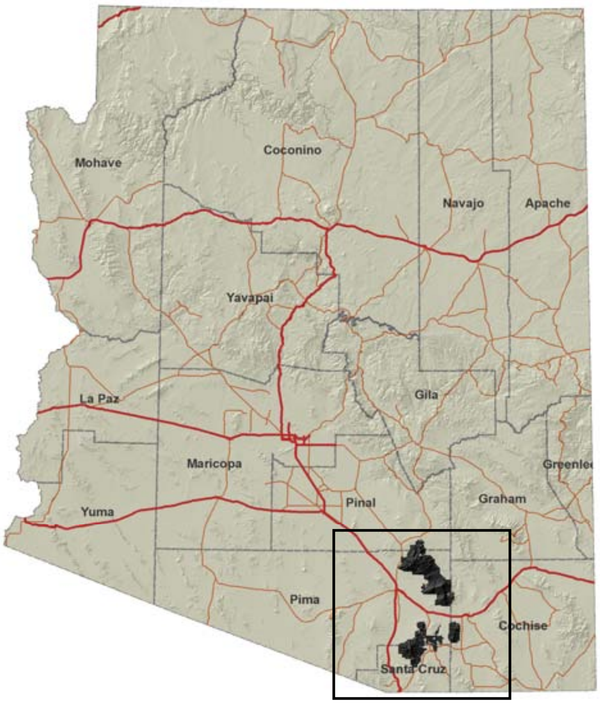
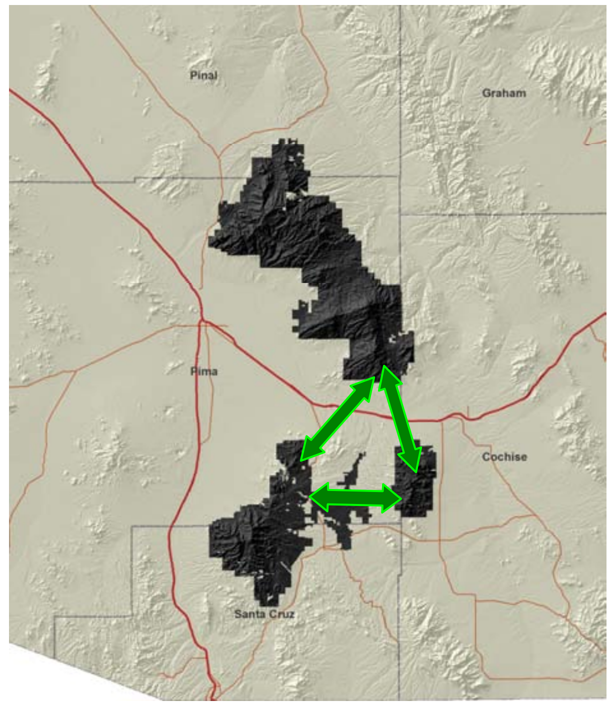
SANTA RITA – RINCON – WHETSTONE LINKAGE DESIGN





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This report is one of eight Linkage Designs being developed in 2006.

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Terminology

Key terminology used throughout the report includes:

Biologically Best Corridor: A continuous swath of land expected to be the best route for one focal species to travel from a potential population core in one protected Wildland block to a potential population core in the other protected wildland block. In some cases, the biologically best corridor consists of 2 or 3 *strands*.

Focal Species: Species chosen to represent the needs of all wildlife species in the linkage planning area.

Linkage Design: A continuous corridor of land which encompasses the biologically best corridors of all focal species and thus should – if conserved – maintain or restore the ability of wildlife to move between the *Wildland blocks*.

Linkage Planning Area: Includes the protected wildland blocks and the Potential Linkage Area. If the Linkage Design in this report is implemented, the biological diversity of the entire Linkage Planning Area will be enhanced.

Permeability: The opposite of travel cost, such that a perfectly permeable landscape would have a travel cost near zero.

Pixel: The smallest unit of area in a GIS map – 30x30 m in our analyses. Each pixel is associated with a vegetation class, topographic position, elevation, and distance from paved road.

Potential Linkage Area: The area of private and ASLD land between the wildland blocks, where current and future urbanization, roads, and other human activities threaten to prevent wildlife movement between the Wildland blocks. The *Linkage Design* would conserve a fraction of this area.

Travel Cost: Effect of habitat on a species' ability to move through an area, reflecting quality of food resources, suitable cover, and other resources. Our model assumes that habitat suitability is the best indicator of the cost of movement through the pixel.

Wildland Blocks: Large areas of publicly owned or tribal land expected to remain in a relatively natural condition for at least 50 years. These are the "rooms" that the Linkage Design is intended to connect. The value of these conservation investments will be eroded if we lose connectivity between them. Wildland blocks include private lands managed for conservation but generally exclude other private lands and lands owned by Arizona State Land Department (ASLD, which has no conservation mandate under current law). Although wildland blocks may contain non-natural elements like barracks or reservoirs, they have a long-term prospect of serving as wildlife habitat. Tribal sovereignty includes the right to develop tribal lands within a wildland block. In map legends in this report, the wildland blocks are labeled "Protected Habitat Blocks."

Executive Summary

Habitat loss and fragmentation are the leading threats to biodiversity, both globally and in Arizona. These threats can be mitigated by conserving well-connected networks of large wildland areas where natural ecological and evolutionary processes operate over large spatial and temporal scales. Large wildland blocks connected by corridors can maintain top-down regulation by large predators, natural patterns of gene flow, pollination, dispersal, energy flow, nutrient cycling, inter-specific competition, and mutualism. Corridors allow ecosystems to recover from natural disturbances such as fire, flood, and to respond to human-caused disturbance such as climate change and invasions by exotic species.

Arizona is fortunate to have vast conserved wildlands that are fundamentally one interconnected ecological system. In this report, we use a scientific approach to design a corridor (Linkage Design) that will conserve and enhance wildlife movement among three large areas of conserved wildlands, namely the Santa Rita Mountains Wildland block (including Las Cienegas National Conservation Area), the Rincon Mountains Wildland block and the Whetstone Mountains Wildland block. These three areas represent a massive public investment in biological diversity, and this Linkage Design is a reasonable step to maintain the value of that investment. This report will be followed by Linkage Designs for other areas in Arizona where connectivity is at risk.

To begin the process of designing this linkage, academic scientists, agency biologists, and conservation organizations identified 25 focal species that are sensitive to habitat loss and fragmentation, including 2 fish, 3 amphibians, 6 reptiles, 1 bird and 12 mammals (Table 1). These focal species cover a broad range of habitat and movement requirements. Some require huge tracts of land to support viable populations (e.g., mountain lion, badger, black bear). Some species are habitat specialists (e.g., Arizona gray squirrel, Gila topminnow, longfin dace, yellow-billed flycatcher), and others are reluctant or unable to cross barriers such as freeways (e.g. Coues white-tailed deer, mule deer, rattlesnakes, desert box turtle, coati). Others species, like the jaguar, need corridors to reoccupy former range. Some species are listed as threatened (Chirachua leopard frog) or endangered (Gila Topminnow), while others like javelina and porcupine are common but still need gene flow among populations. All the focal species are part of the natural heritage of this mosaic of Sonoran Desert and montane Sky Islands. Together, these 25 species cover a wide array of habitats and movement needs in the region, so that the linkage design should cover connectivity needs for other species as well.

To identify potential routes between existing protected areas we used GIS methods to identify a biologically best corridor for each focal species to move between the blocks of federally-protected habitat. We also analyzed the size and configuration of suitable habitat patches to verify that the final Linkage Design (Figure 1) provides live-in or move-through habitat for each focal species. Finally, we visited priority areas in the field to identify and evaluate barriers to wildlife movement. We used these observations to suggest strategies to mitigate those barriers, with special emphasis on opportunities to reduce the adverse effects of Interstate-10 and urbanization.

This linkage design connects 3 Wildland blocks, and the need for 3-way connectivity resulted in a final Linkage Design composed of multiple strands, ranging from approximately 12 to 22 km in length, which provide habitat for wildlife movement and reproduction. There are approximately 129 km (80 mi) of roads and railroads in the Linkage Design. Separating the Rincon wildland block from the Santa Rita, Las Cienegas, and Whetstone wildland blocks, Interstate 10 runs east-west through four of the six strands of the linkage, and is the single most important threat to connectivity. A large area of private land on the north side of the I-10 corridor is within commuting distance to Tucson. Future urban development in this area is the second greatest threat to connectivity in this area. Pima County and others have taken excellent progressive action to conserve lower Davidson Canyon and lower Cienega Creek, and to limit urbanization in other important linkage areas. We provide detailed mitigations in the section titled *Linkage Design and Recommendations*.

The ecological, educational, recreational, and spiritual values of protected wildlands in the Rincon-Santa Rita-Whetstone region are immense. Our Linkage Design represents an opportunity to protect a truly functional landscape-level connection. The cost of implementing this vision will be substantial—but reasonable in relation to the benefits and the existing public investments in protected wild habitat. If implemented, our plan would not only permit movement of individuals and genes between the Rincon, Whetstone, and Santa Rita Mountains, but should also conserve large-scale ecosystem processes that are essential to the continued integrity of existing conservation investments by the US Forest Service, Bureau of Land Management, Arizona State Parks, Arizona Game and Fish Department, U.S. Fish and Wildlife Service, and other conservancy lands.

Next Steps: This Linkage Design Plan is a science-based starting point for conservation actions. The plan can be used as a resource for regional land managers to understand their critical role in sustaining biodiversity and ecosystem processes. Relevant aspects of this plan can be folded into management plans of other agencies managing public lands. Other aspects can help transportation agencies design new project and take opportunities to upgrade existing structures. Regulatory agencies can use this information to help inform decisions regarding impacts on streams and other habitats. This report can also help motivate and inform construction of wildlife crossings, watershed planning, habitat restoration, conservation easements, zoning, and land acquisition. Implementing this plan will take decades, and collaboration among county planners, land management agencies, resource management agencies, land conservancies, and private landowners.

Public education and outreach is vital to the success of this effort – both to change land use activities that threaten wildlife movement and to generate appreciation for the importance of the corridor. Public education can encourage residents at the urban-wildland interface to become active stewards of the land and to generate a sense of place and ownership for local habitats and processes. Such voluntary cooperation is essential to preserving linkage function. The biological information, maps, figures, tables, and photographs in this plan are ready materials for interpretive programs.

Ultimately the fate of the plants and animals living on these lands will be determined by the size and distribution of protected lands and surrounding development and human activities. We hope this linkage conservation plan will be used to protect an interconnected system of natural space where our native biodiversity can thrive, at minimal cost to other human endeavors.

Table 1: Focal species selected for Rincon - Santa Rita - Whetstone Linkage

MAMMALS	AMPHIBIANS & REPTILES	BIRDS
Antelope Jackrabbit	Chiricahua Leopard Frog	Southwestern Willow Flycatcher
Arizona Gray Squirrel	Lowland Leopard Frog	
Badger	Sonoran Desert Toad	
Black Bear	Desert Box Turtle	**FISH**
Coues White-tailed Deer	Giant Spotted Whiptail	Gila Topminnow
Jaguar	Sonoran Whipsnake	Longfin Dace
Javelina	Black-tailed Rattlesnake	
Mountain Lion	Mexican Garter Snake	
Mule Deer	Tiger Rattlesnake	
Porcupine		
Pronghorn		
White-nosed Coati		

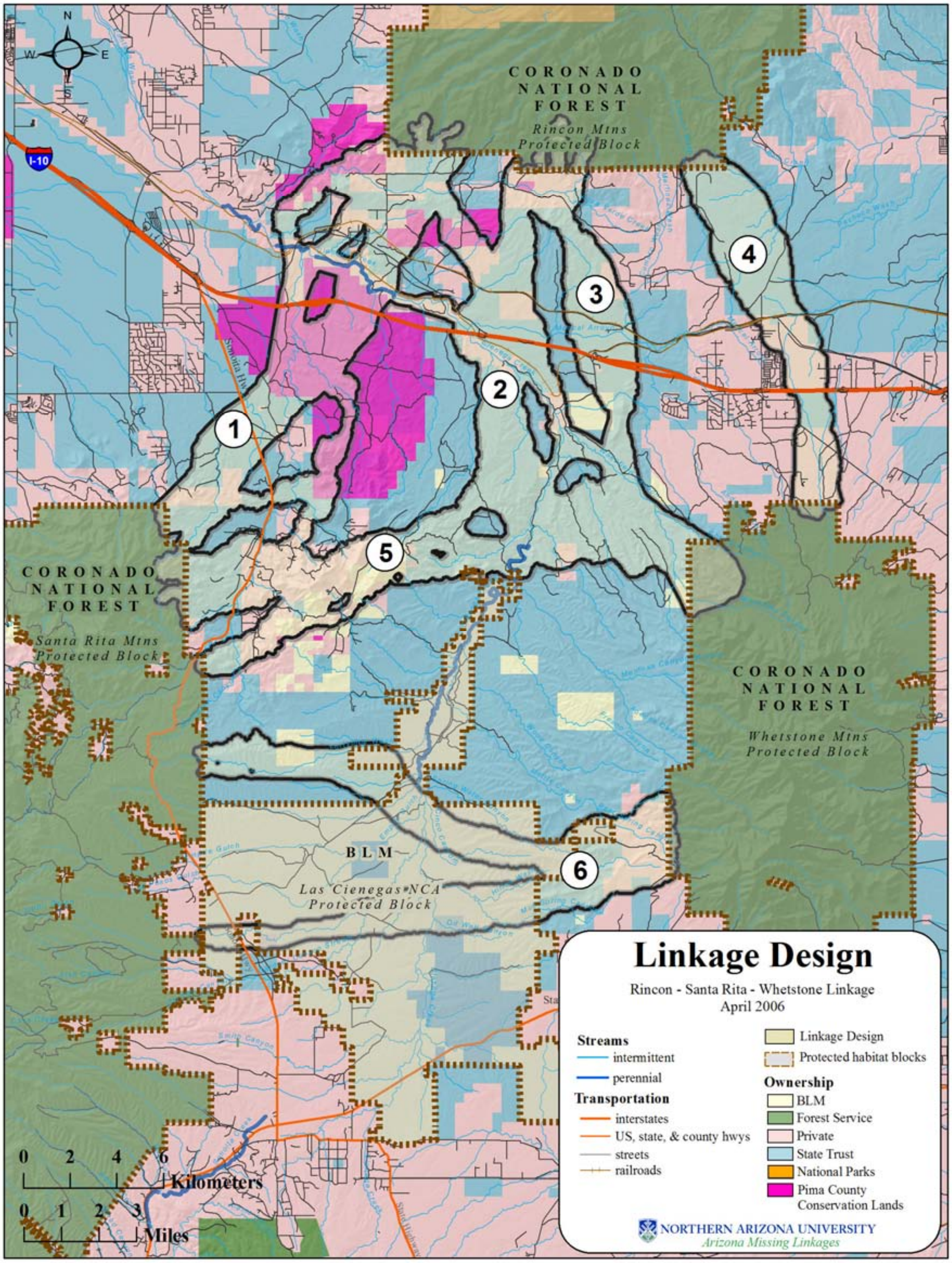

Figure 1: The Linkage Design between the Rincon, Santa Rita, and Whetstone Mountains is composed of six routes or strands, each of which is important to different species.

Introduction

Nature Needs Room to Move

Movement is essential to wildlife survival, whether it be the day-to-day movements of individuals seeking food, shelter, or mates, dispersal of offspring (e.g., seeds, fledglings) to new home areas, gene flow, migration to avoid seasonally unfavorable conditions, recolonization of unoccupied habitat after environmental disturbances, or shifting of a species' geographic range in response to global climate change.

In environments fragmented by human development, disruption of movement patterns can alter essential ecosystem functions, such as top-down regulation by large predators, gene flow, natural patterns and mechanisms of pollination and seed-dispersal, natural competitive or mutualistic relationships among species, resistance to invasion by alien species, and prehistoric patterns of energy flow and nutrient cycling. Without the ability to move among and within natural habitats, species become more susceptible to fire, flood, disease, and other environmental disturbances and show greater rates of local extinction (Soulé and Terborgh 1999). The principles of island biogeography (MacArthur and Wilson 1967), models of demographic stochasticity (Shaffer 1981, Soulé 1987), inbreeding depression (Schonewald-Cox et al. 1983; Mills and Smouse 1994), and metapopulation theory (Levins 1970, Taylor 1990, Hanski and Gilpin 1991) all predict that isolated populations are more susceptible to extinction than connected populations. Establishing connections among natural lands has long been recognized as important for sustaining natural ecological processes and biological diversity (Noss 1987, Harris and Gallagher 1989, Noss 1991, Beier and Noss 1998, Beier and Loe 1992, Noss 1992, Beier 1993, Forman 1995, Crooks and Soulé 1999, Soulé and Terborgh 1999, Penrod et al. 2001, Crooks 2001, Tewksbury et al. 2002, Forman et al. 2003).

Habitat fragmentation is a major reason for regional declines in native species. Species that once moved freely through a mosaic of natural vegetation types are now being confronted with a human-made labyrinth of barriers such as roads, homes, and agricultural fields. Movement patterns crucial to species survival are being permanently altered at unprecedented rates. Countering this threat requires a systematic approach for identifying, protecting, and restoring functional connections across the landscape to allow essential ecological processes to continue operating as they have for millennia.

A Statewide Vision

In April 2004, a statewide workshop called *Arizona Missing Linkages: Biodiversity at the Crossroads* brought together over 100 land managers and biologists from federal, state, and local agencies, academic institutions, and non-governmental organizations to delineate habitat linkages critical for preserving the State's biodiversity. Meeting for 2 days at the Phoenix Zoo, the participants identified over 100 Potential Linkage Areas throughout Arizona (Arizona Wildlife Linkage Workgroup 2006).

The workshop was convened by the Arizona Wildlife Linkage Workgroup, a collaborative effort led by Arizona Game and Fish Department, Arizona Department of Transportation, Federal Highways Administration, US Forest Service, Bureau of Land Management, US Fish and Wildlife Service, Sky Island Alliance, Wildlands Project, and Northern Arizona University. The Workgroup prioritized the potential linkages based on biological importance and the conservation threats and opportunities in each area (AWLW 2006). This Rincon-Santa Rita-Whetstone Linkage is one of these first 8 linkages.

Ecological Significance of the Rincon – Santa Rita – Whetstone Mountains Linkage

The Linkage Planning area lies within the Sky Island Ecoregion of southeastern Arizona and southwestern New Mexico. The Sky Islands are a complex of relatively small, isolated mountain ranges surrounded by lower elevation areas of desert scrub and grasslands that provide unique geological and topographic environments. These features make it one of the most biologically diverse landscapes in North America (Turner et al.1995). The Coronado National Forest, which manages most of the sky island mountain ranges in Arizona, harbors the greatest plant and animal diversity of any National Forest in the United States, totaling more than 2,000 plant species and 576 species of terrestrial vertebrates, including 78 mammals, over 400 birds, and over 60 reptiles (USFS 2005, McLaughlin 1992). Of these species, 175 are considered threatened, endangered or sensitive (USFS 2005).

Within the Sky Island ecosystem, the Linkage Planning Area includes three Wildland blocks: the Santa Rita Mountain Complex, the Whetstone Mountain Complex, and the Santa Catalina-Rincon Mountains Complex (Figure 2).

- The **northern wildland block** includes 2 major protected mountain ranges (the Rincon Mountains and the Santa Catalina Mountains), surrounding smaller mountain ranges, and adjacent protected desert and riparian wildlands. The Rincon Mountains extend for 27 km (17 mi), and rise to 8,600 feet at the top of Rincon Peak. This mountain range connects with the 54 km (28 mile) long Santa Catalina Mountain range, which includes Mt. Lemmon (9,157 feet) and the valuable riparian areas of the Tanque Verde, Sabino Canyon, Bear Creek, Willow Canyon, Rincon Creek, and Agua Verde Creek. Protected desert and riparian wildlands below the mountains add to the ecological resources of this wildland block, which we call the **Rincon Mountains Wildland block** for short.
- The **southwestern wildland block** (which we call the **Santa Rita Mountains Wildland block**) includes the Santa Rita Mountain Range which extends for 42 km (26 mi) and has the highest point of any of the surrounding sky islands at 9,453 feet. These mountains and their canyons such as Davidson and Gardner Canyons, are administered as part of the Coronado National Forest. Immediately to the east, the Las Cienegas National Conservation Area is a large expanse of semi-desert grasslands and rolling oak woodlands administered by the Bureau of Land Management. Las Cienegas NCA includes an important pronghorn population and southern Arizona's most spectacular desert grasslands; it is fed by runoff and springs from the Santa Ritas and Whetstones. As explained in Appendix A, for some species Las Ciengas NCA was treated as part of the Linkage Planning Area rather than part of the Santa Rita Wildland block.
- The **southeastern wildland block** (which we call the **Whetstone Mountains Wildland block**) is another Sky Island administered by the Coronado National Forest. These mountains extend for 18.5 km (11.5 mi), and rise to 7,711 feet at Apache Peak. Protected caverns, ephemeral springs, and canyons such as Wakefield Canyon provide valuable ecological resources. Runoff and springs from the Whetstones help replenish the Cienega watershed.

The Linkage Planning Area ranges from 2,300 feet elevation at the Santa Cruz River valley in Tucson to 9,453 feet at the peak of Mt. Wrightson in the Santa Rita Mountains. Paloverde-mixed cacti desert scrub, semi-desert grassland and steppe, and creosotebush/mixed desert and scrub communities dominate the lower elevations, rising to areas of mesquite upland scrub, chaparral, and bedrock cliff and outcrop. Higher elevations support encinal, pinyon-juniper, and pine-oak woodlands, with conifer-oak and aspen forest types (Figure 3). Riparian areas in the Linkage Planning Area include Cienega Creek, Davidson Creek, Wakefield Canyon, and Aqua Verde Creek.

The diverse vegetation in the Linkage Planning Area supports a diverse assemblage of animal species. Species listed as threatened or endangered by the U.S. Fish and Wildlife Service include the jaguar, Chiricahua leopard frog, lowland leopard frog, giant spotted whiptail lizard, Gila topminnow, and longfin dace (USFWS 2005). The Corridor Design incorporates and connects critical habitat needed for these species. The Linkage Planning Area is also home to far-ranging mammals such as black bears, javelina, pronghorn, Coues white-tailed deer, mountain lion, and badger. These animals move long distances to gain access to suitable foraging or breeding sites, and would benefit significantly from corridors that link large areas of habitat (Turner et al. 1995). Less-mobile species and habitat specialists such as antelope jackrabbits, white-nosed coati, and porcupines also need corridors to maintain genetic diversity, allow populations to shift their range in response to climate change, and promote recolonization after fire or epidemics. A corridor in this area is also essential to maintain the potential for jaguars to recolonize Arizona.

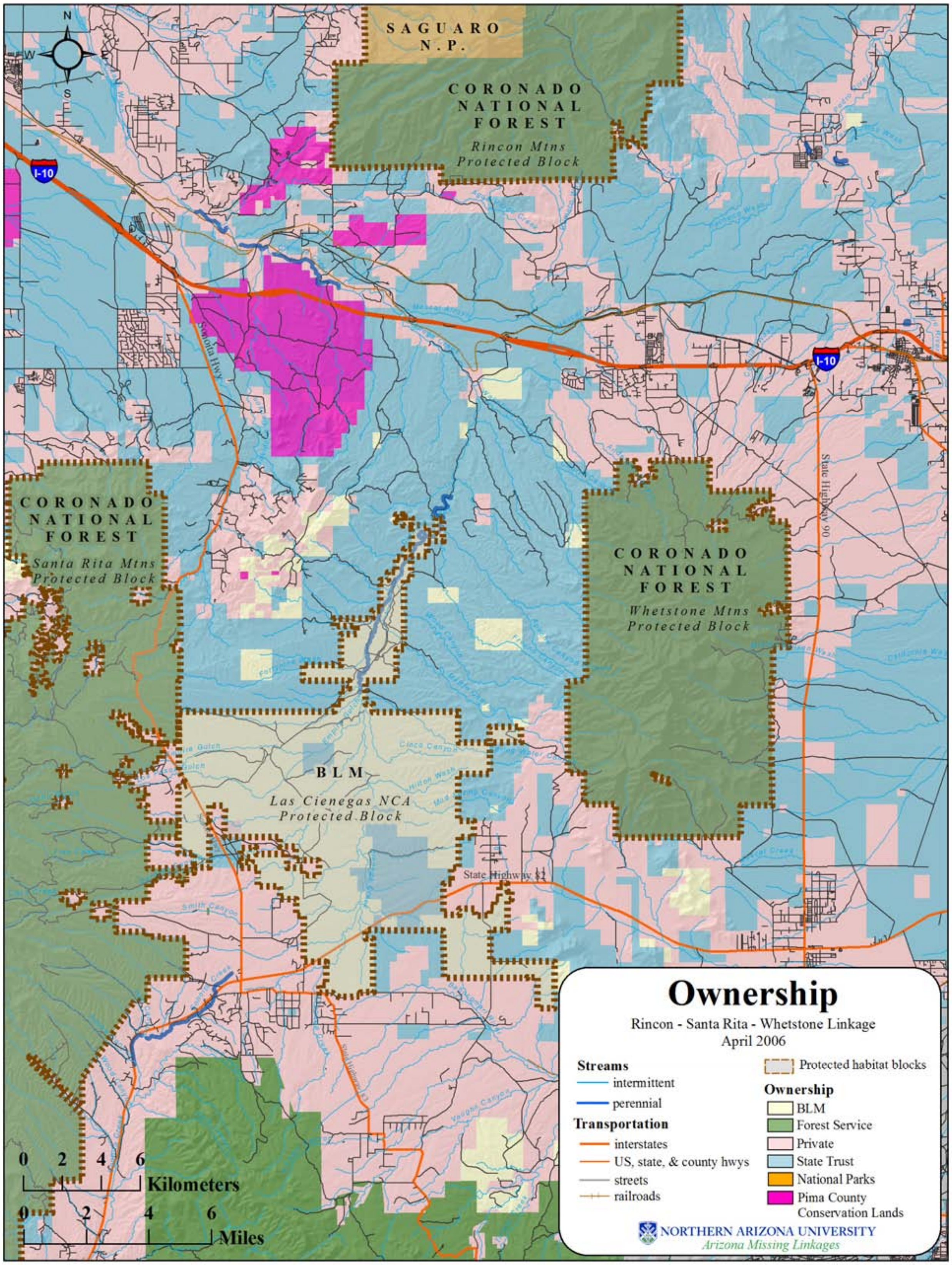

Figure 2: Land ownership within the Linkage Planning Area.

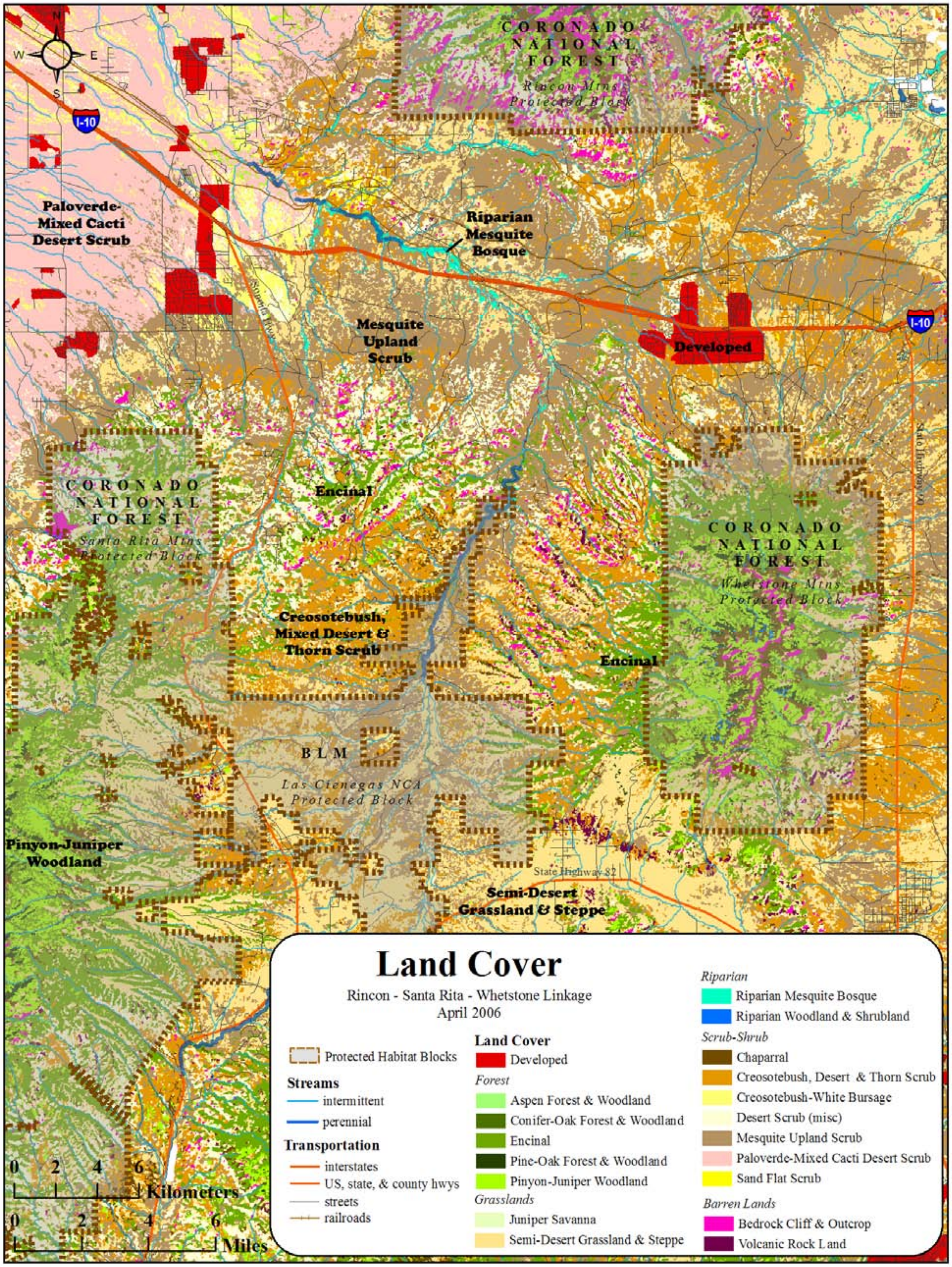

Figure 3: Land cover within the Linkage Planning Area.

Existing Conservation Investments

Large portions of the three wildland blocks are protected within the Coronado National Forest, which manages twelve sky-island mountain ranges totaling 1,780,000 acres in southeastern Arizona and southwestern New Mexico (USFS 2005).

The **Rincon Wildland block** includes many conservation investments:

- 260,000 acres of Coronado National Forest land in the Rincon and Santa Catalina Mountain Ranges, including two major wilderness areas: the Pusch Ridge Wilderness (56,933 acres in the Santa Catalina Mountains) and the Rincon Mountain Wilderness (38,590 acres in the Rincon Mountains and bordering Saguaro National Park - USFS 2005). This also includes two Forest Service Research Natural Areas, protected and maintained in natural conditions to conserve biological diversity, conduct non-manipulative research and monitoring, and foster education (USDA Forest Service 2005). The Santa Catalina Research Natural Area, encompassing 4,464 acres within the Pusch Ridge Wilderness, was the first designated Research Natural Area in the country. The 1,062-acre Butterfly Peak Research Natural Area is also in the Santa Catalina Mountains (USDA Forest Service 2005).
- 61,000 acres in Saguaro National Park East (National Park Service 2005, Pima County Arizona 2005), which recorded over 750,000 visitors in 2000. The park includes the 57,930 acre Saguaro Wilderness (National Park Service 2005).
- The renowned Sabino Canyon Recreation Area in the Santa Catalina Mountains, highly visited for its desert oases and bird-watching opportunities. Recognized as an Important Bird Area by National Audubon Society, Sabino Canyon and adjacent Lower Bear Creek attract over one million visitors a year (Tucson Audubon Society 2005).
- Catalina State Park, a 5,493 acre scenic desert park, managed by Arizona State Parks in cooperation with the U.S. Forest Service within the Coronado National Forest (Arizona State Parks 2005). The park helps connect Coronado National Forest land with Tortolita Mountain Park to the west.
- Tortolita Mountain Park is a 7,762 acre park owned by Pima County that protects one of the most important stands of saguaro cactus in the area from urban encroachment (The Nature Conservancy 2005, Pima Co. Arizona 2005). Many species of special concern are found here, including the Sonoran Desert Tortoise and the peregrine falcon (The Nature Conservancy 2005).
- Colossal Cave Mountain Park, on the southern end of the Rincon Mountains, is a 2,037 acre park managed by the Pima County Parklands Foundation, whose expansion by 18,974 acres has recently been suggested by the Sonoran Desert Conservation Plan (Pima Co, Arizona 2005). The Agua Verde and Posta Quemada Creeks flow through the park connecting with Cienega Creek Natural Preserve, providing an important biological link between the Cienega Creek riparian corridor and the Rincon-Santa Catalina Mountain Complex.
- Buehman Canyon Natural Preserve, 2,796 acres managed by The Nature Conservancy that links the northern Santa Catalinas to the San Pedro River Watershed (Pima Co, Arizona 2005). The Buehman Canyon Natural Preserve also serves as a reserve for the Gila topminnow and the desert pupfish, two rare southwestern native fish (Pima Co, Arizona 2005).
- The 284 acre Bingham Cienega Natural Preserve, a spring fed marsh land near the San Pedro River owned by Pima County's Flood Control District, and managed by The Nature Conservancy for restoration of sacaton grasslands, willow forests, and mesquite woodland (Pima Co. Arizona 2003). (This Preserve is too small to be depicted on our maps).
- Pima County's Roy Drachman Agua Caliente Park, a 101 acre wetland reserve, is a unique park with a perennial warm spring flowing into three large ponds that has attracted a wide variety of waterfowl and other wildlife species (Pima Co. Arizona 2005). (This Preserve is too small to be depicted on our maps).

- Rincon Valley Conservation Reserve, a proposed riparian reserve west of the Rincon Mountains that would protect 6,428 acres of State Trust Land along Rincon Creek from the threat of urbanization (Sonoran Institute 2005).

The **Santa Rita Mountains Wildland block** includes
- 137,000 acres of land in the Coronado National Forest. Wilderness areas include the 25,260-acre Mount Wrightson Wilderness and the proposed Santa Rita Mountain Park, which would preserve 10,703 acres of valuable natural resources and wildlife habitat (Pima Co. Arizona 2005).
- Madera Canyon on the western slopes of the Santa Ritas is internationally renowned for its 240 species of both common and rare birds (USFS 2005). The Madera Canyon Recreation Area, operated by the Nogales Ranger District, attracts thousands of birders to this area. The Audubon Society also recognizes the value of the Santa Rita Mountains for bird species by designating the mountain range as an Important Bird Area (Tucson Audubon Society 2005).
- 45,000 acres in Las Cienegas Natural Conservation Area, administered by the Bureau of Land Management. Las Cienegas NCA includes five of the rarest habitat types in the Southwest: cienegas (marshlands), cottonwood-willow riparian forests, sacaton grasslands, mesquite bosques, and semi-desert grasslands (National Landscape Conservation System Coalition, 2004). This important conservation area also provides flood prevention for the protection of the city of Tucson and surrounding communities (National Landscape Conservation System Coalition, 2004)[1].
- The Santa Rita Experimental Range and Wildlife Refuge is a 53,000 acre area to the west of the Santa Rita Mountains administered as a natural laboratory and preserve by the University of Arizona's College of Agriculture to better understand the unique desert grassland communities it incorporates.
- Davidson Canyon, designated as an Important Riparian Area by Pima County's Sonoran Desert Conservation Plan. Pima County has proposed that this riparian corridor be maintained as a Natural Preserve, protecting its extensive natural resources (Pima Co. Arizona 2005).
- The Nature Conservancy's Patagonia-Sonoita Creek Preserve, a riparian preserve that includes more than 850 acres, with another 500 acres protected through conservation easements and landowner agreements (The Nature Conservancy 2005).

The **Whetstone Mountains Wildland block** includes
- 44,400 acres of Forest Service land.
- Kartchner Caverns State Park, home to protected unique limestone caves operated by Arizona State Parks (Arizona State Parks 2005). Adjacent to this state park is a proposed conservation reserve known as the Kartchner Caverns Corridor, which would allocate 7,340 acres of desert scrub and riparian canyon State Trust lands for conservation purposes (Sonoran Institute 2005).

One major protected area lies in the Linkage Planning Area. The Cienega Creek Natural Preserve is a 3,979 acre preserve operated by Pima County that protects 12 miles of important riparian corridor surrounding Cienega Creek near Interstate 10. A proposal by the Sonoran Desert Conservation Plan suggests expansion of the preserve to protect an additional 7,293 acres (Pima Co. Arizona 2005).

Connectivity between these three valuable and protected Wildland blocks would help to provide the contiguous habitat necessary to sustain viable populations of sensitive and far ranging species in the sky islands of southeastern Arizona.

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[1] As explained in Appendix A, in estimating biologically best corridors for some species, Las Cienega NCA was sometimes treated as part of the Santa Rita wildland block, and sometimes treated as part of the linkage planning area.

Threats to Connectivity

Major potential barriers in the Potential Linkage Area include Interstate 10, State Highway 83, the Southern Pacific Railroad, and urban and suburban development along the I-10 corridor, which inhibit wildlife movement between the three Wildland blocks. Traffic by illegal migrants from Mexico, and by border security efforts to control that traffic, also affects this Potential Linkage Area. Although the linkage area is not directly affected by fencing, steel walls, and stadium lighting, it may increasingly be affected by low level overflights and 24-hour patrols on an expanding network of new roads (Vacariu 2005).

A commitment to preserving minimal viable habitats for both resident and migratory species within the Sky Islands is essential for maintaining this unique area's diverse natural heritage (Warshall 1995). Providing connectivity is paramount in sustaining such viable habitats. However, recent intensive and unsustainable human activities threaten to create barriers that sever natural connections and alter the functional integrity of this natural system. Creating linkages that overcome barriers to movement will ensure that wildlife in all three Wildland blocks and the potential linkage area will thrive there for generations to come.

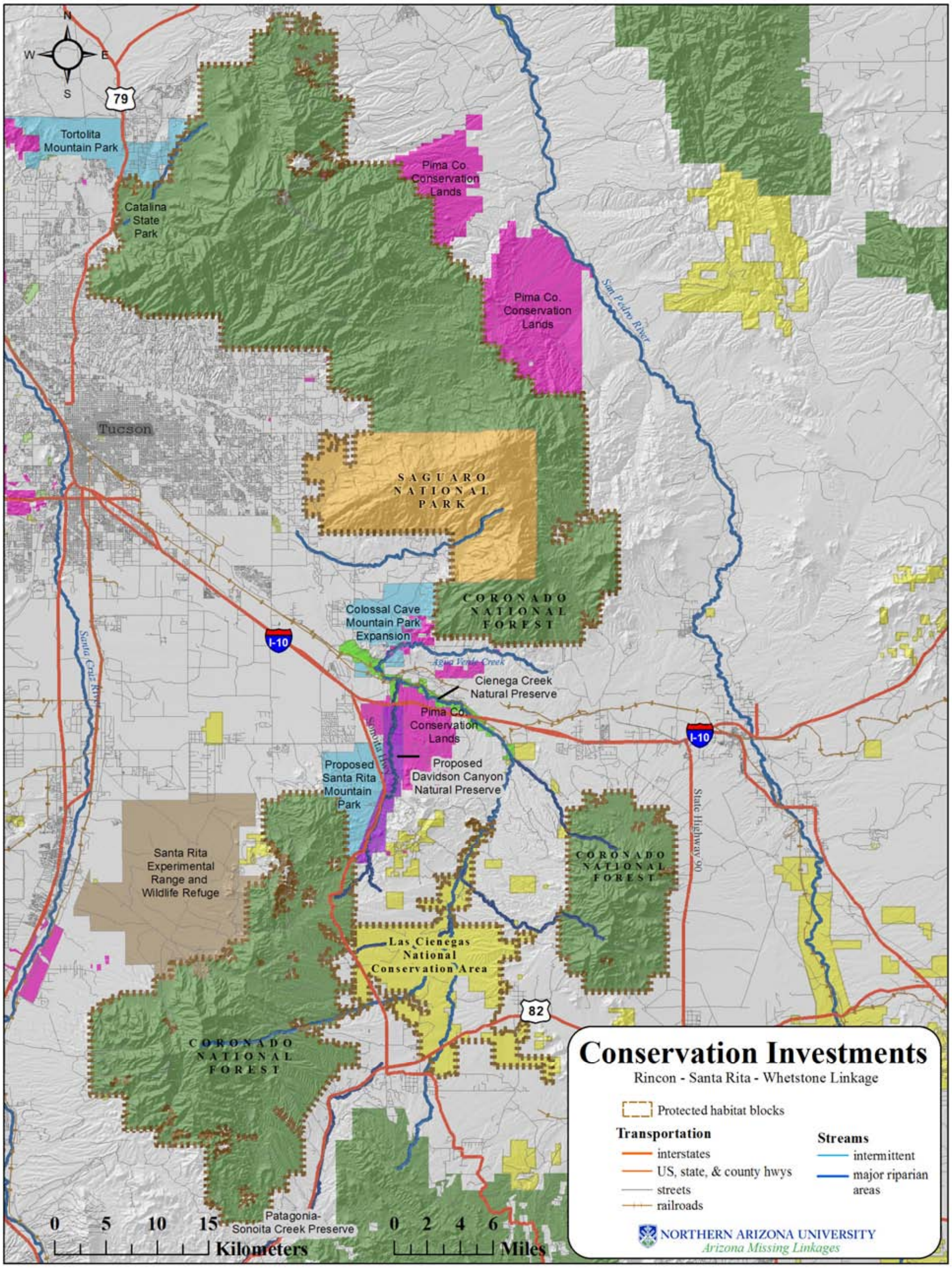

Figure 4: Existing conservation investments in Linkage Planning Area.

Linkage Design & Recommendations

This linkage design connects 3 Wildland blocks[2], and the need for 3-way connectivity resulted in a final Linkage Design (Figure 1, Figure 5 & Figure 6) composed of multiple strands, ranging from approximately 12 to 22 km in length, which provide habitat for movement and reproduction of wildlife between the three protected Wildland blocks. In this section, we describe the land cover and ownership patterns in the linkage design, and recommend mitigations for barriers to animal movement. The methods used to develop the linkage design are described in Appendixes A through C.

Six terrestrial routes provide connectivity across a diverse landscape

LINKAGE DESIGN GOALS
• Provide move-through habitat for diverse group of species • Provide live-in habitat for species with dispersal distances too short to traverse linkage in one lifetime • Provide adequate area for a metapopulation of corridor-dwelling species to move through the landscape over multiple generations • Provide a buffer protecting aquatic habitats from pollutants • Buffer against edge effects such as pets, lighting, noise, nest predation & parasitism, and invasive species • Allow animal movement in response to climate change

The linkage design between wildland blocks has multiple strands which join and diverge at multiple locations, much like a braided river channel or a network of washes in a flat desert landscape. To simplify description of the linkage design, we describe this network in terms of six major strands, labeled 1 through 6 in Figure 5.

Strand 1 runs from the northeastern border of the Santa Rita wildland block to the southwest border of the Rincon wildland block, and is primarily composed of mesquite upland scrub (42%), semi-desert grassland and steppe (18%), desert scrub (15%), and creosotebush, mixed desert and thorn scrub (14%). This strand is approximately 19 km long, and varies from 2.5 to 5 km wide. A distinct narrow (500 – 1,400 m) sub-strand parallels the main route, capturing rugged topography for species such as black-tailed rattlesnake. Important riparian features in strand 1 include approximately 8 km of Davidson Canyon and 6.7 km of Agua Verde Creek.

Strand 2 runs from the northern tip of Las Cienegas wildland block to the southern border of the Rincon wildland block, and is primarily composed of mesquite upland scrub (54.3%), semi-desert grassland and steppe (27%), desert scrub (9%), riparian mesquite bosque (4%) and creosotebush, mixed desert and thorn scrub (3%). This strand is approximately 14 km long (17 km long to northern tip of Las Cienegas wildland block), and varies in width from 1.5 to 2.3 km. Important riparian features include approximately 13 km of Cienega Creek, 4 km of Mescal Arroyo, and a portion of Wakefield Canyon.

Strand 3 connects the Whetstone and Rincon wildland blocks, and is composed of mesquite upland scrub (57%), creosotebush, mixed desert and thorn scrub (12%), desert scrub (11%), encinal (7%), and semi-desert grassland and steppe (7%). This strand is approximately 12-13 km long, and varies in width from 800 to 3,000 m. Important riparian features in strand 3 include a portion of Wakefield Canyon, 4 km of Agua Verde Creek, and 2 km of Anderson Canyon.

Strand 4 is composed of mostly flat topography between the Whetstone and Rincon wildland blocks, and 94% of the land within this route has a slope less than 10%. This stand is composed of a greater percentage of creosotebush, mixed desert and thorn scrub than the other strands (29%), as well as

[2] We connected only 2 wildland blocks in the other 7 linkage designs produced for Arizona Game and Fish Department in this 2005-2006 planning effort.

mesquite upland scrub (42%), semi-desert grassland and steppe (24%), and desert scrub (2%). This strand is approximately 15 km long, varies in width from 1.5 to 3.2 km.

Strand 5 connects the Santa Rita and Whetstone wildland blocks, and joins with strands 1, 2, and 3. This strand is composed of a much greater percentage of encinal than the other strands (24%), as well as desert scrub (26%), mesquite upland scrub (24%), semi-desert grassland and steppe (10%), creosotebush, mixed desert and thorn scrub (10%), and bedrock cliff and outcrop (2%). This strand is approximately 22 km long, and varies in width from 2.3 to 3.5 km. Strand 5 is topographically diverse (61% steep slopes), and contains important riparian features such as 5 km of Davidson Canyon, 4.5 km of Cienega Creek, 7 km of Wakefield Canyon, and 4 km of Cherry Canyon.

Strand 6 connects both the Santa Rita and Las Cienegas wildland blocks with the Whetstone wildland block. Approximately 50% of this strand runs through Las Cienegas National Conservation Area, and thus is already protected. This strand is composed of semi-desert grassland and steppe (34%), mesquite upland scrub (28%), creosotebush, mixed desert and thorn scrub (18%), encinal (15%), and desert scrub (3%). Riparian features in strand 6 include 8.5 km of Fortynine Wash, 2 km of Empire Gulch, 2 km of Gardner Canyon, 5.2 km of Cinco Canyon, 6.5 km of Spring Water Canyon, 2 km of Bear Spring Canyon, and 5 km of Mud Spring Canyon.

Land Ownership, Land Cover, and Topographic Patterns within the Linkage Design

The Linkage Design encompasses 85,000 acres (34,500 ha)[3] of land, and is composed of 57% state trust land, 24% private land, 13% Bureau of Land Management land, and 6% National Forest land (Figure 5). Eighteen natural vegetation communities account for nearly 99.5% of the land cover (Figure 6), and developed land accounts for approximately 0.5% of the land in the Linkage Design (Table 2). Natural vegetation is dominated by scrub-shrub associations, and has less forest vegetation than the vegetation found within the Rincon, Whetstone, and Santa Rita Wildland blocks. Riparian vegetation such as mesquite bosque accounts for 1% of the linkage design, but is particularly important where it occurs in long, relatively continuous band, such as in Strand 2 of the linkage design.

The Linkage Design captured a range of topographic diversity, providing for the present ecological needs of species, as well as creating a buffer against a potential shift in ecological communities due to future climate change. Within the Linkage Design, most land is classified as gentle or steep slopes, while approximately 7% of the land is classified as either canyon bottom or ridgetop. A wide range of slopes were captured, with strands 2 and 4 composed primarily of flat slopes, strands 1, 3, and 6 composed of flat and moderate slopes, and 61% of strand 5 composed of steep slopes . Every aspect category was represented in approximately equal proportions.

[3] This includes about 13,000 acres inside Las Cienegas National Conservation Area. If Las Cienegas is excluded, the Linkage Design encompasses approximately 72,190 acres (29,200 ha).

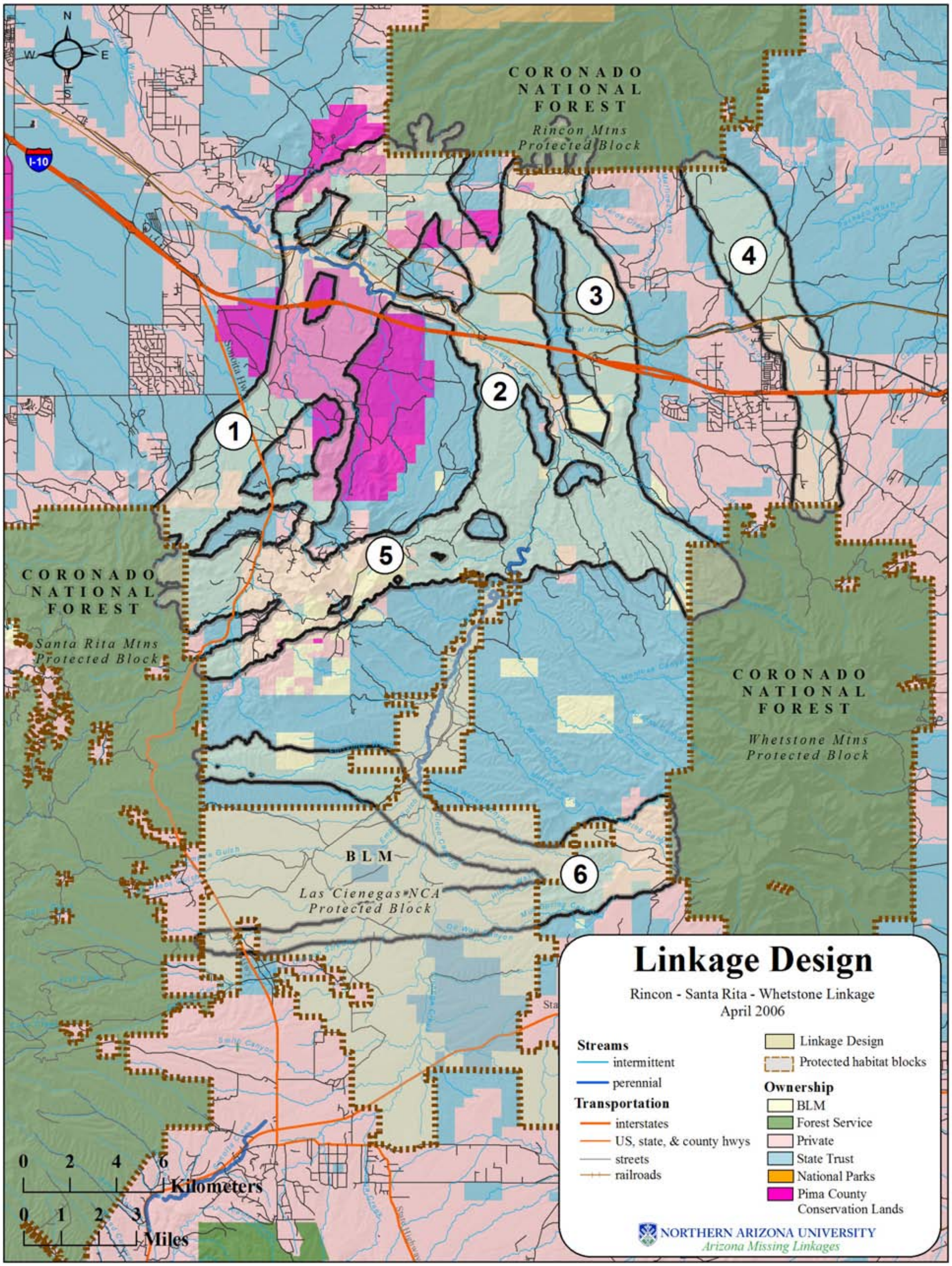

Figure 5: Property ownership and field investigation waypoints within Linkage Design. The accompanying CD-ROM includes photographs taken at most waypoints.

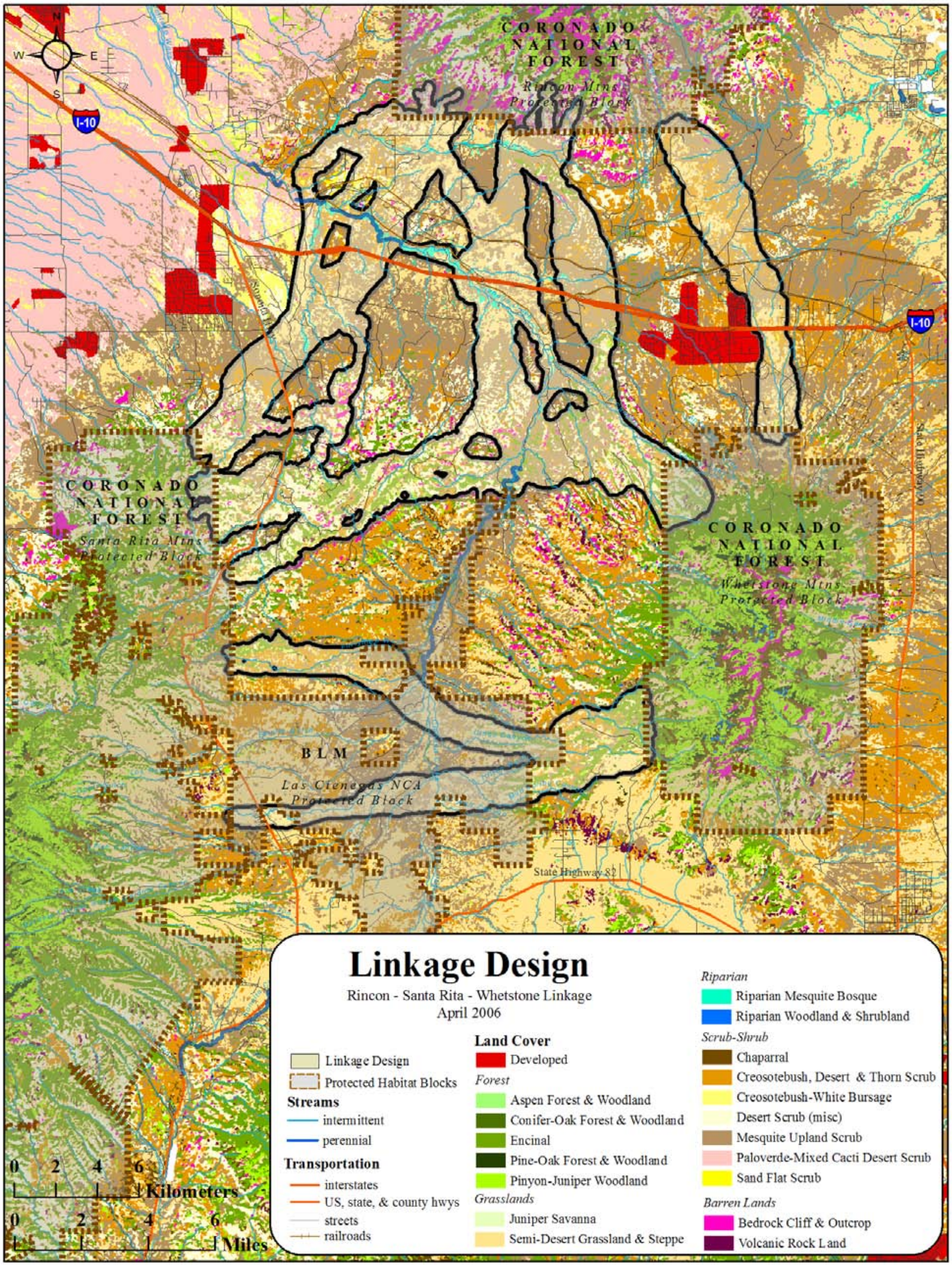

Figure 6: Land cover within Linkage Design.

Table 2: Approximate land cover within Linkage Design.

LAND COVER CATEGORY	ACRES	HECTARES	% OF TOTAL AREA
Evergreen Forest (10.6%)			
Encinal (Oak Woodland)	8461	3424	9.9%
Pine-Oak Forest and Woodland	12	5	<0.1%
Pinyon-Juniper Woodland	536	217	0.6%
Grasslands-Herbaceous (20.2%)			
Juniper Savanna	155	63	0.2%
Semi-Desert Grassland and Steppe	17033	6893	20.0%
Scrub-Shrub (65.7%)			
Chaparral	609	246	0.7%
Creosotebush, Mixed Desert and Thorn Scrub	11661	4719	13.7%
Creosotebush-White Bursage Desert Scrub	117	47	0.1%
Desert Scrub (misc)	10733	4343	12.6%
Mesquite Upland Scrub	32153	13012	37.8%
Paloverde-Mixed Cacti Desert Scrub	377	152	0.4%
Stabilized Coppice Dune and Sand Flat Scrub	312	126	0.4%
Woody Wetland (1.3%)			
Riparian Mesquite Bosque	1078	436	1.3%
Riparian Woodland and Shrubland	19	8	<0.1%
Emergent Herbaceous Wetland (<0.1%)			
Arid West Emergent Marsh	22	9	<0.1%
Barren Lands (1.7%)			
Bedrock Cliff and Outcrop	1249	505	1.5%
Volcanic Rock Land and Cinder Land	210	85	0.2%
Warm Desert Pavement	6	2	<0.1%
Developed and Agriculture (0.5%)			
Medium-High Intensity Developed	325	131	0.4%
Open Space-Low Intensity Developed	99	40	0.1%

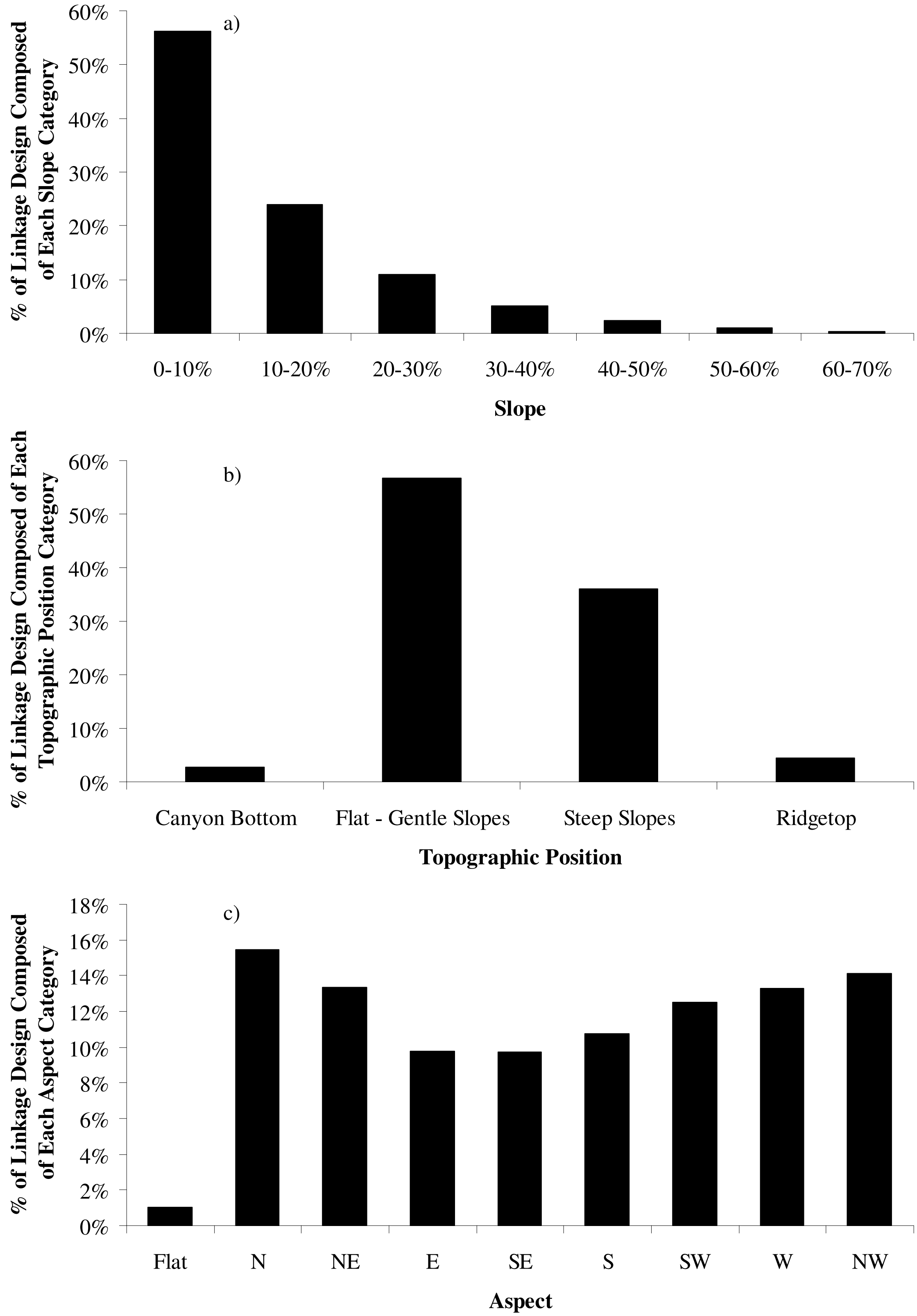

Figure 7: Diversity of slope (a), topographic position (b), and aspect (c) in the Linkage Design.

Removing and Mitigating Barriers to Movement

Although roads, rail lines, residential development, and streamflow impediments occupy only a small fraction of the Linkage Design, their impacts could block animal movement between the Wildland blocks. In this section, we review the potential impacts of these features on ecological processes, identify specific barriers in the Linkage Design, and suggest mitigation methods for these barriers. The complete database of our field investigations, including UTM coordinates and photographs, is provided in Appendix F and the Microsoft Access database on the CD-ROM accompanying this report.

Although roads, canals, and fences impede animal movement, and the crossing structures we recommend are important, we remind the reader that crossing structures are only part of the overall linkage design. To restore and maintain connectivity between the Rincon, Santa Rita and Whetstone Wildland blocks, it is essential to consider the *entire* linkage design, including conserving the land in the linkage. Indeed, investment in a crossing structure would be futile if habitat between the crossing structure and a Wildland block is lost.

Impacts of Roads on Wildlife

While the physical footprint of the nearly 4 million miles of roads in the United States is relatively small, the *ecological* footprint of the road network extends much farther. Roads impact plant and animal populations and movements in a number of ways, depending on the ecological characteristics of a given species. Direct effects of roads include road mortality, habitat fragmentation, habitat loss, and reduced connectivity (Figure 8). Direct **roadkill** affects most species, with severe documented impacts on wide-ranging predators such as the cougar in southern California, the Florida panther, the ocelot, the wolf, and the Iberian lynx (Forman et al. 2003). In a 4-year study of 15,000 km of road observations in Organ Pipe Cactus National Monument, Rosen and Lowe (1994) found an average of at least 22.5 snakes per km per year killed due to vehicle collisions. Although we may not often think of roads as causing **habitat loss**, a single freeway (typical width = 50 m, including median and shoulder) crossing diagonally across a 1-mile section of land results in the loss of 4.4% of habitat area for any species that cannot live in the right-of-way. Roads cause **habitat fragmentation** because they break large habitat areas into small, isolated habit patches which support few individuals; these small populations lose genetic diversity and are at risk of local extinction.

In addition to these obvious effects, roads create noise and vibration that interfere with ability of reptiles, birds, and mammals to communicate, detect prey, or avoid predators. Roads also increase the spread of exotic plants, promote erosion, create barriers to fish, and pollute water sources with roadway chemicals (Forman et al. 2003). Recent research also documents that roadway lighting has important impacts on animals (Rich and Longcore 2006).

Mitigation for Roads

Wildlife crossing structures that have been used in North America and Europe to facilitate movement through landscapes fragmented by roads include wildlife overpasses & green bridges, bridges, culverts, and pipes (Figure 9). While many of these structures were not originally constructed with ecological connectivity in mind, research has shown that a wide range of species benefit from them (Clevenger et al. 2001; Forman et al. 2003). No single crossing structure will allow all species to cross a road. For example rodents prefer to use pipes and small culverts, while bighorn prefer vegetated overpasses or open terrain below high bridges. A concrete box culvert may be readily accepted by a mountain lion or bear, but not by a deer or pronghorn.

Wildlife overpasses are most often designed to improve opportunities for large mammals to cross busy highways. Approximately 50 overpasses have been built in the world, with only 6 of these occurring in North America (Forman et al. 2003). Overpasses are typically 30 to 50 m wide, but can be as large as 200 m wide. In Banff National Park, Alberta, grizzly bears, wolves, and all ungulates (including bighorn sheep, deer, elk, and moose) prefer overpasses to underpasses, while species such as mountain lions prefer underpasses (Clevenger & Waltho 2005). Small mammals, such as deer mice and voles, have also been found to fare better in small culverts than on wildlife overpasses (McDonald & St Clair 2004).

Wildlife underpasses include viaducts, bridges, culverts, and pipes, and are often designed to ensure adequate drainage beneath highways. For ungulates such as deer that prefer open crossing structures, tall, wide bridges are best. Mule deer in southern California only used underpasses below large spanning bridges (Ng et al. 2004), and the average size of underpasses used by white-tailed deer in Pennsylvania was 15 ft wide by 8 ft high (Brudin 2003). Because most small mammals, amphibians, reptiles, and insects prefer cover for security, bridged undercrossings should extend to uplands beyond the scour zone of the stream, and should be high enough to allow enough light for vegetation to grow underneath. In the Netherlands, rows of stumps or branches under crossing structures have increased connectivity for smaller species crossing bridges on floodplains (Forman et al. 2003).

Drainage culverts can mitigate the effects of busy roads for small and medium sized mammals (Clevenger et al. 2001; McDonald & St Clair 2004). Culverts and concrete box structures are used by many species, including mice, shrews, foxes, rabbits, armadillos, river otters, opossums, raccoons, ground squirrels, skunks, coyotes, bobcats, mountain lions, black bear, great blue heron, long-tailed weasel, amphibians, lizards, snakes, and southern leopard frogs (Yanes et al. 1995; Brudin III 2003; Dodd et al. 2004; Ng et al. 2004). Black bear and mountain lion prefer less-open structures (Clevenger & Waltho 2005). In south Texas, bobcats most often used 1.85 m x 1.85 m box culverts to cross highways, preferred structures near suitable scrub habitat, and sometimes used culverts to rest and avoid high temperatures (Cain et al. 2003). Culvert usage can be enhanced by providing a natural substrate bottom, and in locations where the floor of a culvert is persistently covered with water, a concrete ledge established above water level can provide terrestrial species with a dry path through the structure (Cain et al. 2003). It is important for the lower end of the culvert to be flush with the surrounding terrain. Many culverts are built with a concrete pour-off of 8-12 inches, and others develop a pour-off lip due to scouring action of water. A sheer pour-off of several inches makes it unlikely that many small mammals, snakes, and amphibians will find or use the culvert.

Figure 8: Characteristics which make species vulnerable to the three major direct effects of roads (from Forman et al. 2003).

	EFFECT OF ROADS		
CHARACTERISTICS MAKING A SPECIES VULNERABLE TO ROAD EFFECTS	Road mortality	Habitat loss	Reduced connectivity
Attraction to road habitat	★		
High intrinsic mobility	★		
Habitat generalist	★		
Multiple-resource needs	★		★
Large area requirement/low density	★	★	★
Low reproductive rate	★	★	★
Behavioral avoidance of roads			★

Figure 9: Potential road mitigations (from left to right) include: highway overpasses, bridges, culverts, and drainage pipes. Fencing (lower right) should be used to guide animals into crossing structures.

Based on the small but increasing number of scientific studies on wildlife use of highway crossing structures, we offer these standards and guidelines for all existing and future crossing structures intended to facilitate wildlife passage. These recommendations are consistent with AGFD Guidelines for constructing culverts and passage (http://www.azgfd.gov/hgis/guidelines.aspx). In selecting focal species for this report, we solicited experts to identify threatened, endangered, and other species of concern as defined by state or federal agencies, paying attention to those with special needs for culverts or road-crossing structures. At the time of mitigation, we urge planners to determine if additional species need to be considered, and to monitor fish and wildlife movements in the area in order to determine major crossing areas, behaviors, and crossing frequencies. Such data can improve designs in particular locations and provide baseline data for monitoring the effectiveness of mitigations.

1) **Multiple crossing structures should be constructed at a crossing point to provide connectivity for all species likely to use a given area** (Little 2003). Different species prefer different types of structures (Clevenger et al. 2001; McDonald & St Clair 2004; Clevenger & Waltho 2005; Mata et al. 2005). For deer or other ungulates, an open structure such as a bridge is crucial. For medium-sized mammals, black bear, and mountain lions, large box culverts with a natural earthen substrate flooring are optimal (Evink 2002). For small mammals, pipe culverts from 0.3m – 1 m in diameter are preferable (Clevenger et al. 2001; McDonald & St Clair 2004).
2) **At least one crossing structure should be located within an individual's home range**. Because most reptiles, small mammals, and amphibians have small home ranges, metal or cement box culverts should be installed at intervals of 150-300 m (Clevenger et al. 2001). For ungulates (deer, pronghorn, bighorn) and large carnivores, larger crossing structures such as bridges, viaducts, or overpasses should be located no more than 1.5 km (0.94 miles) apart (Clevenger and Wierzchowski 2006, Mata et al. 2005). Inadequate size and insufficient number of crossings are two primary causes of poor use by wildlife (Ruediger 2001).
3) **Suitable habitat for species should occur on both sides of the crossing structure** (Ruediger 2001; Barnum 2003; Cain et al. 2003; Ng et al. 2004). This applies to both *local* and *landscape* scales. On a local scale, vegetative cover should be present near entrances to give animals security, and reduce negative effects such as lighting and noise associated with the road (Clevenger et al. 2001; McDonald & St Clair 2004). A lack of suitable habitat adjacent to culverts originally built for hydrologic function may prevent their use as potential wildlife crossing structures (Cain et al. 2003). On the landscape scale, "Crossing structures will only be as effective as the land and resource management strategies around them" (Clevenger et al. 2005). Suitable habitat must be present throughout the linkage for animals to use a crossing structure.
4) **Whenever possible, suitable habitat should occur *within* the crossing structure.** This can best be achieved by having a bridge high enough to allow enough light for vegetation to grow under the bridge, and by making sure that the bridge spans upland habitat that is not regularly scoured by floods. Where this is not possible, rows of stumps or branches under large span bridges can provide cover for smaller animals such as reptiles, amphibians, rodents, and invertebrates; regular visits are needed to replace artificial cover removed by flood. Within culverts, earthen floors are preferred by mammals and reptiles.
5) **Structures should be monitored for, and cleared of, obstructions such as detritus or silt blockages that impede movement.** Small mammals, carnivores, and reptiles avoid crossing structures with significant detritus blockages (Yanes et al. 1995; Cain et al. 2003; Dodd et al. 2004). In the southwest, over half of box culverts less than 8 x 8 ft have large accumulations of branches, Russian thistle, sand, or garbage that impede animal movement (Beier, personal observation). Bridged undercrossings only occasionally have similar problems.
6) **Fencing should never block entrances to crossing structures, and instead should direct animals towards crossing structures** (Yanes et al. 1995). In Florida, construction of a barrier wall to guide animals into a culvert system resulted in 93.5% reduction in roadkill, and also increased the total number of species using the culvert from 28 to 42 (Dodd et al. 2004). Fences, guard rails, and

embankments at least 2 m high discourage animals from crossing roads (Barnum 2003; Cain et al. 2003; Malo et al. 2004). Slick walls 1 m high can prevent amphibians and reptiles from entering roadways. One-way ramps on roadside fencing can allow an animal to escape if it is trapped on a road (Forman et al. 2003).

7) **Raised sections of road discourage animals from crossing roads, and should be used when possible to encourage animals to use crossing structures**. Clevenger et al. (2003) found that vertebrates were 93% less susceptible to road-kills on sections of road raised on embankments, compared to road segments at the natural grade of the surrounding terrain.
8) **Manage human activity near each crossing structure**. Clevenger & Waltho (2000) suggest that human use of crossing structures should be restricted and foot trails relocated away from structures intended for wildlife movement. However, a large crossing structure (viaduct or long, high bridge) should be able to accommodate both recreational and wildlife use. Furthermore, if recreational users are educated to maintain utility of the structure for wildlife, they can be allies in conserving wildlife corridors. At a minimum, nighttime human use of crossing structures should be restricted.
9) **Design culverts specifically to provide for animal movement**. Most culverts are designed to carry water under a road and minimize erosion hazard to the road. Culvert designs adequate for transporting water often have pour-offs at the downstream ends that prevent wildlife usage. At least 1 culvert every 150-300m of road should have openings flush with the surrounding terrain, and with native land cover up to both culvert openings, as noted above.

Existing Roads and Rail Lines in the Linkage Design Area

There are approximately 129 km (80 mi) of roads and railroads in the Linkage Design. Separating the Rincon wildland block from the Santa Rita, Las Cienegas, and Whetstone blocks, Interstate 10 runs east-west through four of the six strands of the linkage, and is the single most important threat to connectivity. Running north-south through strands 1 and 5 of the linkage, increased lanes or increased traffic on Sonoita Highway would threaten connectivity between the Santa Rita, and Whetstone Wildland blocks. Except for these two highways, the other roads in the linkage are local roads with relatively low traffic and traffic speed. Approximately 31.9 km (19.8 mi) of the Union Pacific Railroad runs through the linkage area. We conducted field investigations of many of these roads to document existing crossing structures that could be modified to enhance species movements through the area.

Table 3: Major transportation routes in the Linkage Design.

ROADNAME	KILOMETERS	MILES
Union Pacific Railroad	31.9	19.8
I-10	13.2	8.2
Sonoita Highway, State Route 83	8.3	5.1
Red Hill Ranch Rd	5.0	3.1
Yucca Farm Rd	4.9	3.0
Marsh Station Rd	3.8	2.3
Old Sonoita Hwy	3.6	2.2
Red Cloud Mine Rd	3.6	2.2
Mescal Rd	3.4	2.1
Agua Verde Rd	3.4	2.1
Hillton Ranch Rd	3.3	2.1
Old Rail Head	3.3	2.0
Desert Sanctuary Rd	3.0	1.9
Empirita Rd	2.9	1.8
Mesquite Mesa Pl	2.9	1.8
Total Wreck Ln	2.7	1.7
Frontage Rd	2.7	1.7
Salcido Rd	2.3	1.4
Davison Ranch Rd	2.0	1.2
Big Thunder Rd	1.9	1.2
Miller Ranch Rd	1.7	1.1
Tequilla Bend	1.7	1.0
Drive Way	1.7	1.0
Roads < 1 mi in Linkage Design	16.2	10.1
Total length of transportation routes	**129**	**80**

Existing Crossing Structures on I-10

Interstate 10 is the most significant road barrier to connectivity within the Linkage Design. The freeway crosses major drainages, including Cienega Creek and Davidson Canyon. Because every animal moving from the Santa Rita Wildland block, Las Cienegas National Conservation Area, or the Whetstone Wildland block to the Rincon block must traverse this highway, crossing structures along I-10 are crucial to success of the corridor. Within the linkage design, crossing structures have been built to accommodate stream flow from Cienega Creek and Davidson Canyon; however, most other structures are box or pipe culverts near the base of fill slopes that are not easily accessed by terrestrial animals. There are 2 large bridges and multiple small cement box culverts along I-10. We list them from west to east.

- A large multiple-span bridge crosses Davidson Canyon in Strand 1 of the linkage between the Santa Rita and Rincon wildland blocks (Figure 10). This crossing structure lies within the biologically best corridor for jaguar, Coues white-tailed deer, mountain lion, porcupine, and black-tailed rattlesnake, and habitat surrounding this crossing structure is potentially suitable for antelope jackrabbit, badger, javelina, mule deer, desert box turtle, Sonoran desert toad, tiger rattlesnake, and giant-spotted whiptail.

Figure 10: Looking east-southeast (azimuth 116) from waypoint 57, Davidson Canyon crosses I-10 via a large multiple-span bridge. See Figure 5 to locate this scene within the linkage design.

- There are small box or pipe culverts over minor unnamed washes at three other locations in Strand 1 (waypoints 54, 55, 56 on Figure 5), as well as at four other locations between Strands 1 and 2 of the linkage design (waypoints 50, 51, 52, 53).

- A large multiple-span bridge crosses Cienega Creek in Strand 2 of the linkage between the Las Cienegas and Rincon wildland blocks (Figure 11). This crossing structure lies within the biologically best corridor for antelope jackrabbit, and habitat surrounding this crossing structure is potentially suitable for badger, coati, jaguar, javelina, mountain lion, mule deer, porcupine, desert box turtle, Sonoran desert toad, Chiricahua leopard frog, giant spotted whiptail, lowland leopard frog, tiger rattlesnake, and Mexican garter snake.

Figure 11: Looking southeast (azimuth 132) from waypoint 49, Cienega Creek crosses I-10 via a large multiple-span bridge. See Figure 5 to locate this scene within the linkage design.

- There is a small box or pipe culvert over an unnamed wash at one location in Strand 3 (waypoint 45 on Figure 5), as well as at two other locations between Strands 3 and 4 of the linkage design between Whetstone and Rincon wildland blocks (waypoints 43, 44).

- In strand 4 of the linkage design, an unnamed wash crosses I-10 via 2 8x10 ft box culverts (Figure 12). This crossing structure lies within the biologically best corridor for antelope jackrabbit, jaguar, javelina, mountain lion, and mule deer.

Figure 12: Looking south from waypoint 40, an unnamed wash crosses I-10 in Strand 4 of the linkage design via 2 8x10 ft box culverts. See Figure 5 to locate this scene within the linkage design.

Recommendations for Interstate 10

While the existing bridges over Davidson Canyon and Cienega Creek are excellent crossing structures for all species, the remaining crossing structures are not adequate to serve the movement needs of the full suite of wildlife species that need to move between wildland blocks. We recommend upgrading the crossing structures described above as follows:

- In Linkage Strand 1 between Santa Rita and Rincon wildland blocks, one additional bridge should be installed to meet the recommendation of one large crossing structure per 1.5 km for large carnivores and ungulates (Clevenger and Wierzchowski 2006, Mata et al. 2005). This bridge could replace a current culvert (such as those found at waypoints 54, 55, and 56 on Figure 5), or in any other feasible location in the eastern half of Linkage Strand 1.

- One additional bridge should be installed in the center or eastern half of Linkage Strand 2 to facilitate movement of ungulates and large carnivores. Additionally, at least 3 culverts should be created in the eastern part of Strand 2 to facilitate movement of reptiles, amphibians, and smaller upland mammals.

- Replace the crossing structure in the center of Strand 3 between the Whetstone and Rincon wildland blocks (waypoint 45 on Figure 5) with a bridge or larger, more open culvert adequate for use by mountain lion, jaguar, and deer, and meeting the recommendations in the previous section. The existing railroad underpass on the western border of Strand 3 (waypoint 47 on Figure 5; Figure 13) may be sufficient as an secondary crossing location for large carnivores and ungulates in this strand, but is not as good as a bridged crossing without railroad tracks. To maximize usability of this location as a crossing structure for wildlife, we recommend maintaining vegetation adjacent to the bridge.

Figure 13: Top: Looking north from waypoint 47 on Figure 5 , a railroad crosses under I-10 on the western edge of Strand 3. Bottom: South of this point, natural vegetation dominates except near the rail line.

- One bridge should be installed in Strand 4 between the Whetstone and Rincon wildland blocks. This bridge could replace the existing culvert located on the western edge of Strand 4 (Figure 12) or be located elsewhere within the linkage strand.

Other roads within the Linkage Design

While Interstate 10 is the major transportation barrier to connectivity, State Route 83 (Sonoita Highway) lies between the Santa Rita Wildland block and other two Wildland blocks. Only moderate traffic now occurs on this 2-lane road, so it is not a major barrier today. However, if the road is widened or traffic increases significantly, it could become less permeable to wildlife. When road improvements are planned within a linkage strand (or within any publicly owned land), one bridged crossing for large mammals should be created per 0.9 miles of roadway, plus small pipe or box culverts approximately every 1/5 mile, as recommended in the section above, *Mitigation for Roads*.

The Union Pacific Railroad crosses through strands 1-4 of the linkage design. Large mammals can probably cross the rail line at many locations. To mitigate the impacts of the railroad on reptiles, amphibians, and small mammals, culverts should be placed at the intervals and design standards recommended above for highways.

Impediments to Streams in the Cienega Creek Riparian Corridor

Importance of Riparian Systems in the Southwest

Riparian systems are one of the rarest habitat types in North America. In the arid Southwest, about 80% of all animals use riparian resources and habitats at some life stage, and more than 50% of breeding birds nest chiefly in riparian habitats (Krueper 1996). They are of particular value in lowlands (below 5,000 feet) as a source of direct sustenance for diverse animal species (Krueper 1993). Cienega Creek, Agua Verde Creek, Davidson Canyon, Gardner Canyon, Apache-Montosa Canyon, Wakefield Canyon, and associated riparian vegetation are preferred habitat for many species in the linkage area, including chiricahua and lowland leopard frogs, sonoran desert toad, mexican garter snake, southwestern willow flycatcher, Gila topminnow, and longfin dace.

Stream Impediments in the Linkage Design Area

Most streams in Arizona have areas without surface water or riparian vegetation, and thus are naturally fragmented from the perspective of many wildlife species. But over 80% of riparian systems in the Southwest also have been altered by human activity (Stromberg 2000), often in ways that increase fragmentation. For animals associated with streams or riparian areas, impediments are presented by road crossings, vegetation clearing, livestock grazing, invasion of non-native species, accumulation of trash and pollutants in streambeds, farming in channels, and gravel mining. Groundwater pumping, upland development, water recharge basins, dams, and concrete structures to stabilize banks and channels change natural flow regimes which negatively impacts riparian systems. Increased runoff from urban development not only scours native vegetation but can also create permanent flow or pools in areas that were formerly ephemeral streams. Invasive species, such as bullfrogs and giant reed, displace native species in some permanent waters.

Mitigating Stream Impediments

Fortunately, few of these impediments affect the main streams in this area, and prompt action can maintain and enhance these functioning riparian systems. We endorse the following management recommendations for riparian connectivity and habitat conservation in the Linkage Planning Area:

1) **Retain natural fluvial processes** – Maintaining or restoring natural timing, magnitude, frequency and duration of surface flows is essential for sustaining functional riparian ecosystems (Shafroth et al. 2002, Wissmar 2004).
    - Do not issue permits for dams or diversions in Cienega Creek, Agua Verde Creek, Davidson Canyon, Gardner Canyon, Apache-Montosa Canyon, or Wakefield Canyon or their major

tributaries. If any such structures exist, consider removing them if they affect wildlife movement or reproduction (Hart et al. 2002).

- Upland development contributes to a "flashier" (more flood-prone) system. Currently residential development in the middle reaches of Davidson Canyon (Figure 17, Figure 18) is of only moderate density. Similarly, residential development on Cienega Creek occurs only in the lowest reaches, and most of it is very low density, but pockets of higher-density housing (Figure 14, Figure 16) are being built. If similar residential development occurs in these streams or their major tributaries, require small check dams to increase infiltration and reduce the impact of intense flooding (Stromberg 2000)].
- Maintain natural channel-floodplain connectivity—do not harden riverbanks and do not build in the floodplain (Wissmar 2004).
- Release of treated municipal waste water in some riparian corridors has been effective at restoring reaches of cottonwood and willow ecosystems. Habitat quality is generally low directly below the release point but improves downstream (Stromberg et al. 1993). However in an intermittent reach with native amphibians or fishes, water releases should not create perennial (year-round) flows. Non-native bullfrogs, crayfish, and mosquito fish can and do displace native amphibians and fishes from perennial waters (Kupferberg 1997, Kiesecker and Blaustein 1998, Maret et al. 2006).

2) **Promote base flows and maintain groundwater levels within the natural tolerance ranges of native plant species** – Subsurface water is important for riparian community health, and can be sustained more efficiently by reducing ground water pumping near the river, and providing municipal water sources to homes (Stromberg 1997, Colby and Wishart 2002). Cottonwood/willow habitat requires maintaining water levels within 9 feet (2.6 m) below ground level (Lite and Stromberg 2005).
3) **Maintain or improve native riparian vegetation** – Moist surface conditions in spring and flooding in summer after germination of tamarisk seeds selects for native cottonwood/willow stands against the invasive tamarisk (Stromberg 1997). Pumps within ½ mile of Cienega Creek or near springs should cease pumping in early April through May, or, if this is impossible, some pumped water should be spilled on to the floodplain in early April to create shallow pools through May (Stromberg 1997, Wilbor 2005). Large mesquite *bosques* should receive highest priority for conservation protection because of their rarity in the region (Stromberg 1992, Wilbor 2005).
4) **Maintain biotic interactions within evolved tolerance ranges**. Arid Southwest riparian systems evolved under grazing and browsing pressure from bison, deer and pronghorn antelope—highly mobile grazers and browsers. High intensity livestock grazing is a major stressor for riparian systems in hot Southwest deserts; livestock should thus be excluded from stressed or degraded riparian areas (Belsky et al. 1999), National Academy of Sciences 2002). In healthy riparian zones unstressed by other factors (e.g., drought, invasive species, unnatural flow regimes), grazing pressure should not exceed the historic grazing intensity of native ungulates (Belsky et al. 1999, Stromberg 2000).
5) **Eradicate non-native invasive plants and animals** – Hundreds of exotic species have become naturalized in riparian corridors, with a few becoming significant problems like tamarisk and Russian olive. Removing stressors and reestablishing natural flow regimes can help bring riparian communities back into balance, however some exotics are persistent and physical eradication is necessary to restore degraded systems (Stromberg 2000, D'Antonio and Meyerson 2002, Savage 2004).
6) **Where possible, protect or restore a continuous strip of native vegetation at least 200 m wide along each side of the channel**. Buffer strips can protect and improve water quality, provide habitat and connectivity for a disproportionate number of species (compared to upland areas), and provide numerous social benefits including improving quality of life for residents and increasing nearby property values (Fisher and Fischenich 2000, Parkyn 2004, Lee et al. 2004). Continuous corridors provide important wildlife connectivity but recommended widths to sustain riparian plant and animal communities vary widely (from 30 to 500 m) (Wenger 1999, Fisher and Fischenich 2000, Wenger and Fowler 2000, Environmental Law Institute 2003). At a minimum, buffers should capture the

stream channel and the terrestrial landscape affected by flooding and elevated water tables (Naiman et al. 1993). Buffers of sufficient width protect edge sensitive species from negative impacts like predation and parasitism. We therefore recommend buffer strips on each side of the channel at least 200 m wide measured perpendicular to the channel starting from the annual high water mark.

7) **Enforce existing regulations**. We recommend aggressive enforcement of existing regulations restricting dumping of soil, agricultural waste, and trash in streams, and of regulations restricting farming, gravel mining, and building in streams and floodplains. Restricted activities within the buffer should include OHV use which disturbs soils, damages vegetation and disrupts wildlife (Webb and Wilshire 1983).

Urban Development as a Barrier to Movement

Urban and industrial development, unlike roads, creates barriers to movement which cannot easily be removed, restored, or otherwise mitigated. Most large carnivores, small mammals, and reptiles cannot occupy these areas for a significant period of time, although some species occasionally occupy residential areas. While mapped urban areas only accounted for 0.5% of the land cover, residential development is increasing in some parts of the Linkage Design. A large area of private land on the north side of the I-10 corridor is within commuting distance to Tucson. Future urban development in this area is the second greatest threat (after I-10 itself) to connectivity in this area. Pima County and others have taken excellent progressive action to conserve lower Davidson Canyon and lower Cienega Creek, and to limit urbanization in other important linkage areas.

Urban Barriers in the Linkage Design Area

We documented three main locations of residential development in the linkage zone. While most of the residential development is unlikely to greatly impact wildlife movement, any future permits for development in the linkage area should consider potential impacts on wildlife and require appropriate mitigation for urban development in any strand of the linkage design.

- In Linkage Strand 1 north of I-10 and Cienega Creek, there is low-level residential development along Marsh Station Rd (Figure 14).

Figure 14: North of I-10 in Strand 1 of the Linkage Design, there is currently low-density residential housing along Marsh Station Rd (waypoint 65 on Figure 5). Azimuths of photos: 158 (top) and 208 (bottom).

- The village of Mescal Village forms the western border of Strand 4 of the Linkage Design between the Rincon and Whetstone Mountains (Figure 15 & Figure 16). Although Mescal's developed area is outside the Linkage Design, any eastward expansion of the village would threaten Strand 4.

Figure 15: The village of Mescal creates a barrier to the west of Linkage Strand 4 (waypoint 41, azimuth 300).

Figure 16: Looking south from waypoint 59 at the village of Mescal and the Whetstone Mountains beyond.

- There are several low-density residential developments in the Empire Mountains which may affect wildlife movement in Strand 5 between the Santa Rita and Whetstone Mountains (Figure 17) and near a sub-strand between Strands 1 and 5 (Figure 18).

Figure 17: Taken from the junction of Hilton Ranch Rd. & Sonoita Hwy, this photograph shows low-density residential development in the Empire Mountains (waypoint 30, azimuth 100) in Strand 5 of the Linkage Design.

Figure 18: There are 36 mailboxes for this small residential development in the Empire Mountains (waypoint 33, azimuth 106).

Mitigation for Urban Barriers

The most important step is to limit further residential and urban development in the linkage design. To conserve connectivity, we have the following recommendations for all existing and future urban, residential, and industrial developments in this linkage zone:

1) Discourage the conversion of natural areas within the Linkage Design into residential or urban areas. Where development is permitted, encourage small building footprints on large (> 10-acre) parcels.
2) Encourage conservation easements and land acquisition with willing land owners in the Linkage Design to protect important habitat.
3) Develop a public education campaign to inform those living and working within the linkage area about the local wildlife and the importance of maintaining ecological connectivity.
4) Encourage homeowners to focus outside lighting on their houses only, and never out into the linkage area.
5) Ensure that all domestic pets are kept indoors or in fenced areas outdoors.
6) Reduce vehicle traffic speeds in sensitive locations.
7) Encourage the use of wildlife-friendly fencing.
8) Discourage the killing of ‘threat’ species such as rattlesnakes.

Appendix A: Linkage Design Methods

Our goal was to identify a continuous corridor of land which – if conserved and integrated with underpasses or overpasses across potential barriers – will best maintain or restore the ability of wildlife to move between large protected Wildland blocks. We call this proposed corridor the *Linkage Design*.

To create the Linkage Design, we used GIS approaches to identify optimal travel routes for focal species representing the ecological community in the area[4]. By carefully selecting a diverse group of focal species and capturing a range of topography to accommodate climate change, the Linkage Design should ensure the long-term viability of all species in the protected areas. Our approach included six steps:

1) Select focal species.
2) Create a habitat suitability model for each focal species.
3) Join pixels of suitable habitat to identify potential breeding patches & potential population cores (areas that could support a population for at least a decade).
4) Identify the biologically best corridor (BBC) through which each species could move between protected core areas. Join the BBCs for all focal species.
5) Ensure that the union of BBCs includes enough population patches and cores to ensure connectivity.
6) Carry out field visits to identify barriers to movement and the best locations for underpasses or overpasses within Linkage Design area.

Focal Species Selection

To represent the needs of the ecological community within the potential linkage area, we used a focal species approach (Lambeck 1997). Regional biologists familiar with the region identified 23 species (Table 1) that had one or more of the following characteristics:

- habitat specialists, especially habitats that may be relatively rare in the potential linkage area.
- species sensitive to highways, canals, urbanization, or other potential barriers in the potential linkage area, especially species with limited movement ability.
- area-sensitive species that require large or well-connected landscapes to maintain a viable population and genetic diversity.
- ecologically important species such as keystone predators, important seed dispersers, herbivores that affect vegetation, or species that are closely associated with nutrient cycling, energy flow, or other ecosystem processes.
- species listed as threatened or endangered under the Endangered Species Act, or species of special concern to Arizona Game and Fish Department, US Forest Service, or other management agencies.

Information on each focal species is presented in Appendix B.

Habitat Suitability Models

We created habitat suitability models (Appendix B) for each species by estimating how the species responded to four habitat factors that were mapped at a 30x30 m level of resolution (Figure 19):

[4] Like every scientific model, our models involve uncertainty and simplifying assumptions, and therefore do not produce absolute "truth" but rather an estimate or prediction of the optimal wildlife corridor. Despite this limitation, there are several reasons to use models instead of maps hand-drawn by species experts or other intuitive approaches. (1) Developing the model forces important assumptions into the open. (2) Using the model makes us explicitly deal with interactions (e.g., between species movement mobility and corridor length) that might otherwise be ignored. (3) The model is transparent, with every algorithm and model parameter available for anyone to inspect and challenge. (4) The model is easy to revise when better information is available.

- *Vegetation and land cover.* We used the Southwest Regional GAP Analysis (ReGAP) data, merging some classes to create 46 vegetation & land cover classes, as described in Appendix D.
- *Elevation.* We used the USGS National Elevation Dataset digital elevation model.
- *Topographic position.* We characterized each pixel as ridge, canyon bottom, flat to gentle slope, or steep slope.
- *Straight-line distance from the nearest paved road or railroad.* Distance from roads reflects risk of being struck by vehicles as well as noise, light, pets, pollution, and other human-caused disturbances.

To create a habitat suitability map, we assigned each of the 46 vegetation classes (and each of 4 topographic positions, and each of several elevation classes and distance-to-road classes) a score from 1 (best) to 10 (worst), where 1-3 is optimal habitat, 4-5 is suboptimal but usable habitat, 6-7 may be occasionally used but cannot sustain a breeding population, and 8-10 is strongly avoided. Whenever possible we recruited biologists with the greatest expertise in each species to assign these scores (see *Acknowledgements*). When no expert was available for a species, three biologists independently assigned scores and, after discussing differences among their individual scores, were allowed to adjust their scores before the three scores were averaged. Regardless of whether the scores were generated by a species expert or our biologists, the scorer first reviewed the literature on habitat selection by the focal species[5].

This scoring produced 4 scores (land cover, elevation, topographic position, distance from roads) for each pixel, each score being a number between 1 and 10. We then weighted each of the by 4 factors by a weight between 0% and 100%, subject to the constraint that the 4 weights must sum to 100%, and added the 4 weighted scores to produce an overall habitat suitability score that was also scaled 1-10. We used these habitat suitability scores to create a habitat suitability map that formed the foundation for the later steps.

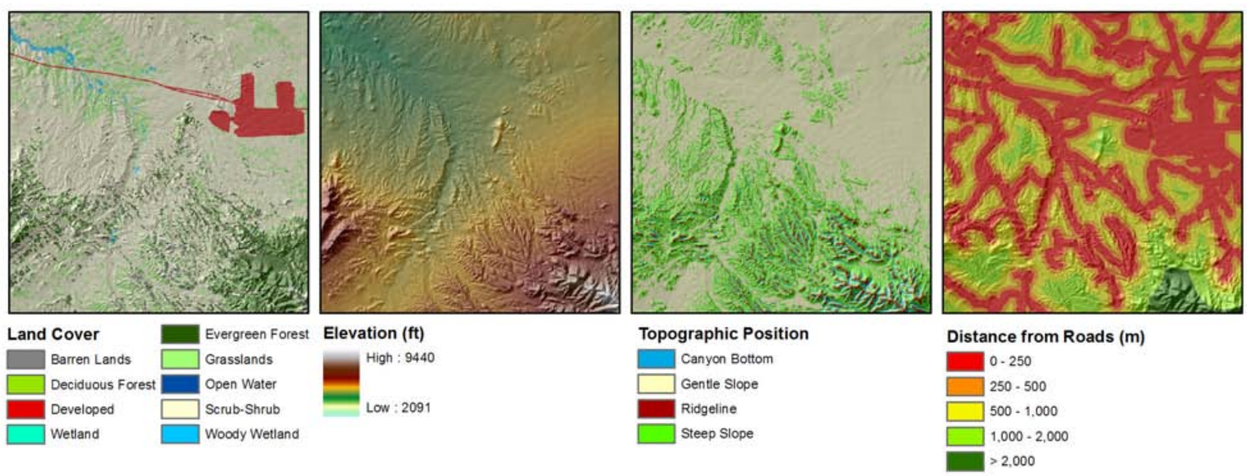

Figure 19: Four habitat factors used to create habitat suitability models. Inputs included land cover, elevation, topographic position, and distance from roads.

If necessary, we also used additional factors critical for a particular species, such as a minimum slope needed as escape terrain for bighorn sheep, or proximity to water for frogs. To create a habitat suitability model using critical features, we reclassified any pixel beyond a specified threshold distance from the critical feature as unsuitable for breeding (score > 5). This was accomplished using the equation:

New habitat score for pixel beyond threshold distance = (½ of original habitat score) + 5

5 Clevenger et al. (2002) found that literature review significantly improved the fit between expert scores and later empirical observations of animal movement.

Therefore, if a pixel of habitat located *beyond* the threshold distance from a critical feature had an original habitat score of 1 (optimal habitat), it received a reclassified score of 5.5 (usable, but not breeding habitat). Likewise, unsuitable habitat located outside of the threshold distance remained unsuitable: an original score of 9 would be reclassified as 9.5. All pixels of habitat *within* the threshold distance of a critical feature maintained their original habitat score.

Identifying Potential Breeding Patches & Potential Population Cores

The habitat suitability map provides scores for each 30x30-m pixel. For our analyses, we also needed to identify – both in the Protected Wildland blocks and in the Potential linkage area – areas of good habitat large enough to support reproduction. Specifically, we wanted to identify

- *potential breeding patches*: areas large enough to support a breeding unit (individual female with young, or a breeding pair) for one breeding season. Such patches could be important stepping-stones for species that are unlikely to cross a potential linkage area within a single lifetime.
- *potential population cores*: areas large enough to support a breeding population of the focal species for about 10 years.

To do so, we first calculated the suitability of any pixel as the average habitat suitability in a neighborhood of pixels surrounding it (Figure 20). We averaged habitat suitability within a 3x3-pixel neighborhood (0.81 ha) for less-mobile species, and within a 200-m radius (12.6 ha) for more-mobile species[6]. Thus each pixel had both a *pixel score* and a *neighborhood score*. Then we joined adjacent pixels of suitable habitat (pixels with neighborhood score < 5) into polygons that represented potential breeding patches or potential population cores. The minimum sizes for each patch type were specified by the biologists who provided scores for the habitat suitability model.

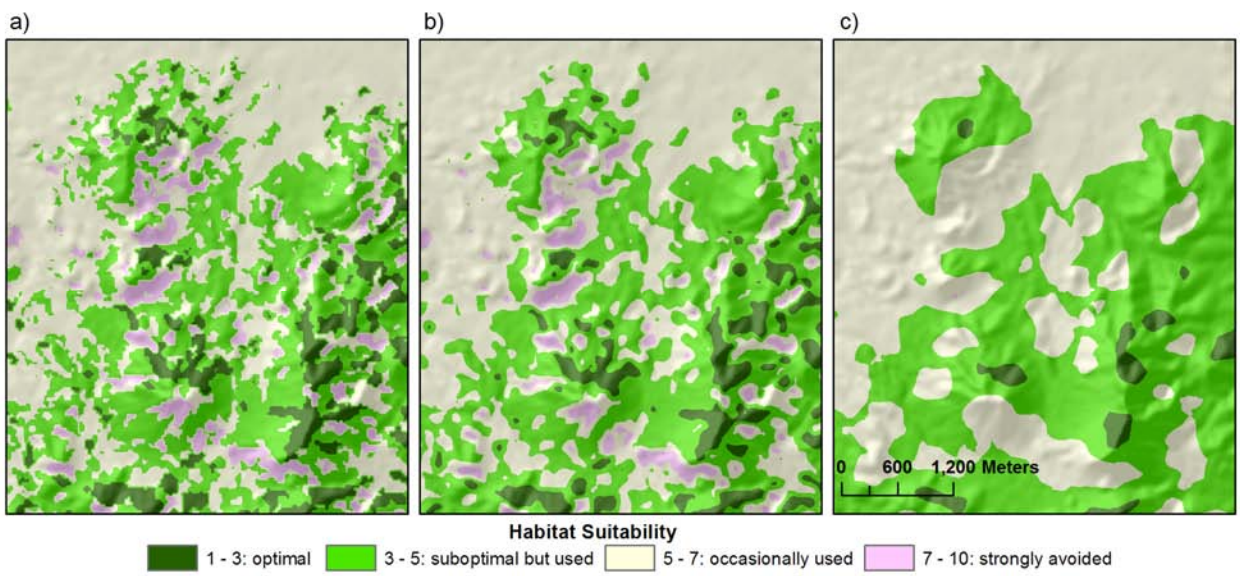

Figure 20: Example moving window analysis which calculates the average habitat suitability surrounding a pixel. a) original habitat suitability model, b) 3x3-pixel moving window, c) 200m radius moving window.

[6] An animal that moves over large areas for daily foraging perceives the landscape as composed of relatively large patches, because the animal readily moves through small swaths of unsuitable habitat in an otherwise favorable landscape (Vos et al. 2001). In contrast, a less-mobile mobile has a more patchy perception of its surroundings. Similarly, a small island of suitable habitat in an ocean of poor habitat will be of little use to an animal with large daily spatial requirements, but may be sufficient for the animal that requires little area.

Identifying Biologically Best Corridors

The *biologically best corridor*[7] (BBC) is a continuous swath of land that is predicted to be the best (highest permeability, lowest cost of travel) route for a species to travel from a potential population core in one protected Wildland block to a potential population core in the other protected Wildland block. *Travel cost* increases in areas where the focal species experiences poor nutrition or lack of suitable cover. *Permeability* is simply the opposite of travel cost, such that a perfectly permeable landscape would have a travel cost at or near zero.

We developed BBCs only for some focal species, namely species that (a) exist in both protected Wildland blocks, or have historically existed in both and could be restored to them, (b) can move between wildland blocks in less time than disturbances such as fire or climate change will make the current vegetation map obsolete, and (c) move near the ground through the vegetation layer (rather than flying, swimming, or being carried by the wind). For focal species that did not meet these criteria, we conducted patch configuration analysis (next section).

To define the start and end points for a corridor, we identified potential population cores and habitat patches that fell completely within each protected Wildland block. If potential population cores existed within each block, we used these potential cores as the starting & ending points for the corridor analysis. Otherwise, the start-end points were potential habitat patches within the protected Wildland block or (for a wide-ranging species with no potential habitat patch entirely within a Wildland block) any suitable habitat within the wildland block.

To create each biologically best corridor, we used the habitat suitability score as an estimate of the cost of movement through the pixel[8]. We used three rules to transform habitat suitability scores into travel costs, depending on ecological characteristics of the species:

- For a *locally widespread species* (habitat suitability score < 5 in nearly all of the potential linkage zone, suggesting that breeding populations could occur throughout), we used the raw pixel habitat suitability score as the travel cost score.

Species that were not widespread throughout the potential linkage area were divided into 2 groups:

- For *corridor-dwelling species* (species needing weeks to generations to traverse the potential linkage area – including most reptiles, amphibians, and small mammals)[9], we reassigned a score of 1 to each pixel in a potential habitat patch or potential population core. Our rationale was that these areas provide steppingstones for multi-generational movement. We did not rescore single pixels, or polygons smaller than a potential breeding area, because these are too small to provide meaningful stopover habitat.
- For *passage species* (mobile species that can make the journey between protected Wildland blocks in a single movement event of a few hours or days), we assigned each pixel with a pixel habitat suitability score of 1 through 5 a travel cost score of 1. In preliminary models that lacked this rescoring, the biologically best corridor tended to follow an unrealistic straight line rather than best habitat.

For each pixel, we calculated the lowest cumulative cost to that pixel from a starting point in one protected Wildland block. We similarly calculated the lowest cumulative travel cost from the 2nd protected Wildland block, and added these 2 travel costs to calculate the *total travel cost* for each pixel.

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7 Our approach has often been called Least Cost Corridor Analysis (Beier et al. 2006) because it identifies areas that require the least cost of travel (energetic cost, risk of mortality) to the animal. However, we avoid the words "least cost" because it is easily misunderstood as referring to the dollar cost of conserving land or building an underpass.

8 Levey et al. (2005) provide evidence that animals make movement decisions based on habitat suitability.

9 Beier & Loe (1992) introduced this distinction between *passage species* and *corridor-dwelling* species.

For each focal species, we conducted this analysis 3 times for each pair of Wildland blocks – that is between the Rincon and Santa Rita Wildland blocks, then between the Santa Rita and Whetstone Wildland blocks, and then between the Whetstone and the Rincon Wildland blocks[10].

Las Cienegas National Conservation Area is adjacent to the Santa Rita Wildland block and usually was treated as part of that wildland block. However, Las Cienegas was a large block of grasslands and lowland habitats that differed from the montane habitats of the rest of the Santa Rita Wildland block. There was much more optimal habitat for antelope jackrabbit, javelina, badger, desert box turtle, and Sonoran desert toad in Las Cienegas than in the Santa Rita Mountains. Therefore for these species, north-south connectivity was modeled between Las Cienegas and the Rincon Wildland block, thus ensuring that the corridor would serve large blocks of optimal habitat in the south, instead of running to a small patch of good habitat in the Santa Ritas that happened to be a mile closer to the Rincons.

Conversely, Las Cienegas NCA was treated as part of the linkage planning area when more optimal habitat for a particular focal occurred in the Santa Rita Mountains than in Las Cienegas NCA. This again ensured that the biologically best corridor leading south from the Rincons or west from the Whetstones reached all the way to the large habitat areas in the Santa Ritas rather than having a corridor that linked to a small patch of good habitat in Las Cienegas. This option was appropriate for black bear, mountain lion, gray squirrel, Coues deer, jaguar, mule deer, porcupine, coati, and black-tailed rattlesnake.

The total travel cost reflects the lowest possible cost associated with a path through the pixel between a pair of wildland blocks. We defined the biologically best corridor as the swath of pixels with the lowest total travel cost and a minimum width of 500 m (Figure 21). If a species had two or more distinct strands in its biologically best corridor, we eliminated any strand markedly worse than the best strand, but we retained multiple strands if they had roughly equal travel cost and spacing among habitat patches. After developing a biologically best corridor for each species, we combined biologically best corridors to form a union of biologically best corridors (UBBC).

Patch Configuration Analysis

Although the UBBC identifies an optimum corridor between the protected wildland blocks, this optimum might be poor for a species with little suitable habitat in the potential linkage area. Furthermore, corridor analyses were not conducted for some focal species (see 2nd paragraph of previous section). To address these issues, we examined the maps of potential population cores and potential habitat patches for each focal species (including species for which a BBC was estimated) in relation to the UBBC. For each species, we examined whether the UBBC encompasses adequate potential habitat patches and potential habitat cores, and we compared the distance between neighboring habitat patches to the dispersal distance[11] of the species. For those species (*corridor-dwellers*, above) that require multiple generations to move between protected wildland blocks, a patch of good habitat beyond dispersal distance will not promote movement. For such species, we looked for potential habitat patches within the potential linkage area but outside of the UBBC. When such patches were within the species' dispersal distance from patches within the UBBC or a wildland block, we added these polygons to the UBBC to create a *preliminary linkage design*.

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[10] Exception: There was little optimal habitat for desert box turtle or Sonoran desert toad in the Whetstone Wildland block. Therefore we did not estimate a biologically best corridor for desert box turtles or Sonoran desert toads between the Whetstones and the other 2 wildland blocks.

[11] Dispersal distance is how far an animal moves from its birthplace to its adult home range. We used dispersal distances reported by the species expert, or in published literature. In some cases, we used dispersal distance for a closely-related species.

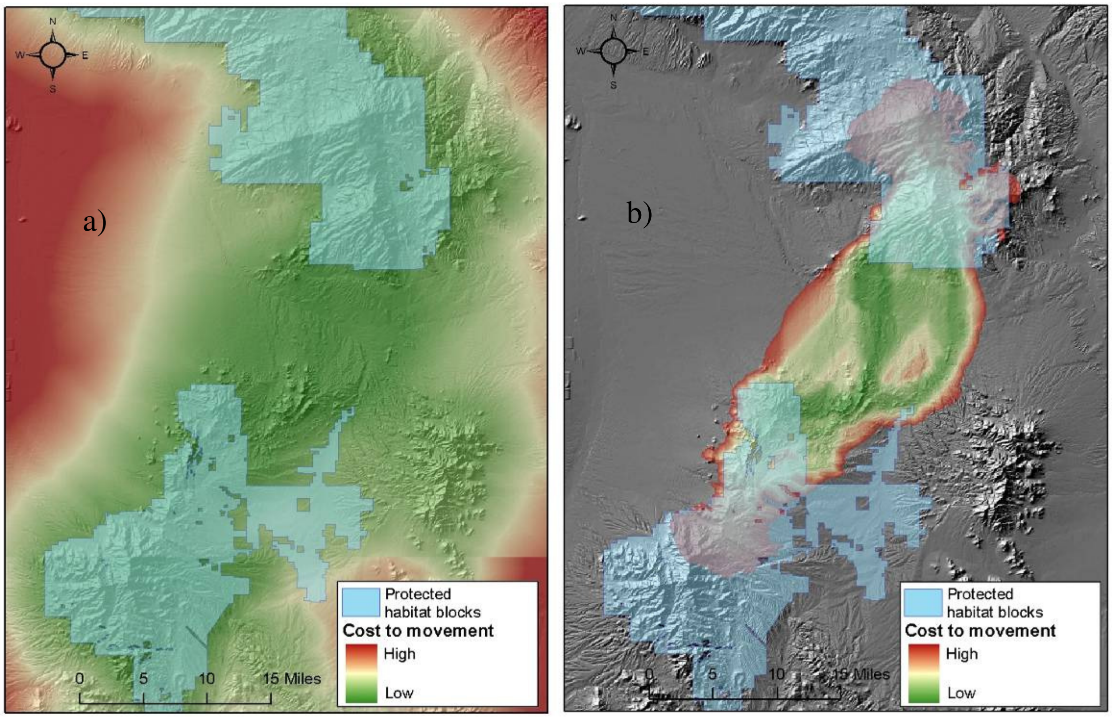

Figure 21: Landscape permeability layer for a hypothetical species across a) entire landscape, b) most permeable 10% of landscape.

Minimum Linkage Width

Wide linkages are beneficial for several reasons. They (1) provide adequate area for development of metapopulation structures necessary to allow corridor-dwelling species (individuals or genes) to move through the landscape; (2) reduce pollution into aquatic habitats; (3) reduce edge effects such as pets, lighting, noise, nest predation & parasitism, and invasive species; (4) provide an opportunity to conserve natural fire regimes and other ecological processes; and (5) improve the opportunity of biota to respond to climate change.

To address these concerns, we established a minimum width of 1.5 km (0.94 mi) along the length of each terrestrial branch of the preliminary linkage design, except where existing urbanization precluded such widening. We widened bottlenecks first by adding natural habitats, and then by adding agricultural lands if no natural areas were available.

It is especially important that the linkage will be useful in the face of climate change. Climate change scientists unanimously agree that average temperatures will rise 2 to 6.4 C over pre-industrial levels by 2100, and that extreme climate events (droughts and storms) will become more common (Millennium Ecosystem Assessment 2005). Although it is less clear whether rainfall will increase or decrease in any location, there can be no doubt that the vegetation map in 2050 and 2100 will be significantly different than the map of current vegetation used in our analyses. Implementing a corridor design narrowly conforming to current distribution of vegetation types would be risky. Therefore, in widening terrestrial linkage strands, we attempted to maximize local diversity of aspect, slope, and elevation to provide a better chance that the linkage will have most vegetation types well-distributed along its length during the coming decades of climate change. Because of the diversity of focal species used to develop the UBBC, our preliminary linkage design had a lot of topographic diversity, and minimal widening was needed to encompass this diversity.

Expanding the linkage to this minimum width produced the final linkage design.

Field Investigations

Although our analyses consider human land use and distance from roads, our GIS layers only crudely reflect important barriers that are only a pixel or two in width, such as freeways, canals, and major fences. Therefore we visited each linkage design area to assess such barriers and identify restoration opportunities. We documented areas of interest using GPS, photography, and field notes. We evaluated existing bridges, underpasses, overpasses, and culverts along highways as potential structures for animals to cross the highway, or as locations where improved crossing structures could be built. We noted recent (unmapped) housing & residential developments, major fences, and artificial night lighting that could impede animal movement, and opportunities to restore native vegetation degraded by human disturbance or exotic plant species. A database of field notes, GPS coordinates, and photos of our field investigations can be found in Appendix F, as well as in a MS Access database on the CD-ROM accompanying this report.

Appendix B: Individual Species Analyses

Table 4: Habitat suitability scores and factor weights for each species. Scores range from 1 (best) to 10 (worst), with 1-3 indicating optimal habitat, 4-5 suboptimal but usable habitat, 6-7 occasionally used but not breeding habitat, and 8-10 avoided.

	Antelope Jackrabbit	Arizona Gray Squirrel	Badger	Black Bear	Coues White-tailed Deer
Factor Weights					
Land Cover	70	70	65	75	65
Elevation	10	10	7	10	5
Topography	13	10	15	10	15
Distance from Roads	7	10	13	5	15
Land Cover					
Conifer-Oak Forest and Woodland	8	2	6	1	2
Encinal	4	2	6	1	1
Pine-Oak Forest and Woodland	9	2	5	1	2
Pinyon-Juniper Woodland	7	6	4	6	3
Aspen Forest and Woodland	10	7	6	5	5
Juniper Savanna	6	8	2	7	3
Semi-Desert Grassland and Steppe	1	10	1	5	6
Chaparral	7	6	5	3	3
Creosotebush, Mixed Desert and Thorn Scrub	2	10	2	6	5
Creosotebush-White Bursage Desert Scrub	2	10	2	9	7
Desert Scrub (misc)	2	10	3	5	6
Mesquite Upland Scrub	3	9	3	6	4
Paloverde-Mixed Cacti Desert Scrub	2	10	4	5	8
Ponderosa Pine Woodland	9	4	5	9	5
Stabilized Coppice Dune and Sand Flat Scrub	6	10	4	10	8
Riparian Mesquite Bosque	3	5	6	5	3
Riparian Woodland and Shrubland	4	1	6	5	2
Arid West Emergent Marsh	9	9	8	5	5
Barren Lands, Non-specific	8	10	7	10	10
Bedrock Cliff and Outcrop	8	9	9	10	8
Volcanic Rock Land and Cinder Land	8	10	10	10	10
Warm Desert Pavement	9	10	9	10	10
Recently Mined or Quarried	10	10	9	10	9
Agriculture	6	7	6	6	7
Developed, Medium - High Intensity	9	9	10	10	10
Developed, Open Space - Low Intensity	6	9	7	10	9
Open Water	9	9	9	10	7
Elevation (ft)					
Elevation range: cost	0-500: 3 500-1500: 2 1500-5000: 1 5000-5500: 8 5500-11000: 9	0-3290: 9 3290-5000: 4 5000-6600: 1 6600-9350: 4 9350-11000: 8	0-5500: 1 5500-8000: 3 8000-11000: 6	0-2500: 8 2500-4000: 6 4000-6500: 2 6500-8500: 3 8500-11000: 4	0-2000: 7 2000-3000: 6 3000-4000: 2 4000-6000: 1 6000-8000: 3 8000-11000: 7
Topographic Position					
Canyon Bottom	5	1	5	3	1
Flat - Gentle Slopes	1	4	1	6	5
Steep Slope	4	5	8	3	2
Ridgetop	4	7	7	4	4
Distance from Roads (m)					
Distance from Roads range: cost	0-250: 9 250-500: 6 500-1000: 3 1000-1500: 1	0-250: 7 250-500: 4 500-15000: 1	0-250: 6 250-1500: 1	0-100: 10 100-500: 4 500-15000: 1	0-250: 8 250-500: 6 500-750: 2 750-15000: 1

	Jaguar	Javelina	Mountain Lion	Mule Deer	Porcupine
Factor Weights					
Land Cover	60	50	70	80	87
Elevation	5	30	0	0	0
Topography	15	20	10	15	3
Distance from Roads	20	0	20	5	10
Land Cover					
Conifer-Oak Forest and Woodland	2	7	1	4	1
Encinal	2	4	1	3	1
Pine-Oak Forest and Woodland	3	7	1	3	1
Pinyon-Juniper Woodland	2	5	1	5	1
Aspen Forest and Woodland	6	10	3	1	1
Juniper Savanna	3	7	4	4	5
Semi-Desert Grassland and Steppe	1	2	5	2	6
Chaparral	4	3	3	4	4
Creosotebush, Mixed Desert and Thorn Scrub	2	3	6	6	5
Creosotebush-White Bursage Desert Scrub	4	4	6	6	5
Desert Scrub (misc)	4	2	6	6	5
Mesquite Upland Scrub	4	2	4	3	4
Paloverde-Mixed Cacti Desert Scrub	5	1	7	3	5
Ponderosa Pine Woodland	4	6	4	5	1
Stabilized Coppice Dune and Sand Flat Scrub	6	7	5	6	6
Riparian Mesquite Bosque	1	1	4	3	3
Riparian Woodland and Shrubland	1	2	2	3	3
Arid West Emergent Marsh	2	5	8	5	9
Barren Lands, Non-specific	10	9	8	10	9
Bedrock Cliff and Outcrop	6	8	6	8	6
Volcanic Rock Land and Cinder Land	9	9	9	8	9
Warm Desert Pavement	9	8	9	9	10
Recently Mined or Quarried	10	10	8	6	9
Agriculture	9	7	10	6	7
Developed, Medium - High Intensity	10	7	10	9	9
Developed, Open Space - Low Intensity	10	4	8	5	7
Open Water	7	10	9	10	10
Elevation (ft)					
Elevation range: cost	0-2000: 3 2000-4000: 3 4000-6000: 1 6000-8000: 3 8000-11000: 4	0-5000: 1 5000-7000: 3 7000-11000: 10			
Topographic Position					
Canyon Bottom	1	1	1	2	1
Flat - Gentle Slopes	5	1	3	2	2
Steep Slope	2	7	3	4	1
Ridgetop	4	4	4	6	2
Distance from Roads (m)					
Distance from Roads range: cost	0-250: 10 250-500: 7 500-1000: 5 1000-2000: 2 2000-15000: 1		0-200: 8 200-500: 6 600-1000: 5 1000-1500: 2 1500-15000: 1	0-250: 7 250-1000: 3 1000-15000: 1	0-250: 8 250-500: 5 500-1000: 2 1000-15000: 1

	Pronghorn	White-nosed Coati	Black-tailed Rattlesnake	Chiricahua Leopard Frog	Desert Box Turtle
Factor Weights					
Land Cover	45	95	0	55	40
Elevation	0	0	0	25	15
Topography	37	0	90	10	20
Distance from Roads	18	5	10	10	25
Land Cover					
Conifer-Oak Forest and Woodland	8	2		10	10
Encinal	7	1		6	6
Pine-Oak Forest and Woodland	8	2		6	10
Pinyon-Juniper Woodland	6	2		6	10
Ponderosa Pine Woodland	7	2		6	10
Aspen Forest and Woodland	10	7		7	10
Juniper Savanna	4	5		6	7
Semi-Desert Grassland and Steppe	1	7		6	2
Chaparral	8	5		6	6
Creosotebush, Mixed Desert and Thorn Scrub	2	5		10	5
Creosotebush-White Bursage Desert Scrub	2	7		10	6
Desert Scrub (misc)	3	8		10	5
Mesquite Upland Scrub	7	3		6	3
Paloverde-Mixed Cacti Desert Scrub	3	6		10	5
Stabilized Coppice Dune and Sand Flat Scrub	7	9		10	2
Riparian Mesquite Bosque	8	2		6	1
Riparian Woodland and Shrubland	8	1		6	1
Arid West Emergent Marsh	7	3		1	3
Barren Lands, Non-specific	7	9		10	7
Bedrock Cliff and Outcrop	10	7		10	10
Mixed Bedrock Canyon and Tableland	8	6		10	10
Volcanic Rock Land and Cinder Land	8	7		10	10
Warm Desert Pavement	7	7		10	10
Recently Mined or Quarried	10	9		10	10
Agriculture	8	5		6	5
Developed, Medium - High Intensity	10	9		7	10
Developed, Open Space - Low Intensity	8	7		6	5
Open Water	7	10		2	5
Elevation (ft)					
Elevation range: cost				0-3300: 10 3300-6000: 1 6000-9000: 2 9000-11000: 3	0-1900: 10 1900-2600: 4 2400-5500: 1 5500-6500: 5 6500-11000: 9
Topographic Position					
Canyon Bottom	7		1	1	3
Flat - Gentle Slopes	1		9	1	1
Steep Slope	8		1	6	4
Ridgetop	6		1	7	4
Distance from Roads (m)					
Distance from Roads range: cost	0-100: 10 100-250: 6 250-1000: 3 1000-15000: 1	0-500: 8 500-15000: 3	0-35: 10 35-500: 5 500-15000: 1	0-100: 8 100-500: 5 500-1000: 3 1000-15000: 1	0-500: 5 500-1500: 3 1500-15000: 1

	Giant Spotted Whiptail	Lowland Leopard Frog	Mexican Garter Snake	Sonoran Desert Toad	Tiger Rattlesnake
Factor Weights					
Land Cover	70	60	40	5	20
Elevation	30	30	15	50	30
Topography	0	0	40	25	40
Distance from Roads	0	10	5	20	10
Land Cover					
Conifer-Oak Forest and Woodland	10	10	10	10	10
Encinal	6	6	6	7	5
Pine-Oak Forest and Woodland	10	7	6	10	10
Pinyon-Juniper Woodland	10	7	6	10	6
Ponderosa Pine Woodland	10	10	10	10	10
Aspen Forest and Woodland	10	10	10	10	10
Juniper Savanna	10	7	7	4	10
Semi-Desert Grassland and Steppe	7	6	6	2	5
Chaparral	4	6	6	4	6
Creosotebush, Mixed Desert and Thorn Scrub	4	6	6	2	3
Creosotebush-White Bursage Desert Scrub	10	6	10	4	7
Desert Scrub (misc)	10	6	10	2	3
Mesquite Upland Scrub	7	6	6	1	4
Paloverde-Mixed Cacti Desert Scrub	10	6	10	1	1
Stabilized Coppice Dune and Sand Flat Scrub	10	10	10	2	10
Riparian Mesquite Bosque	4	6	5	1	5
Riparian Woodland and Shrubland	1	6	4	2	5
Arid West Emergent Marsh	2	1	1	5	10
Barren Lands, Non-specific	10	10	10	7	10
Bedrock Cliff and Outcrop	10	10	10	5	2
Mixed Bedrock Canyon and Tableland	10	10	10	5	2
Volcanic Rock Land and Cinder Land	10	10	10	10	1
Warm Desert Pavement	10	10	10	5	6
Recently Mined or Quarried	10	10	10	4	10
Agriculture	4	6	7	4	10
Developed, Medium - High Intensity	4	7	10	6	9
Developed, Open Space - Low Intensity	3	6	10	4	1
Open Water	2	2	2	4	10
Elevation (ft)					
Elevation range: cost	0-2000: 10 2000-2330: 5 2300-4000: 1 4000-4600: 4 4600-11000: 9	0-900: 4 900-4000: 1 4000-5500: 3 5500-7000: 6 7000-11000: 10	0-2000: 4 2000-5500: 1 5500-6750: 3 6750-11000: 7	0-4600: 1 4600-5250: 4 5250-5800: 5 5800-11000: 7	0-4000: 1 4000-5100: 5 5100-11000: 10
Topographic Position					
Canyon Bottom					1
Flat - Gentle Slopes					6
Steep Slope					1
Ridgetop					3
Distance from Roads (m)					
Distance from Roads range: cost		0-100: 8 100-500: 5 500-1000: 3 1000-15000: 1		0-200: 5 200-1000: 4 1000-3000: 2 3000-15000: 1	0-35: 10 35-1000: 5 1000-15000: 1

Antelope Jackrabbit (*Lepus alleni*)

Justification for Selection
Antelope jackrabbits have a geographic distribution limited to the deserts and grasslands of southern Arizona and northern Mexico, and are threatened with habitat alteration from expanding agriculture and development (Best & Henry 1993).

Distribution
Within the United States, the antelope jackrabbit is limited to southern Arizona. The species is also found in the northern portion of the Mexican state Nayarit, and on Tiburón Island in the Gulf of California (Best & Henry 1993).

Habitat Associations
Antelope jackrabbits are primarily associated with grassy slopes on moderate elevations up to 4,900 feet (Best & Henry 1993). In southern Arizona, antelope jackrabbits live on dry valley slopes away from water, and do not drink water if it is available (Best & Henry 1993). Brown & Krausman (2003) identified the species 73% of the time within vegetation associations composed of mesquite and creosote, while others have found stomach content comprised of 45% grass, 35% mesquite, and 7.8% cactus (Vorhies & Taylor 1933).

Spatial Patterns
The average home range of antelope jackrabbits has been estimated as 642.8 ha (Swihart 1986), and population density has may range from 0.025 ha to 0.5 ha (Best & Henry 1993). Swihart's (1986) estimate of home range for antelope jackrabbits is much larger than the home range for congeners of the species, such as the black-tailed jackrabbit, which have estimated home ranges ranging from 20 to 140 ha (Best 1993). No information was available on dispersal distances for the species.

Conceptual Basis for Model Development
Habitat suitability model – Because Brown & Krausman (2003) censused the species using a roadway survey which identified the species within 100m of the road, we assumed antelope jackrabbits do not show an aversion to roads. However, this non-sensitivity may result in increased roadkill, so we assigned distance from roads a weight of 7%. Vegetation received an importance weight of 70%, while elevation and topography received weights of 10% and 13%, respectively. For specific costs of classes within each of these factors used for the modeling process, see Table 4.

Patch size & configuration analysis – We defined minimum potential habitat patch size as 100 ha, based on Best's (1993) estimate of home range size for black-tailed jackrabbits. Minimum potential habitat core size was defined as 500 ha, or five times the minimum patch size. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – While no information was available on dispersal distance for this species, antelope jackrabbits were considered potential corridor dwellers in this analysis because of their spatial requirements and the high habitat suitability within the linkage area. Nearly all habitat within the linkage zone was calculated as suitable, so the standard habitat suitability model was used in the corridor analysis. Biologically best corridors were only created between the Rincon Mountains wildland block and the Las Cienegas & Whetstone wildland blocks, because there was little suitable habitat on the western edge of the Whetstone wildland block.

Results & Discussion

Initial biologically best corridor – Modeling results indicate ample suitable habitat for this species within the linkage area (Figure 22). Within the biologically best corridor (BBC) for this species between the Las Cienegas and Rincon wildland blocks, the average habitat suitability ranged from 1 to 7.5, with an average suitability of 2.3 (S.D: 0.9). Within the BBC for this species between the Whetstone and Rincon wildland blocks, the average habitat suitability ranged from 1 to 7.2, with an average suitability of 2.3 (S.D: 0.8). Due to the high suitability of habitat within this species' corridor, nearly the entire corridor was a potential habitat core (Figure 23).

Union of biologically best corridors – The UBBC adequately serves this species. Nearly all of the union is a potential habitat core, and the corridor between Las Cienegas and Whetstone wildland blocks captures potential habitat.

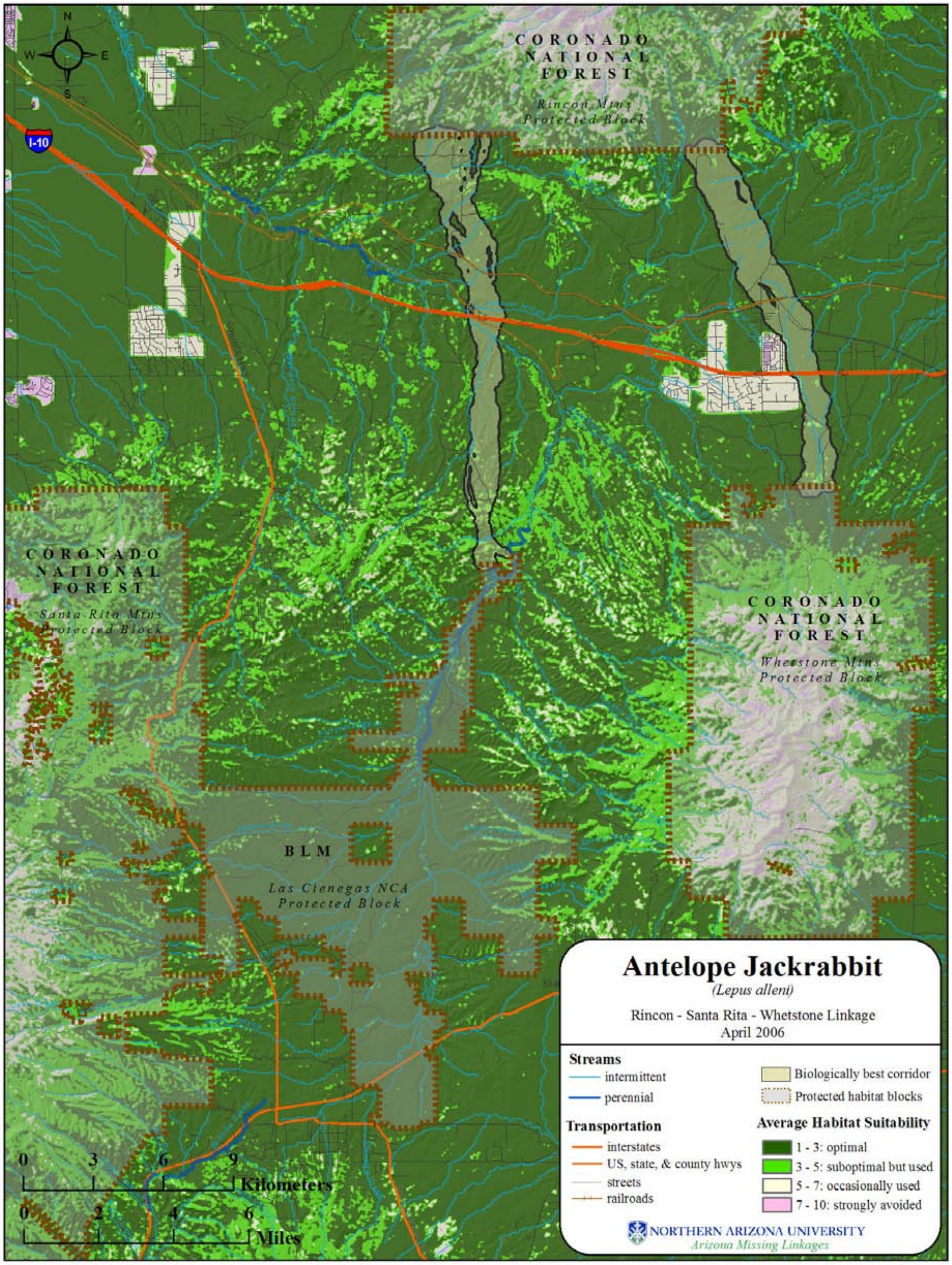

Figure 22: Modeled habitat suitability of antelope jackrabbit.

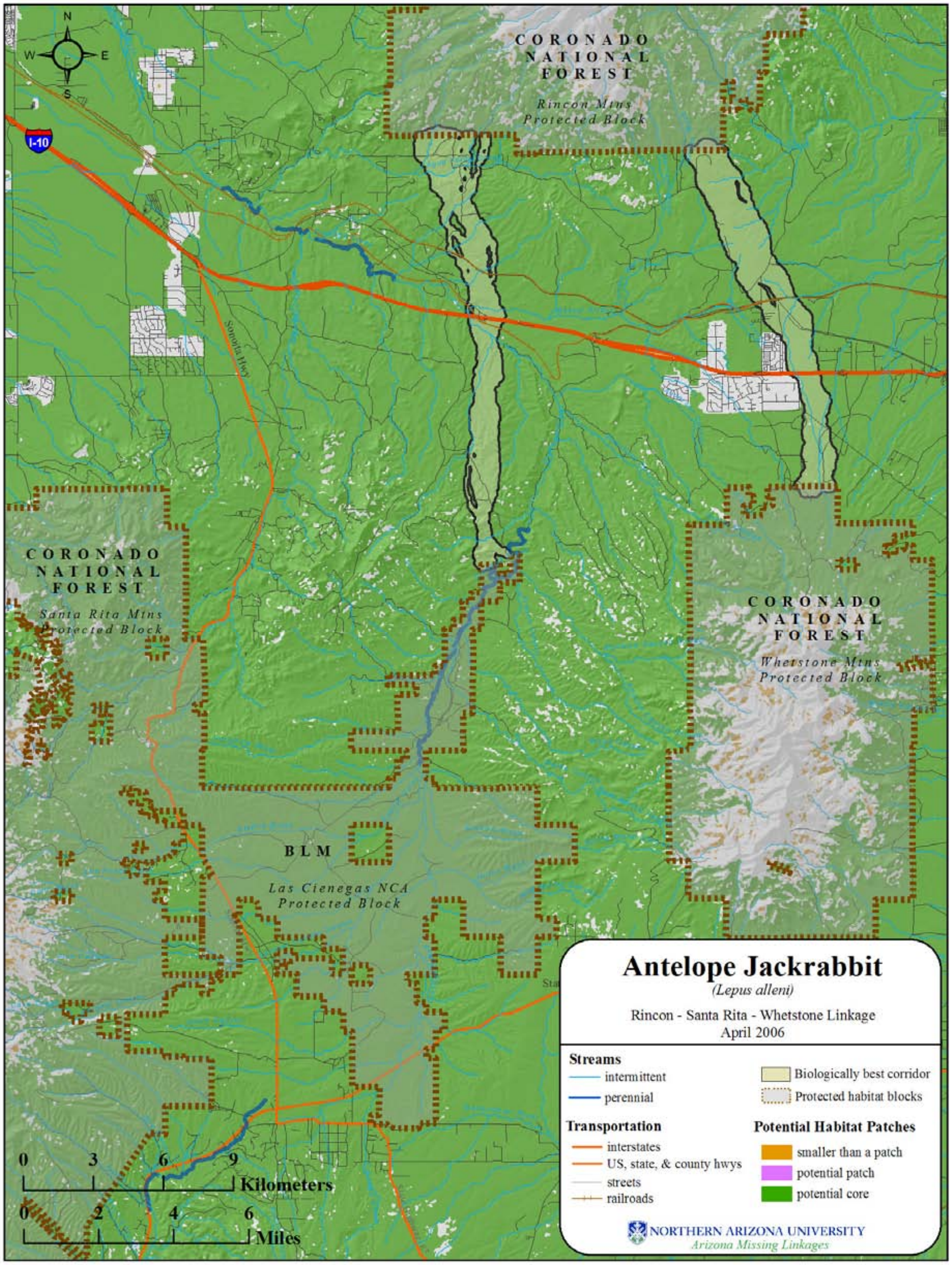

Figure 23: Potential habitat patches and cores for antelope jackrabbit.

Arizona Gray Squirrel (*Sciurus arizonensis*)

Justification for Selection

Arizona gray squirrels have limited geographic distributions and are habitat specialists with strong dependency on montane forest. They are also sensitive to roads (Brown 1984 *in* Best & Riedel 1995), and most likely dispersal limited.

Distribution

The Arizona gray squirrel is found in Arizona and New Mexico, and to a limited extent in Sonora, Mexico. In Arizona, they occupy a number of mountain ranges in the southern part of the state, as well as the southern and western slopes of the Mogollon Plateau (Best & Riedel 1995).

Habitat Associations

Arizona gray squirrels are primarily associated with dense, mixed broadleaf forests within deciduous riparian forests (Best & Riedel 1995). They may extend along streams into semi-desert and chaparral areas. Ponderosa pine (*Pinus ponderosa*) and Gambel oak (*Quercus gambeli*) are used extensively when found within riparian communities. Key indicators of Arizona gray squirrel include Arizona walnut (*Juglans major*), Arizona oak (Quercus arizonica), and Gambel oak, which provide key nesting & foraging sources (Best & Riedel 1995). While individuals of this species are often killed on roadways, they are not greatly disturbed by dogs and humans. In Arizona, typical elevation range is between 4900 & 6400 feet, although the species can range from approximately 3,600 to 8,900 feet (Best & Riedel 1995).

Spatial Patterns

No information is known on spatial requirements of the Arizona gray squirrel. Abert's Squirrel (*Sciurus aberti*), a species within the same genus, has been found to have an average home range of 2.5 to 13 ha (6.2 – 32 acres), with larger home ranges associated with recent timber harvesting (Patton 1977). Average summer home ranges of western gray squirrels in California and Oregon have been found to vary between 2.6 and 4.2 ha (6.4-10.4 acres) (Ryan & Carey 1995). Home ranges of Abert's squirrel have been observed to commonly overlap (Keith 2003), while the home ranges of western gray squirrel displayed little overlap (Vander Haegen et al. 2005) While no dispersal information is available for the Arizona gray squirrel, dispersal distance for tree squirrels is generally not more than several kilometers (NatureServe 2005).

Conceptual Basis for Model Development

Habitat suitability model – Due to this species' strong vegetation preferences, vegetation received an importance weight of 70%, while elevation, topography, and distance from roads each received a 10% weight. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Based on the range of home ranges for western gray squirrels estimated by Ryan & Carey (1995), we defined minimum patch size for Arizona gray squirrel as 3.4 ha. We assumed the amount of high-quality habitat necessary to support a relatively isolated breeding group of Arizona gray squirrels for approximately 10 years was 17 ha, or five times estimated minimum patch size. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – Other squirrels only disperse several kilometers, and potential habitat within the linkage area is patchily distributed, so we considered this species a potential corridor dweller. Because potential habitat was patchily distributed, we re-assigned all 'suitable' habitat (score < 5) a cost of 1, to encourage the biologically best corridor to capture this available habitat.

Results & Discussion

Initial biologically best corridor – The biologically best corridor for this species was comprised of three strands connecting the Santa Rita, Rincon, and Whetstone Mountains. Suitable habitat was patchily distributed in all strands (Figure 24 & Figure 25). Between the Santa Rita and Whetstone blocks, the average habitat suitability ranged from 1.3 to 8.8, with an average suitability of 6.4 (S.D: 2.5). Between the Santa Rita and Rincon blocks, the average habitat suitability ranged from 1.7 to 8.8, with an average suitability of 7.0 (S.D: 2.0). Between the Rincon and Whetstone blocks, the average habitat suitability ranged from 1.7 to 8.8, with an average suitability of 7.1 (S.D: 1.9).

Union of biologically best corridors – Because the Arizona gray squirrel is primarily forest-dwelling, the union of biologically best corridors provides little habitat for the species, and the farthest distance between patches in most strands of the linkage design is beyond any recorded distance for gray squirrels. In the Santa Rita – Rincon strand of the UBBC, the farthest distance between a core or patch and another core or patch is approximately 11.5 km, between several potential patches north of the Santa Rita block and several patches found along Cienega Creek. In the Santa Rita – Whetstone strand of the UBBC, the farthest distance between a core or patch and another core or patch is approximately 2 km. In the Rincon – Whetstone strand, the farthest distance is approximately 7 km.

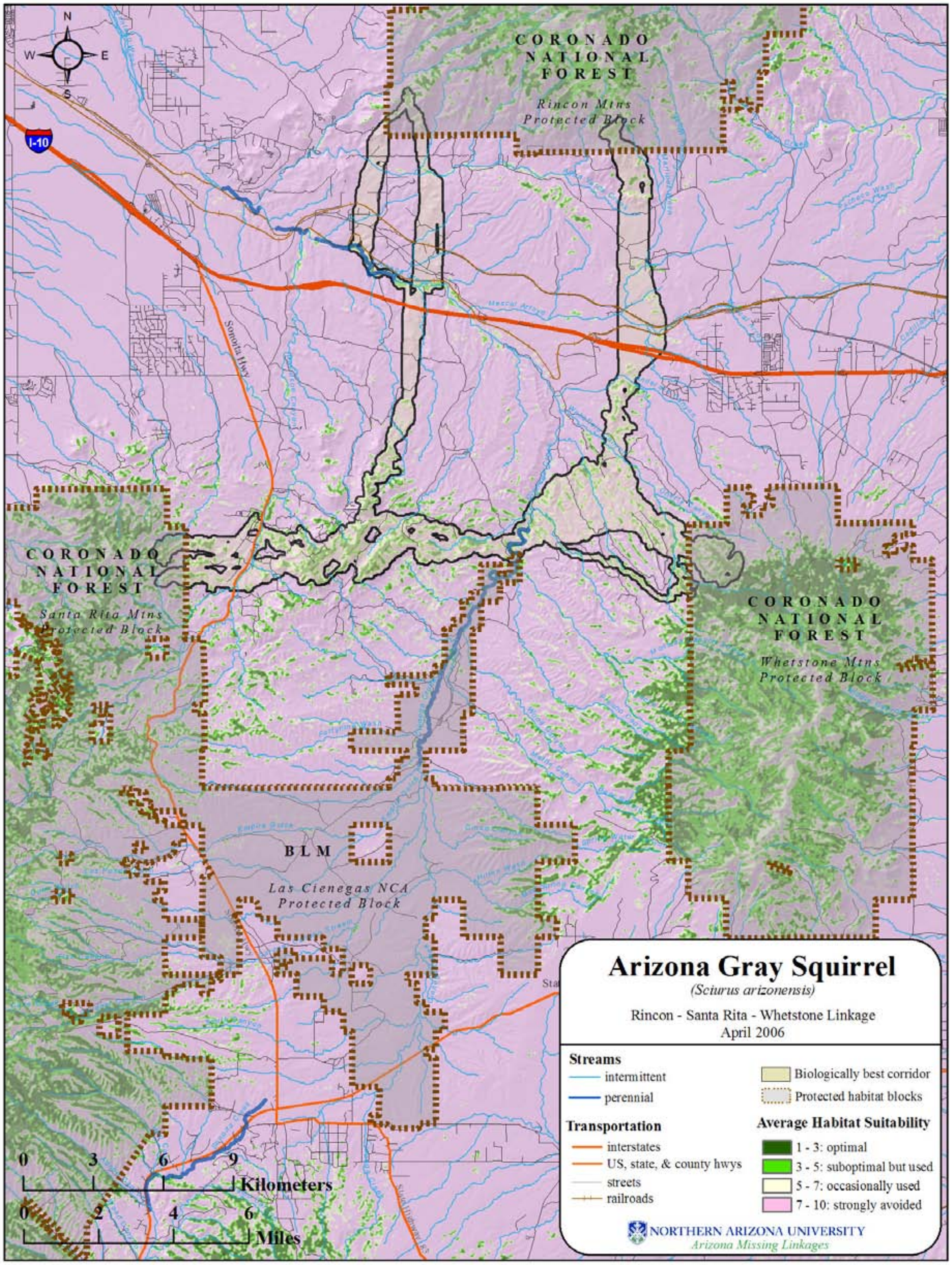

Figure 24: Modeled habitat suitability of Arizona gray squirrel.

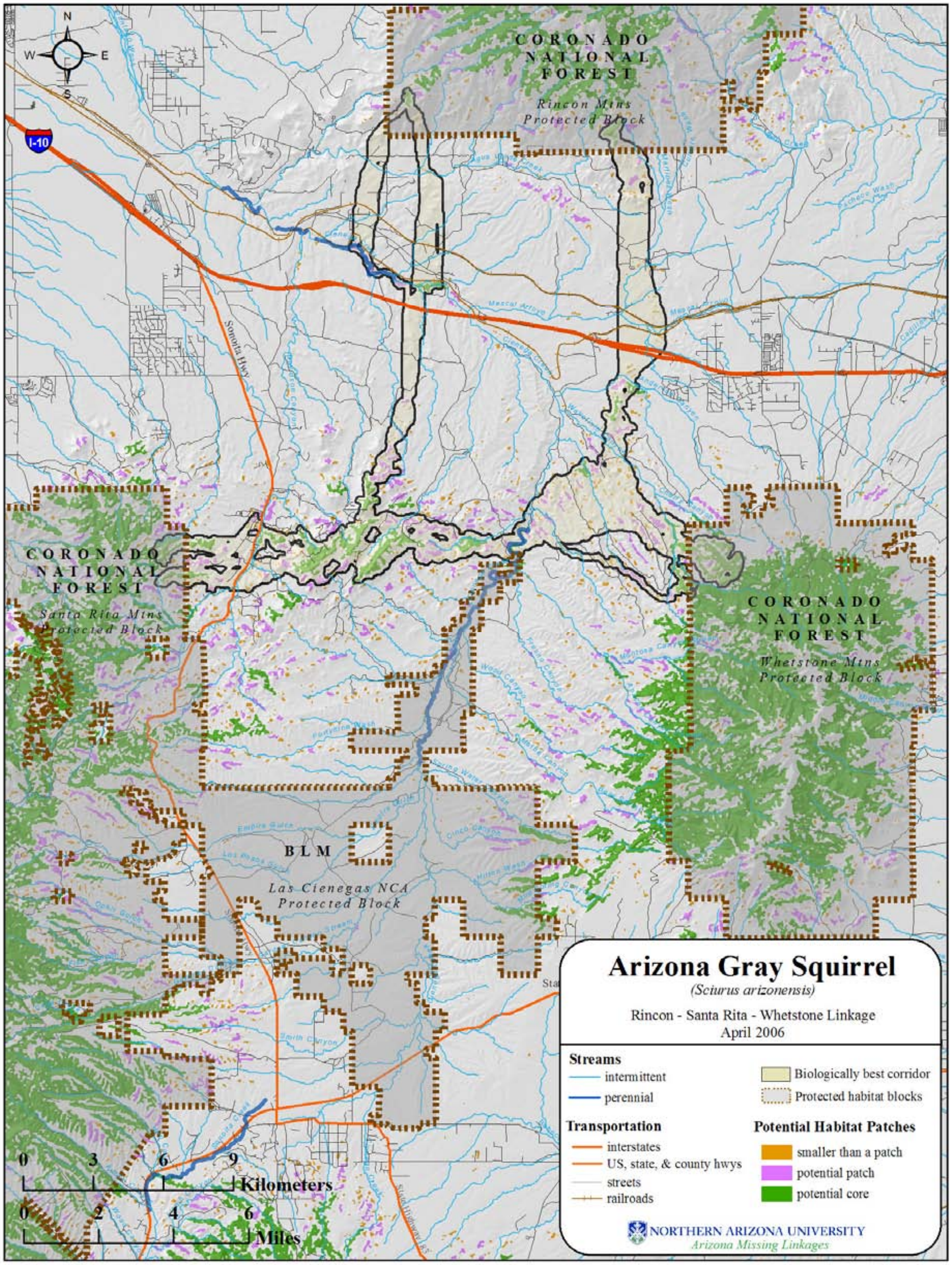

Figure 25: Potential habitat patches and cores for Arizona gray squirrel.

Justification for Selection

Because of their large home ranges, many parks and protected lands are not large enough to ensure protection of a badger population, or even an individual (NatureServe 2005). Consequently, badgers have suffered declines in recent decades in areas where grasslands have been converted to intensive agricultural areas, and where prey animals such as prairie dogs and ground squirrels have been reduced or eliminated (NatureServe 2005). Badgers are also threatened by collisions with vehicles while attempting to cross highways intersecting their habitat (New Mexico Department of Game and Fish 2004, NatureServe 2005).

Distribution

Badgers are found throughout the western United States, extending as far east as Illinois, Wisconsin, and Indiana (Long 1973). They are found in open habitats throughout Arizona.

Habitat Associations

Badgers are primarily associated with open habitats such as grasslands, prairies, and shrublands, and avoid densely wooded areas (NMGF 2004). They may also inhabit mountain meadows, marshes, riparian habitats, and desert communities including creosote bush, juniper and sagebrush habitats (Long & Killingley 1983). They prefer flat to gentle slopes at lower elevations, and avoid rugged terrain (Apps et al. 2002).

Spatial Patterns

Overall yearly home range of badgers has been estimated as 8.5 km^2 (Long 1973). Goodrich and Buskirk (1998) found an average home range of 12.3 km^2 for males and 3.4 km^2 for females, found male home ranges to overlap more than female ranges (male overlap = 0.20, female = 0.08), and estimated density as 0.8 effective breeders per km^2. Messick and Hornocker (1981) found an average home range of 2.4 km^2 for adult males and 1.6 km^2 for adult females, and found a 20% overlap between a male and female home range. Nearly all badger young disperse from their natal area, and natal dispersal distances have been recorded up to 110 km (Messick & Hornocker 1981).

Conceptual Basis for Model Development

Habitat suitability model – Badgers prefer grasslands and other open habitats on flat terrain at lower elevations. They do not show an aversion to roads (Apps et al. 2002), which makes them sensitive to high road mortality. Vegetation received an importance weight of 65%, while elevation, topography, and distance from roads received weights of 7%, 15%, and 13%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – We defined minimum potential habitat patch size as 2 km^2, which is an average of the home range found for both sexes by Messick and Hornocker (1981), and equal to the female home range estimated by Goodrich and Buskirk (1998), minus 1 standard deviation. Minimum potential habitat core size was defined as 10 km^2, approximately enough area to support 10 effective breeders, allowing for a slightly larger male home range size and 20% overlap of home ranges (Messick & Hornocker 1981). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

Biologically best corridor analysis – Nearly all habitat within the linkage zone was calculated as suitable (cost <5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate ample suitable habitat for this species within the potential linkage area (Figure 26), with nearly the entire linkage area a potential habitat core or patch (Figure 27). Between the Las Cienegas and Whetstone blocks, the average habitat suitability ranged from 1.0 to 7.5, with an average suitability of 2.6 (S.D: 1.5). Between the Las Cienegas and Rincon blocks, the average habitat suitability ranged from 1.0 to 8.6, with an average suitability of 2.6 (S.D: 1.2). Between the Rincon and Whetstone blocks, the average habitat suitability ranged from 1.0 to 7.5, with an average suitability of 2.2 (S.D: 0.9).

Union of biologically best corridors – The union of biologically best corridors provides ample habitat for the badger, and nearly all of the UBBC is a potential habitat core for this species.

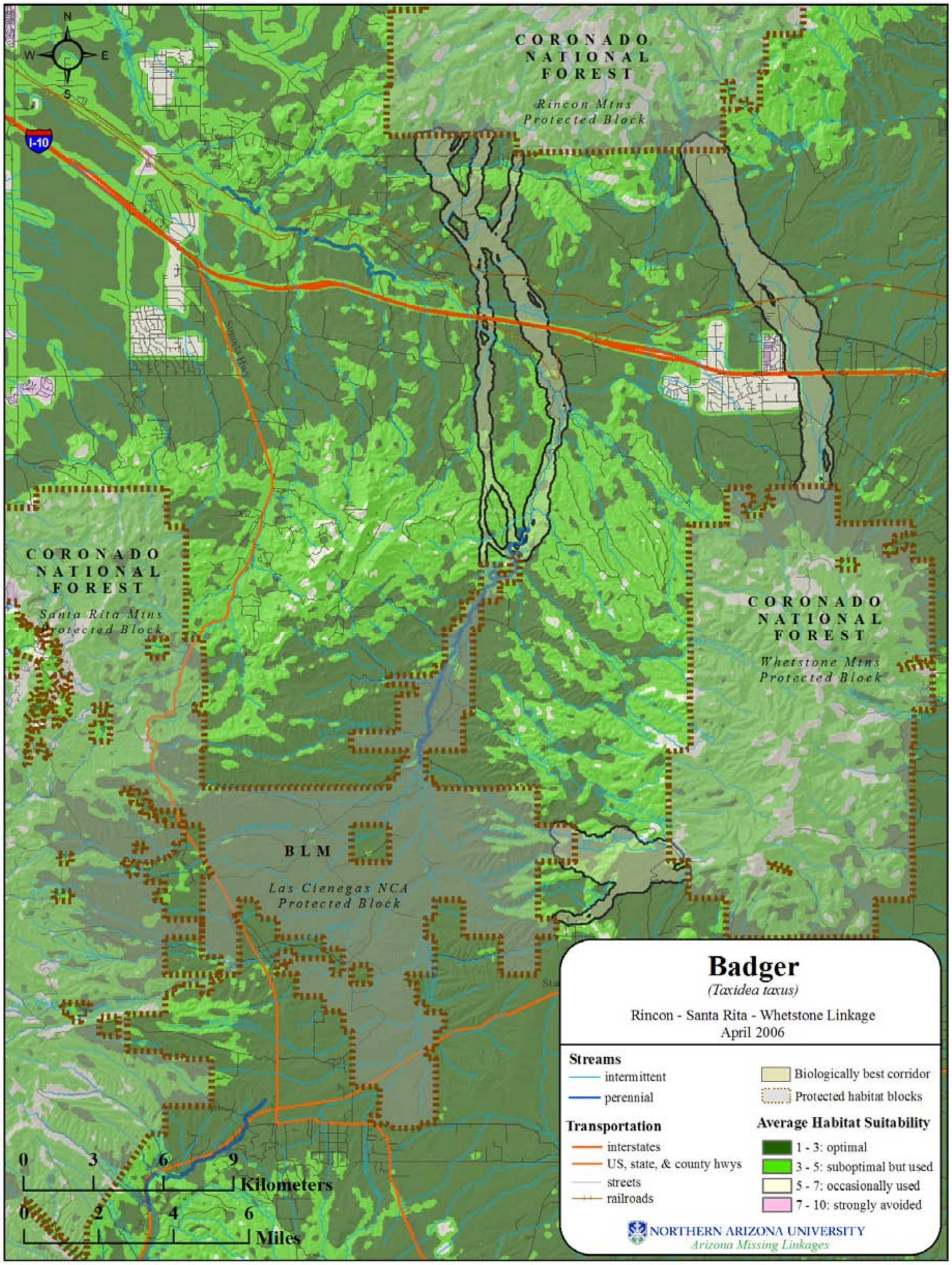

Figure 26: Modeled habitat suitability of badger.

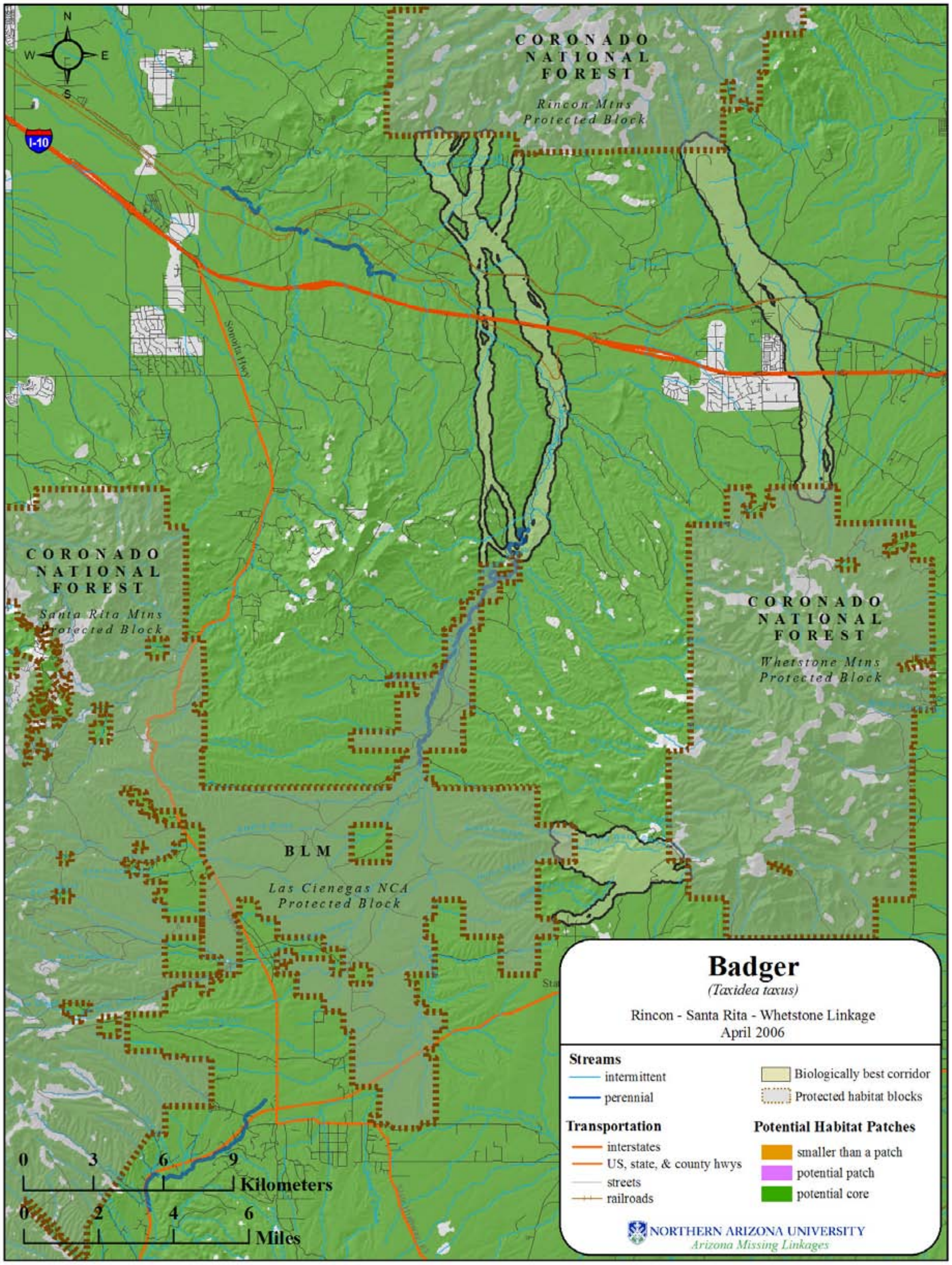

Figure 27: Potential habitat patches and cores for badger.

Black Bear (*Ursus americanus*)

Justification for Selection
Black bears require a variety of habitats to meet seasonal foraging demands and have naturally low population densities, making them especially vulnerable to habitat fragmentation (Larivière 2001).

Distribution
Black bears are widely distributed throughout North America, ranging from Alaska and Canada to the Sierra Madre Occidental and Sierra Madre Oriental of Mexico (Larivière 2001). In Arizona, they are found primarily in forested areas from the South Rim of the Grand Canyon to mountain ranges in the southeastern part of the state (Hoffmeister 1986).

Habitat Associations
Black bears are primarily associated with mountainous ranges throughout Arizona. Within these areas they use a variety of vegetation types, ranging from semidesert grasslands to encinal woodlands and montane conifer forests (Hoffmeister 1986). Encinal woodlands and conifer-oak woodlands are optimal habitat, providing food such as acorns (LeCount 1982; LeCount et al. 1984; Cunningham 2004). In autumn, black bears use grass and shrub mast as well as prickly pear found in desert scrub (S. Cunningham, personal comm.). In many locations throughout Arizona, black bears are found in riparian communities (Hoffmeister 1986), and prefer to bed in locations with 20-60% slopes (S. Cunningham, personal comm.).

Spatial Patterns
Individual black bears do not have territorial interactions, and home ranges of both sexes commonly overlap. Home ranges are generally larger in locations or years of low food abundance, and smaller when food is plentiful and have been observed to range from 2 - 170 km^2 (Larivière 2001). Daily foraging movements are also dependent on food supply, and have been observed to range from 1.4 – 7 km (Larivière 2001). Males have larger dispersal distances than females, as females stay close to their natal range, and males must migrate to avoid larger males as their mother comes back into estrus (Schwartz & Franzmann 1992). Depending on vegetation, females may disperse up to 20 km, while males often move 20-150 km (S. Cunningham, personal comm.).

Conceptual Basis for Model Development
Habitat suitability model – Cover is the most important factor for black bears, so vegetation was assigned an importance weight of 75%. Elevation and topography each received a weight of 10%, and distance from roads received a weight of 5%. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – We defined minimum potential habitat patch size as 10 km^2, since this is the minimum amount of optimum habitat necessary to support a female and cub (Bunnell & Tait 1981; S. Cunningham, pers. comm.). Minimum potential habitat core size was defined as 50km^2, or five times the minimum patch size. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

Biologically best corridor analysis – We used the standard habitat suitability model in the corridor analyses for this species.

Results & Discussion

Initial biologically best corridor – The biologically best corridor for this species was comprised of three strands connecting the Santa Rita, Rincon, and Whetstone Mountains. Suitable habitat was patchily distributed in all strands (Figure 28), and while the strand linking the Santa Rita and Whetstone Mountains was composed of potential habitat cores, the remaining strands had habitat patches insufficiently large to support a breeding pair (Figure 29). Between the Santa Rita and Whetstone blocks, the average habitat suitability ranged from 1.3 to 8.8, with an average suitability of 4.1 (S.D: 1.7). Between the Santa Rita and Rincon blocks, the average habitat suitability ranged from 1.3 to 9.2, with an average suitability of 4.5 (S.D: 1.6). Between the Rincon and Whetstone blocks, the average habitat suitability ranged from 1.3 to 9.2, with an average suitability of 5.0 (S.D: 1.6).

Union of biologically best corridors – Because the black bear is primarily associated with mountainous areas, the union of biologically best corridors provides only marginal bear habitat. In the Santa Rita – Rincon strand of the UBBC, the farthest distance between a core or patch and another core or patch is approximately 16 km. In the Santa Rita – Whetstone strand of the UBBC, potential habitat is nearly connected in both northern and southern strands. In the Rincon – Whetstone strand, the farthest distance is approximately 13 km, although two large habitat patches within this strand are only approximately 6 km apart.

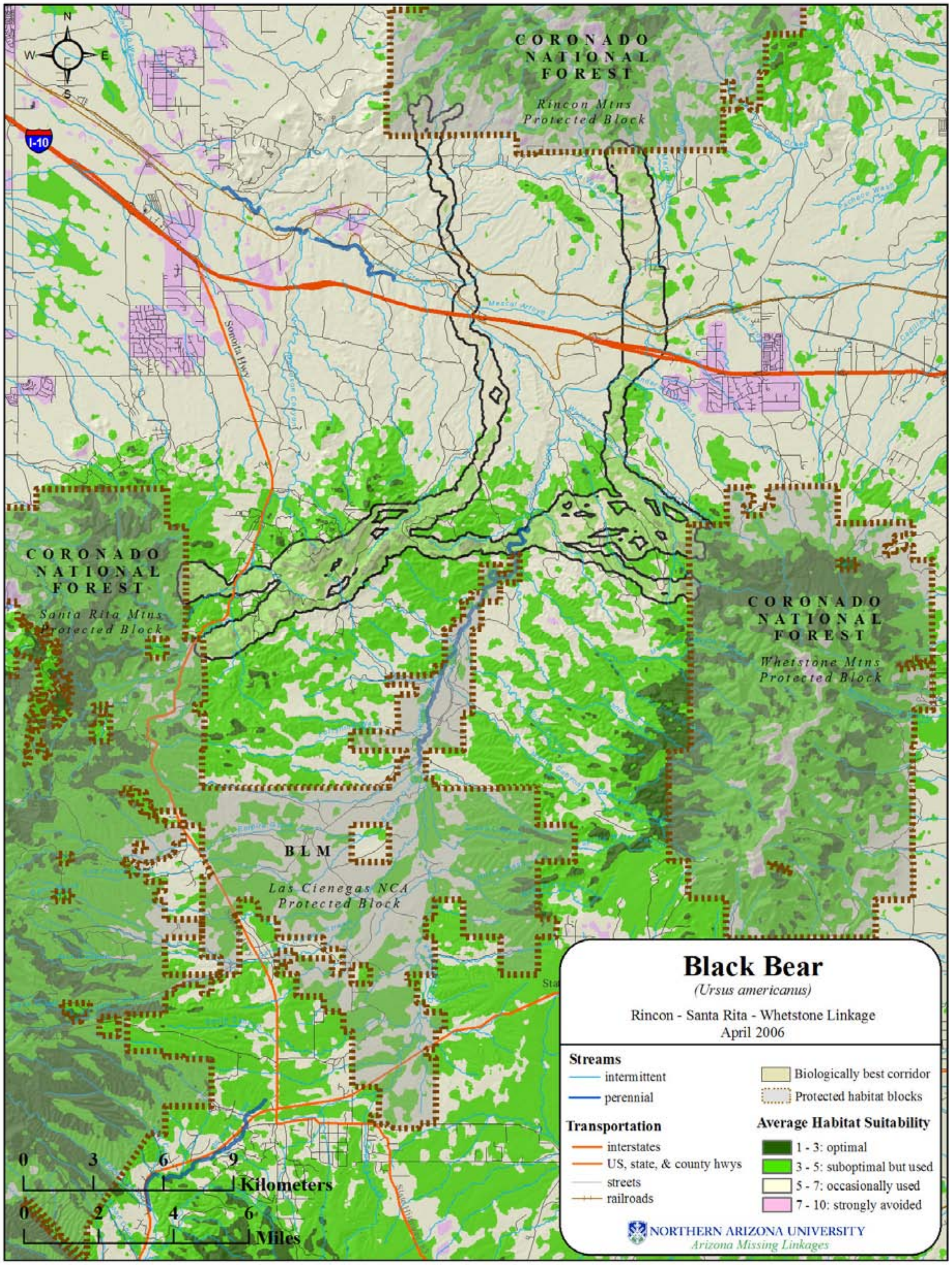

Figure 28: Modeled habitat suitability of black bear.

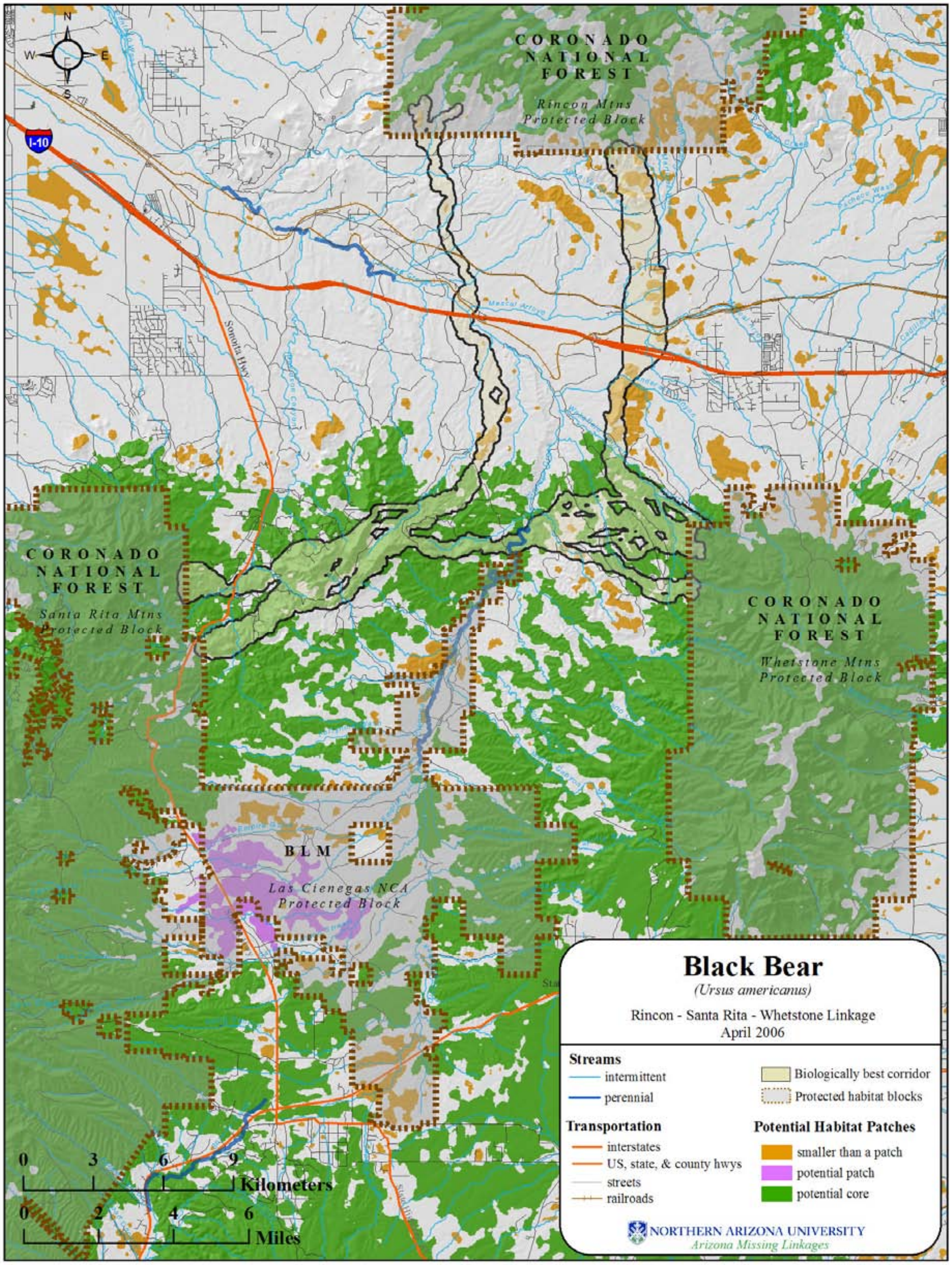

Figure 29: Potential habitat patches and cores for black bear.

Coues White-tailed Deer (*Odocoileus virginianus couesi*)

Justification for Selection
Coues white-tailed deer are sensitive to human disturbance (Galindo et al. 1993; Ockenfels et al. 1991) and are prey for mountain lions, jaguars, coyotes, bobcats, black bears, and eagles (Knipe 1977; Leopold 1959; Ligon 1927; Ockenfels et al. 1991). They are also important game species. Local populations of these deer have become extinct (apparently due to natural causes) in some small Arizona mountain ranges and connectivity is necessary for natural recolonization to occur.

Distribution
White-tailed deer range throughout most of the coterminous United States, into southern Canada (Smith 1991). As a small-sized, long-eared subspecies of white-tailed deer, Coues white-tailed deer are found primarily in the mountain ranges of southeastern Arizona, southwestern New Mexico, and northern Mexico (Knipe 1977).

Habitat Associations
The chief habitat association of Coues white-tailed deer is oak or oak-pinyon-juniper woodlands (Hoffmeister 1986; Knipe 1977). They also use chaparral, desert scrub, and mesquite habitats, and forage primarily on shrubs and trees (Gallina et al. 1981). Cacti and grasses are generally not used, and are of little importance to foraging (Gallina et al. 1981; Henry & Sowls 1980; Ockenfels et al. 1991). Coues white-tailed deer favor canyons and moderately steep slopes, and are usually found within several kilometers of water (Evans 1984; Ligon 1951; Ockenfels et al. 1991). Elevation does not appear to constrain the species; however, vegetation associated with elevation does. Coues white-tailed deer are susceptible to human disturbance – particularly hunting, dogs, cattle grazing, and roads (Galindo et al. 1993; Ockenfels et al. 1993).

Spatial Patterns
White-tailed deer are not territorial, and may have large overlap of home ranges (Smith 1991). Female home ranges in the Santa Rita Mountains were found to average 5.18 km^2, while male home ranges averaged 10.57 km^2 (Ockenfels et al. 1991). Knipe (1977) speculated that Coues white-tailed deer have a home range from 5-16 km^2. Galindo-Leal (1992) estimated the density of Coues white-tailed deer to range from 0.82-14.21 deer/km^2 in the Michilia Biosphere Reserve of Mexico, while Leopold (1959) estimated a density of 12-15 deer/km^2 in an undisturbed area of the Sierra Madre Occidental mountain area of Mexico. While this species does not migrate, it does shift habitat use seasonally, eating fruits (nuts, beans, berries) in summer, forbs and browse in fall, and evergreen browse in winter (McCulloch 1973; Welch 1960). Dispersal distance for young males at two areas in southern Texas established new areas of use 4.4±1.0 km and 8.2±4.3 km, respectively, from the center of their autumn home range (McCoy et al. 2005).

Conceptual Basis for Model Development
Habitat suitability model – Due to this species' strong preferences for woodlands and shrubs, vegetation received an importance weight of 65%, while elevation, topography, and distance from roads received a

weight of 5%, 15%, and 15%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – We defined minimum patch size for Coues white-tailed deer as 5.2 km^2, the average home range for females in the Santa Rita Mountains (Ockenfels 1991). While this species exhibits high home range overlap, we defined minimum core size as 26 km^2, or five times minimum patch size, to ensure potential cores could account for seasonal movements and use of different habitats. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

Biologically best corridor analysis – Most of the habitat within the linkage zone was calculated as suitable (cost <5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate a fair amount of suitable habitat for this species within the linkage area, although optimal habitat is concentrated within the wildland blocks of mountainous habitat (Figure 30). Between the Santa Rita and Rincon blocks, the average habitat suitability ranged from 1.1 to 8.6, with an average suitability of 4.7 (S.D: 1.0). Between the Santa Rita and Whetstone blocks, the average habitat suitability ranged from 1.0 to 7.5, with an average suitability of 3.7 (S.D: 1.3). Between the Rincon and Whetstone blocks, the average habitat suitability ranged from 1.0 to 7.5, with an average suitability of 4.1 (S.D: 1.2).

Union of biologically best corridors – The union of biologically best corridors provides significant amount of suitable habitat for Coues white-tailed deer, although the majority of suitable habitat is only classified as "suboptimal but usable." The farthest distance between a core or patch and another core or patch in any of the strands of the UBBC is approximately 700 meters, significantly less than recorded dispersal distances for this species.

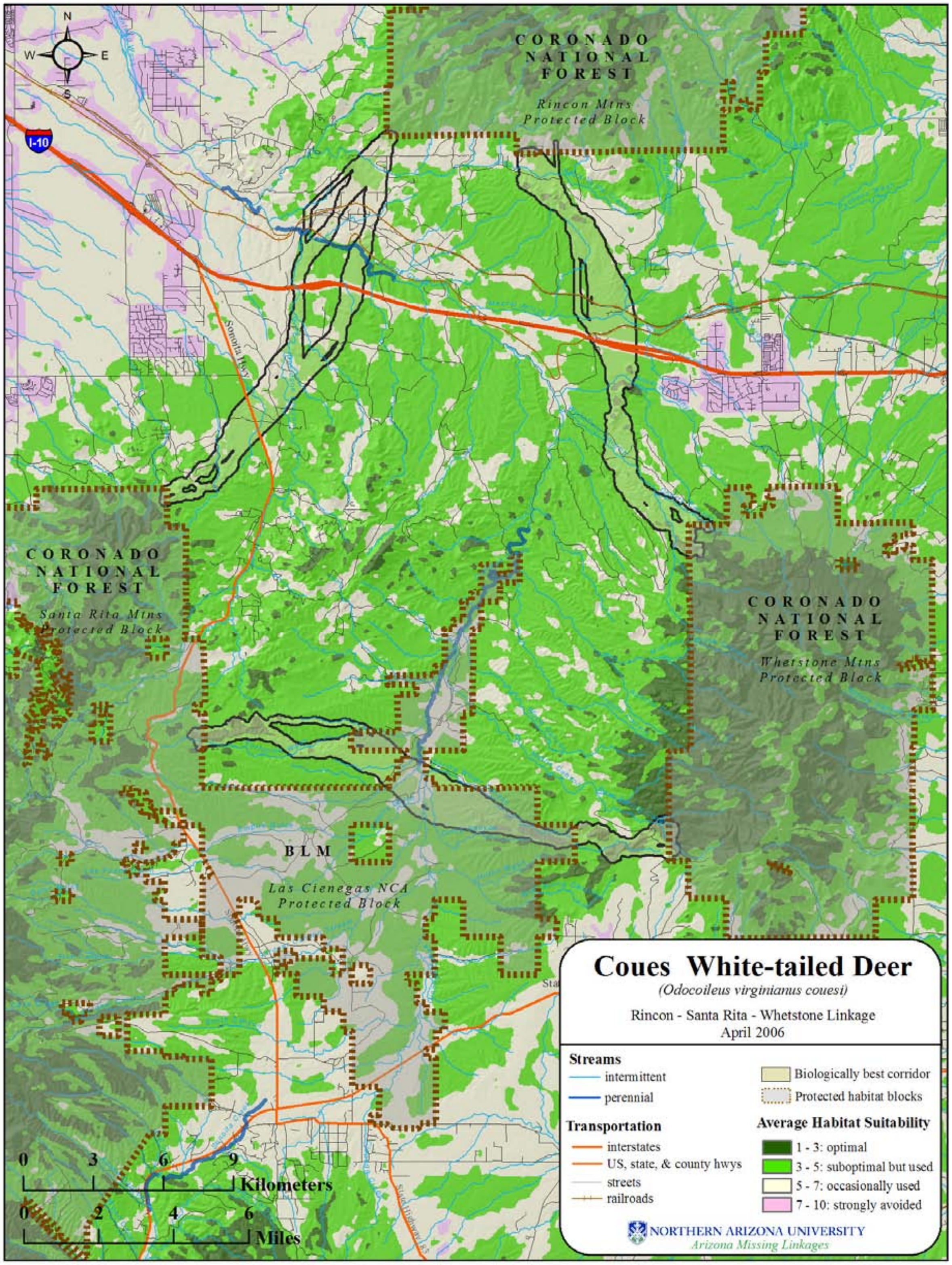

Figure 30: Modeled habitat suitability of Coues white-tailed deer.

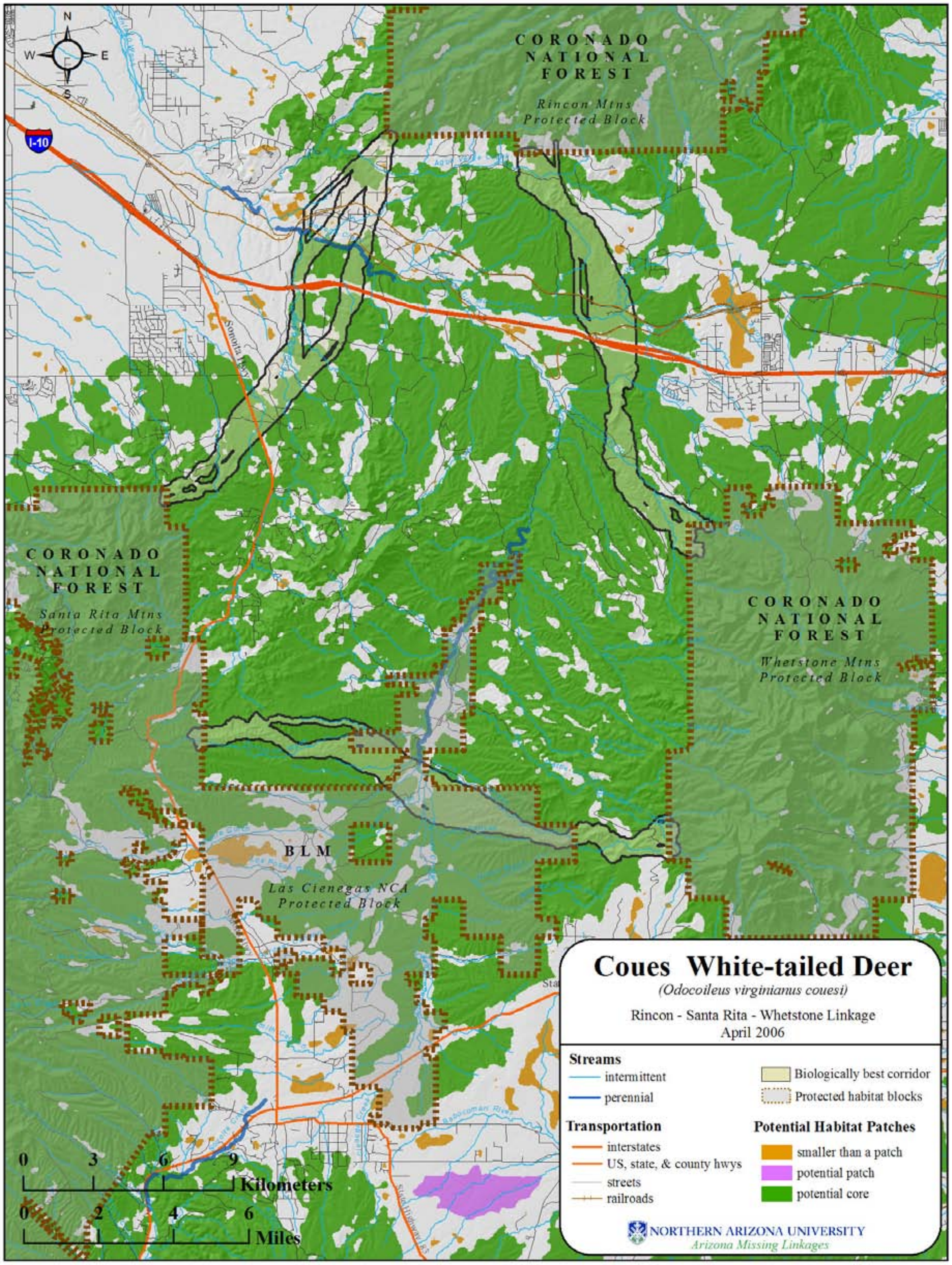

Figure 31: Potential habitat patches and cores for Coues white-tailed deer.

Justification for Selection

Jaguars are listed both as a federally endangered species without critical habitat and as Wildlife Special Concern species by the state of Arizona. They have suffered from a loss of habitat and hunting by ranchers, and persistence in Arizona is contingent on habitat corridors which allow movement from source populations in Mexico (AZGFD 2004).

Distribution

Jaguars have a limited range in Mexico, Guatemala, and Argentina, and are rare in the United States, Bolivia, Panama, Costa Rica, and Honduras, Peru, Colombia, and Venezuela (Seymour 1989). The largest known populations of jaguars exist in the Amazonian rainforest of Brazil. Within Arizona, they historically occurred in the southeastern part of the state, with several recorded sightings in central Arizona and as far north as the south rim of the Grand Canyon (Hoffmeister 1986).

Habitat Associations

Jaguars are adaptable to a variety of conditions, and are most often found in areas with sufficient prey, cover, and water supply (Seymour 1989). Within Arizona, habitat preferences are not clear; however, the species appears to prefer scrub and grasslands, evergreen forest, and conifer forest & woodlands (Hatten et al. 2003). It has been suggested that their apparent preference for grasslands may reflect movement corridors from the Sierra Madres of Mexico into southeast Arizona, rather than a preference for this habitat type (Hatten et al. 2003). Jaguars have a strong preference for water, and are often found within several kilometers of a water source such as perennial rivers or cienegas (Hatten et al. 2003; AZGFD 2004). They also appear to prefer intermediate to rugged terrain, and seem to be especially sensitive to human disturbance (Hatten et al. 2003; Menke & Hayes 2003).

Spatial Patterns

The home range of jaguars may vary from 10 to 170 km^2, with smaller home ranges in rain forests, and larger home ranges recorded in open habitats (AZGFD 2004). In Brazil, the average density of jaguars was approximately one animal per 25 km^2, with one female ranging up to 38 km^2, and one male ranging more than 90 km^2 (Schaller & Crawshaw 1980).

Conceptual Basis for Model Development

Habitat suitability model –Vegetation received an importance weight of 60%, while elevation, topography, and distance from roads received weights of 5%, 15%, and 20%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Minimum patch size for jaguar was defined as 41 km2 and minimum core size as 205 km2. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

Biologically best corridor analysis – Nearly all habitat within the linkage zone was calculated as suitable (score < 5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate ample suitable habitat for this species within the linkage area, although optimal habitat is concentrated within the wildland blocks of mountainous habitat (Figure 32). Between the Santa Rita and Rincon blocks, the average habitat suitability ranged from 1.2 to 8.9, with an average suitability of 3.9 (S.D: 1.1). Between the Santa Rita and Whetstone blocks, the average habitat suitability ranged from 1.0 to 7.2, with an average suitability of 2.6 (S.D: 1.1). Between the Rincon and Whetstone blocks, the average habitat suitability ranged from 1.4 to 8.8, with an average suitability of 3.8 (S.D: 1.0).

Union of biologically best corridors – The union of biologically best corridors provides significant amount of suitable habitat for jaguar, although the majority of suitable habitat is only classified as "suboptimal but usable." Interstate-10 provides the largest gap in connectivity between wildland blocks. Nearly all of the UBBC is a potential habitat core for this species.

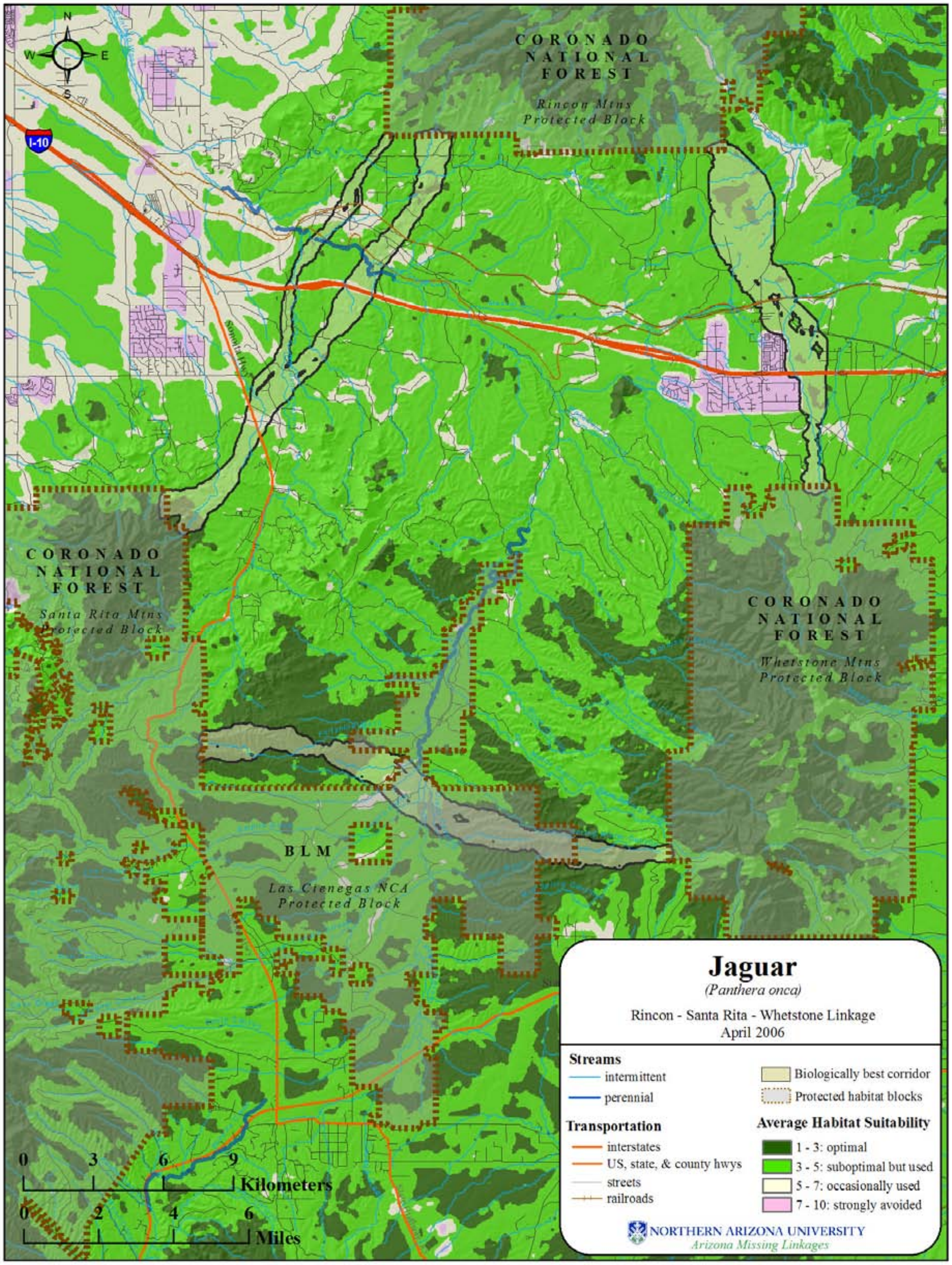

Figure 32: Modeled habitat suitability of jaguar.

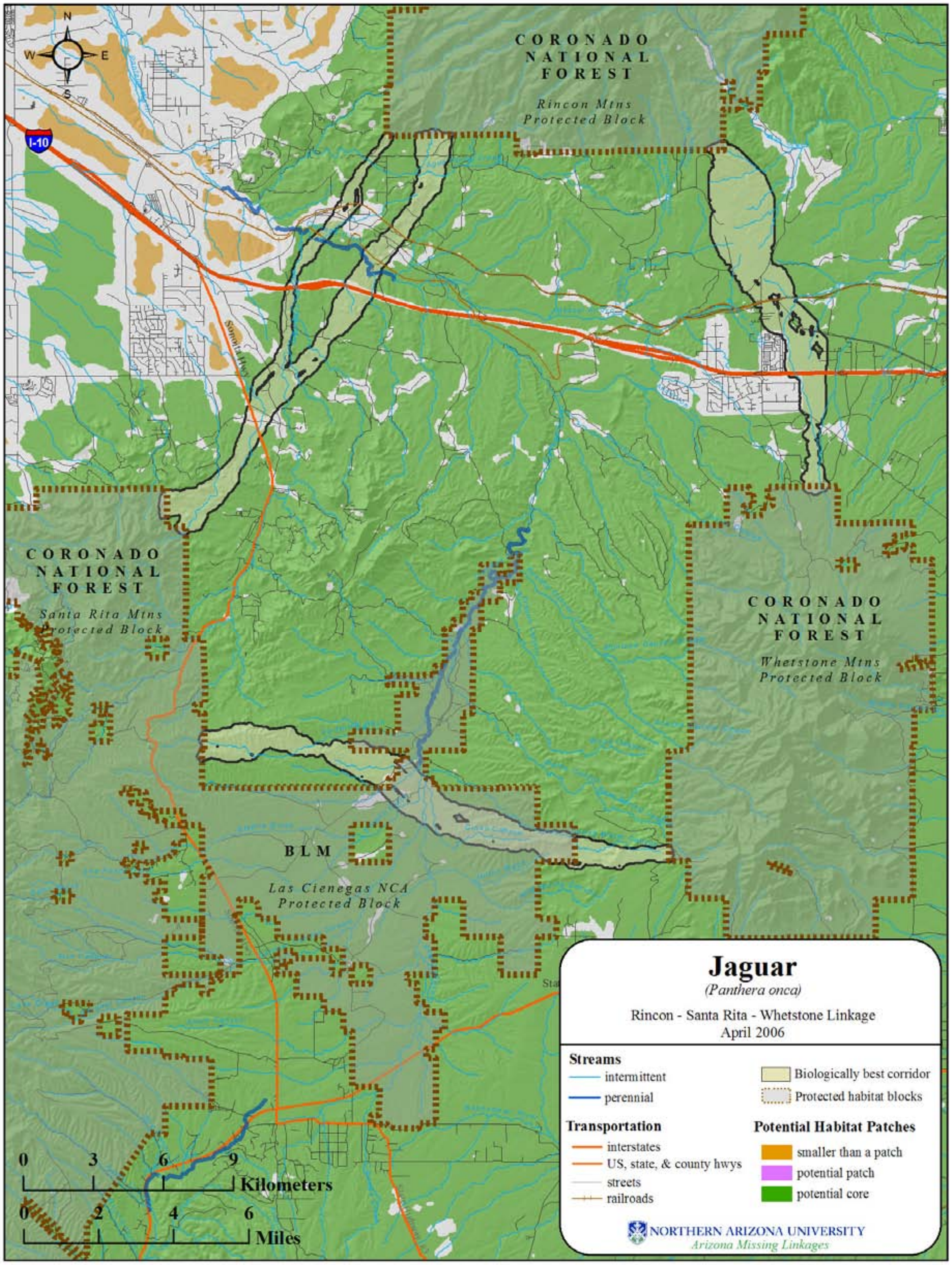

Figure 33: Potential habitat patches and cores for jaguar.

Javelina (*Tayassu tajacu*)

Justification for Selection

Young javelina are probably prey items for predators such as coyotes, bobcats, foxes (Hoffmeister 1986), and jaguars (Seymour 1989). Although they habituate well to human development, their herds require contiguous patches of dense vegetation for foraging and bed sites (Hoffmeister 1986; Ticer et al. 2001; NatureServe 2005). Roads are dangerous for urban dwelling javelina (Ticer et al. 1998). Javelina are an economically important game species (Ticer et al. 2001). They probably play an important role in seed dispersal and as part of the natural disturbance regime.

Distribution

Javelina are found from Northern Argentina and northwestern Peru to north-central Texas, northwestern New Mexico, and into central Arizona (NatureServe 2005). Specifically in Arizona, they occur mostly south of the Mogollon Rim and west to Organ Pipe National Monument (Hoffmeister 1986).

Habitat Associations

Javelina have adapted to a variety of plant communities, varied topography, and diverse climatic conditions (Ticer et al. 2001). However, javelina confine themselves to habitats with dense vegetation (Ticer et al. 2001; Hoffmeister 1986; NatureServe 2005), and rarely are found above the oak forests on mountain ranges (Hoffmeister 1986). Javelina prefer habitat types such as areas of open woodland overstory with shrubland understory, desert scrub, and thickets along creeks and old stream beds (Ticer et al. 1998; Hoffmeister 1986). They also will forage in chaparral (Neal 1959; Johnson and Johnson 1964). Prickly pear cactus provides shelter, food, and water (Ticer et al. 2001, Hoffmeister 1986). Other plants in javelina habitat include palo verde, jojob, ocotillo, catclaw, and mesquite (Hoffmeister 1986). Javelina habituate well to human development, as long as dense vegetation is available (Ticer et al. 2001). Their elevation range is from 2000 to 6500 feet (New Mexico Department of Fish and Game 2004).

Spatial Patterns

Javelina live in stable herds, though occasionally some individuals may move out of the herd to join another or establish their own (Hoffmeister 1986). Home ranges for herds have been reported as 4.7 km^2 in the Tortolita Mountains (Bigler 1974), 4.93 km^2 near Prescott (Ticer et al. 1998), and between 1.9 and 5.5 ha in the Tonto Basin (Ockenfels and Day 1990). Dispersal of javelina has not been adequately studied, but they are known to be capable of extensive movements of up to several kilometers (NatureServe 2005).

Conceptual Basis for Model Development

Habitat suitability model – Vegetation as it relates to both forage and cover requirements is very important for javelina. Sowls (1997) lists climate, vegetation, and topography as important factors in javelina habitat use. For this species', vegetation received an importance weight of 50%, while elevation and topography received weights of 30% and 20%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Minimum habitat patch size for javelina was defined as 44 ha, based on an estimate for a single breeding season for one "herd" of one breeding pair. The estimate for minimum habitat core size is 222 ha, based on an estimate of 10 breeding seasons for 1 herd of mean size 9 to 12 animals (Chasa O'Brien, personal comm.). The calculation of area is based upon 3 different estimates of density of animals/ha in south-central and southern Arizona. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – Nearly all habitat within the linkage zone was calculated as suitable (cost < 5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate ample potential suitable habitat for this species within the linkage area (Figure 34). Between the Las Cienegas and Rincon blocks, the average habitat suitability ranged from 1.0 to 6.2, with an average suitability of 1.9 (S.D: 0.7). Between the Las Cienegas and Whetstone blocks, the average habitat suitability ranged from 1.5 to 4.8, with an average suitability of 2.7 (S.D: 0.9). Between the Rincon and Whetstone blocks, the average habitat suitability ranged from 1.5 to 5.7, with an average suitability of 1.7 (S.D: 0.4).

Union of biologically best corridors – The UBBC adequately serves this species. Nearly the entire linkage area is a potential habitat core (Figure 35).
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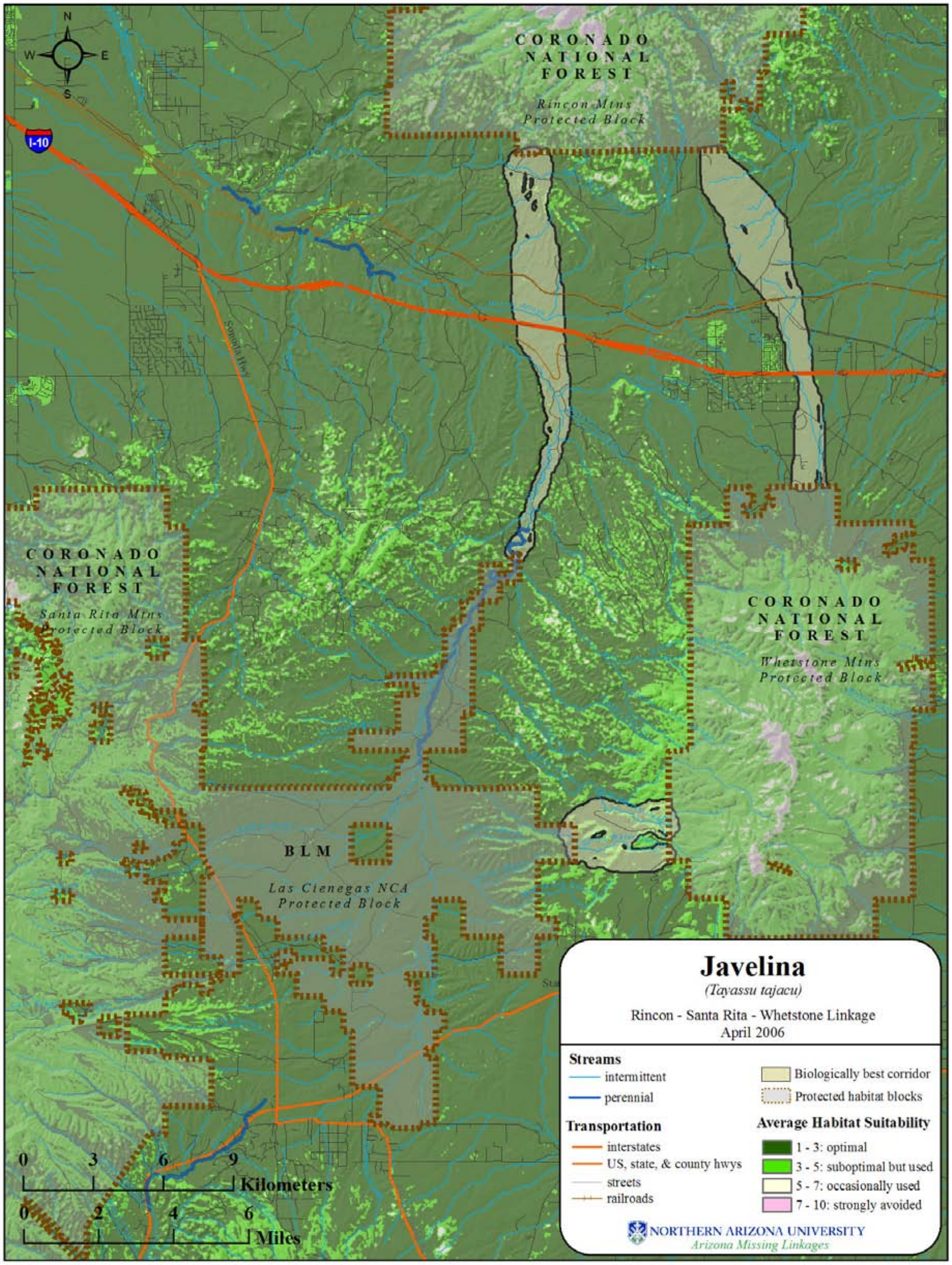

Figure 34: Modeled habitat suitability of javelina.

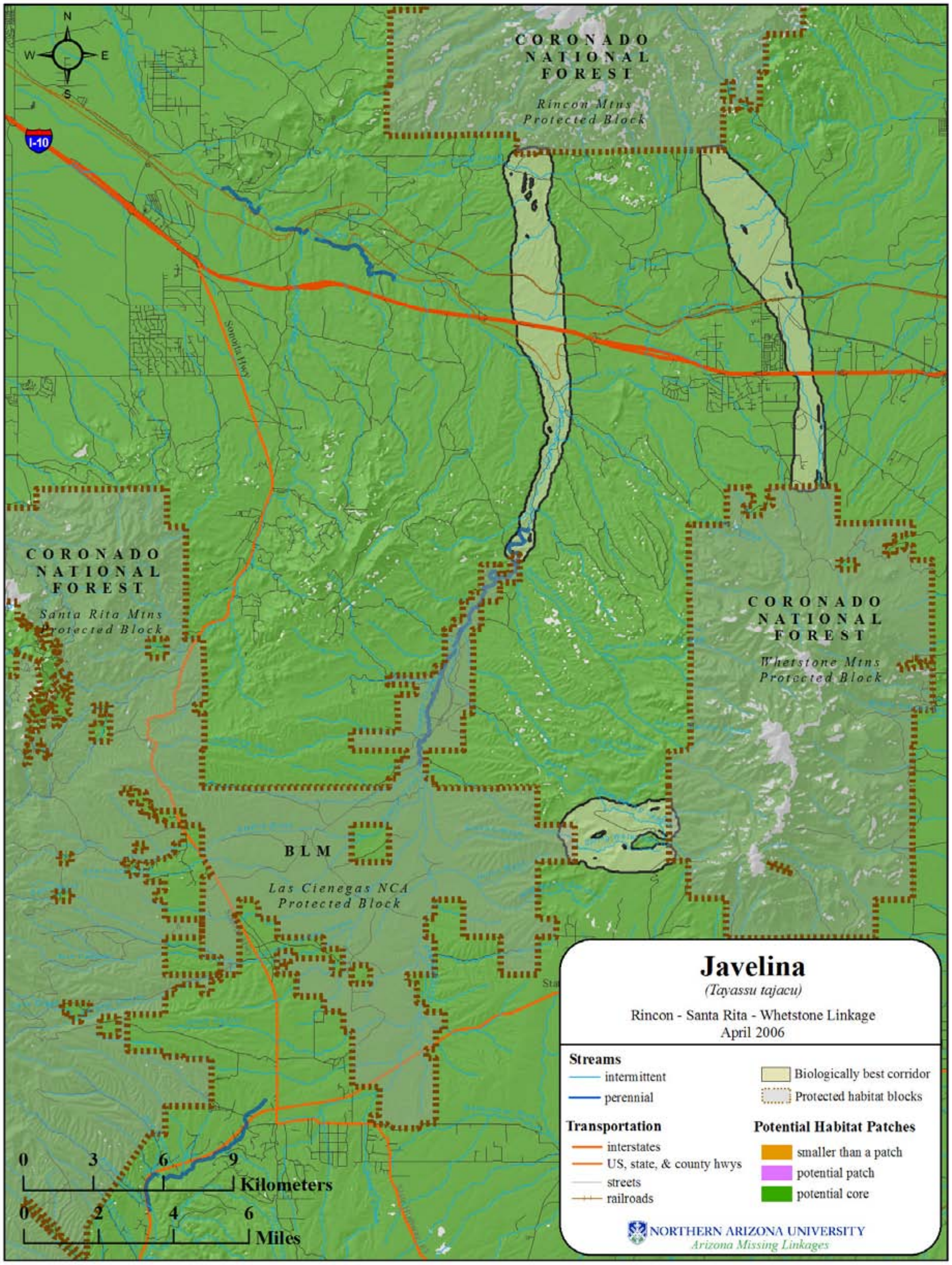

Figure 35: Potential habitat patches and cores for javelina.

Mountain Lion (*Puma concolor*)

Justification for Selection
Mountain lions occur in low densities across their range and require a large area of connected landscapes to support even minimum self sustaining populations (Beier 1993; Logan and Sweanor 2001). Connectivity is important for hunting, seeking mates, avoiding other pumas or predators, and dispersal of juveniles (Logan and Sweanor 2001).

Distribution
Historically, mountain lions ranged from northern British Columbia to southern Chile and Argentina, and from coast to coast in North America (Currier 1983). Presently, the mountain lion's range in the United States has been restricted, due to hunting and development, to mountainous and relatively unpopulated areas from the Rocky Mountains west to the Pacific coast, although isolated populations may still exist elsewhere (Currier 1983). In Arizona, mountain lions are found throughout the state in rocky or mountainous areas (Hoffmeister 1986).

Habitat Associations
Mountain lions are associated with mountainous areas with rocky cliffs and bluffs (Hoffmeister 1986; New Mexico Game and Fish Department 2004). They use a diverse range of habitats, including conifer, hardwood, and mixed forests, and shrubland, chaparral, and desert environments (NatureServe 2005). They are also found in pinyon/juniper on benches and mesa tops (New Mexico Game and Fish Department 2004). Mountain lions are found at elevations ranging from 0 to 4000 m (Currier 1983).

Spatial Patterns
Home range sizes of mountain lions vary depending on sex, age, and the distribution of prey. One study in New Mexico reported annual home range size averaged 193.4 km^2 for males and 69.9 km^2 for females (Logan and Sweanor 2001). This study also reported daily movements averaging 4.1 km for males and 1.5 km for females (Logan and Sweanor 2001). Dispersal rates for juvenile mountain lions also vary between males and females. Logan and Sweanor's study found males dispersed an average of 102.6 km from their natal sites, and females dispersed an average of 34.6 km. A mountain lion population requires 1000 - 2200 km^2 of available habitat in order to persist for 100 years (Beier 1993). These minimum areas would support about 15-20 adult cougars (Beier 1993).

Conceptual Basis for Model Development
Habitat suitability model – While mountain lions can be considered habitat generalists, vegetation is still the most important factor accounting for habitat suitability, so it received an importance weight of 70%, while topography received a weight of 10%, and distance from roads received a weight of 20%. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Minimum patch size for mountain lions was defined as 79 km^2, based on an average home range estimate for a female in excellent habitat (Logan & Sweanor 2001; Dickson & Beier 2002). Minimum core size was defined as 395 km^2, or five times minimum patch size. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

Biologically best corridor analysis – Most of the habitat within the linkage zone was calculated as suitable (cost <5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate a fair amount of suitable habitat for this species within the potential linkage area, although optimal habitat is concentrated within the wildland blocks of mountainous habitat (Figure 36). Between the Santa Rita and Rincon blocks, the average habitat suitability ranged from 2.0 to 8.9, with an average suitability of 4.9 (S.D: 0.8). Between the Santa Rita and Whetstone blocks, the average habitat suitability ranged from 1.0 to 7.0, with an average suitability of 3.6 (S.D: 1.4). Between the Rincon and Whetstone blocks, the average habitat suitability ranged from 1.2 to 8.9, with an average suitability of 4.6 (S.D: 1.2).

Union of biologically best corridors – The union of biologically best corridors provides significant amount of suitable habitat for mountain lion, although the majority of suitable habitat is only classified as "suboptimal but usable." The farthest distance between a core or patch and another core or patch in any of the strands of the UBBC is approximately 3.5 km in the Santa Rita – Rincon strand, although distance between a large potential habitat patch (not large enough to support a breeding pair) and potential population core is only approximately 1.5 km. This is much less than recorded movements of the mountain lion; this species appears to be well-served by the linkage design (Figure 37).

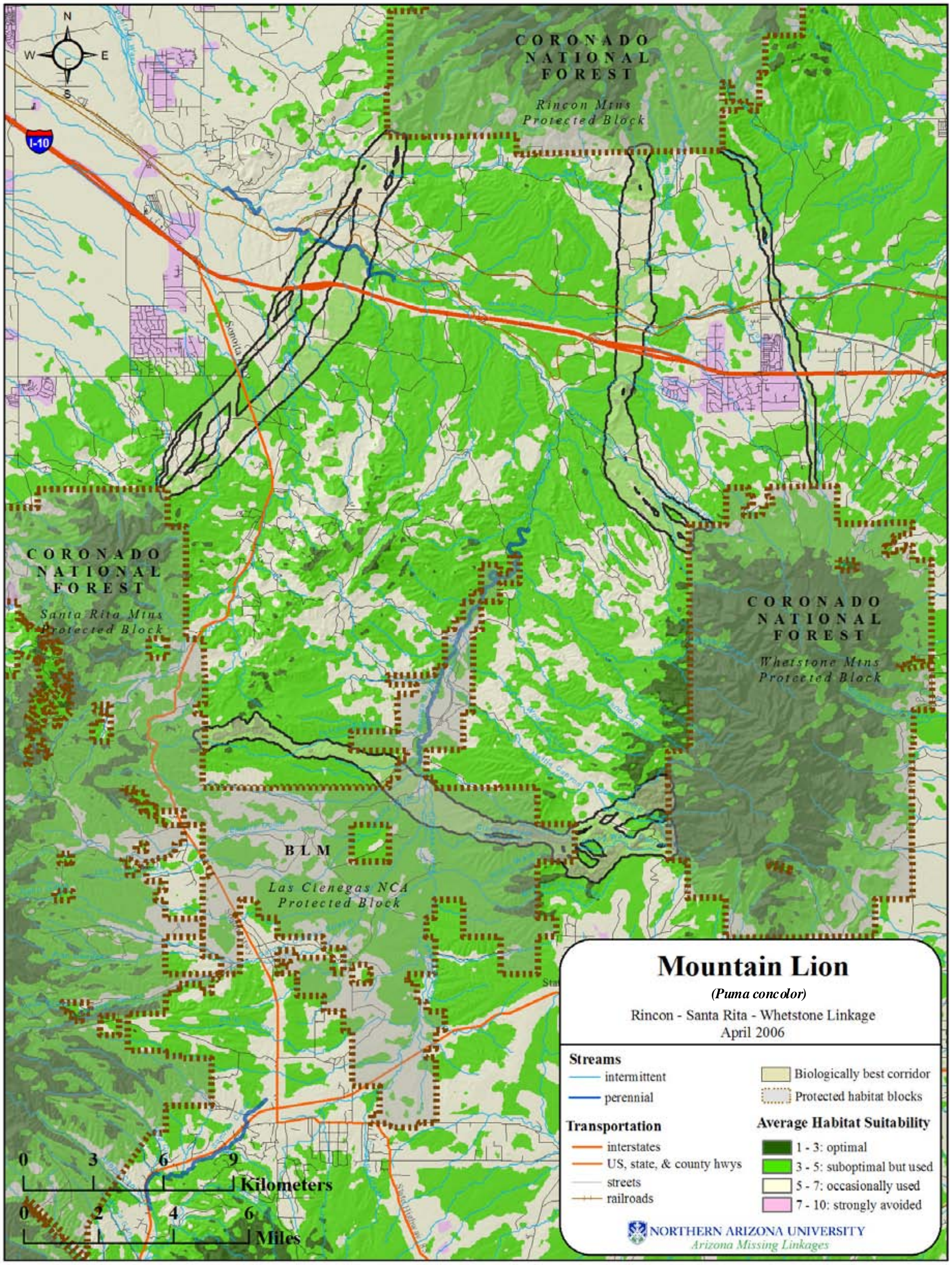

Figure 36: Modeled habitat suitability of mountain lion.

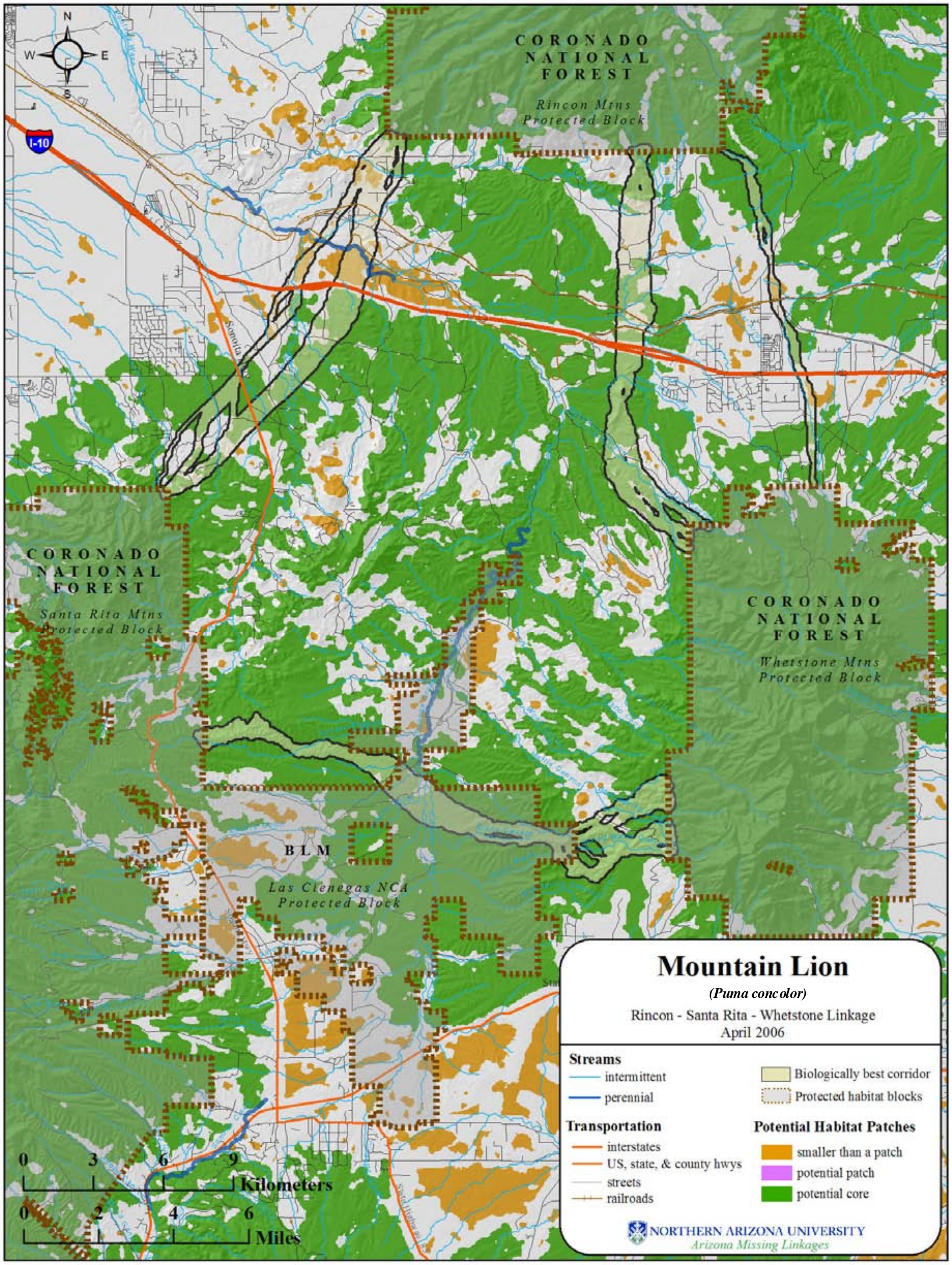

Figure 37: Potential habitat patches and cores for mountain lion.

Mule Deer (*Odocoileus hemionus*)

Justification for Selection

Mule deer are widespread throughout Arizona, and are an important prey species for carnivores such as mountain lion, jaguar, bobcat, and black bear (Anderson & Wallmo 1984). Road systems may affect the distribution and welfare of mule deer (Sullivan and Messmer 2003).

Distribution

Mule deer are found throughout most of western North America, extending as far east as Nebraska, Kansas, and western Texas. In Arizona, mule deer are found throughout the state, except for the Sonoran desert in the southwestern part of the state (Anderson & Wallmo 1984).

Habitat Associations

Mule deer in Arizona are categorized into two groups based on the habitat they occupy. In northern Arizona mule deer inhabit yellow pine, spruce-fir, buckbrush, snowberry, and aspen habitats (Hoffmeister 1986). The mule deer found in the yellow pine and spruce-fir live there from April to the beginning of winter, when they move down to the pinyon-juniper zone (Hoffmeister 1986). Elsewhere in the state, mule deer live in desert shrub, chaparral or even more xeric habitats, which include scrub oak, mountain mahogany, sumac, skunk bush, buckthorn, and manzanita (Wallmo 1981; Hoffmeister 1986).

Spatial Patterns

The home ranges of mule deer vary depending upon the availability of food and cover (Hoffmeister 1986). Swank (1958) reports that home ranges of mule deer vary from 2.6 to 5.8 km^2, with bucks' home ranges averaging 5.2 km^2 and does slightly smaller (Hoffmeister 1986). Deer that require seasonal migration movements use approximately the same winter and summer home ranges in consecutive years (Anderson & Wallmo 1984). Desert mule deer home ranges are larger, varying from 5.2 to 13 km^2, with bucks having larger home ranges than does. Desert mule deer are generally not considered migratory, although they may make transient movements of several miles. Dispersal distances for male mule deer have been recorded from 97 to 217 km, and females have moved 180 km (Anderson & Wallmo 1984). Two desert mule deer yearlings were found to disperse 18.8 and 44.4 km (Scarbrough & Krausman 1988).

Conceptual Basis for Model Development

Habitat suitability model – Vegetation has the greatest role in determining deer distributions in desert systems, followed by topography (Jason Marshal, personal comm.). For this reason, vegetation received an importance weight of 80%, while topography and distance from roads received weights of 15% and 5%, respectively. For specific scores of classes within each of these factors, Table 4.

Patch size & configuration analysis – Minimum patch size for mule deer was defined as 9 km^2 and minimum core size as 45 km^2. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

Biologically best corridor analysis – Nearly all habitat within the linkage zone was calculated as suitable (cost < 5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate significant amounts of suitable habitat for this species within the potential linkage area (Figure 38). Between the Santa Rita and Rincon blocks, the average habitat suitability ranged from 1.9 to 8.2, with an average suitability of 3.2 (S.D: 1.1). Between the Santa Rita and Whetstone blocks, the average habitat suitability ranged from 1.9 to 7.7, with an average suitability of 2.8 (S.D: 1.0). Between the Rincon and Whetstone blocks, the average habitat suitability ranged from 1.9 to 7.9, with an average suitability of 3.4 (S.D: 1.3).

Union of biologically best corridors – The UBBC adequately serves this species. Nearly the entire linkage area is a potential habitat core (Figure 39).

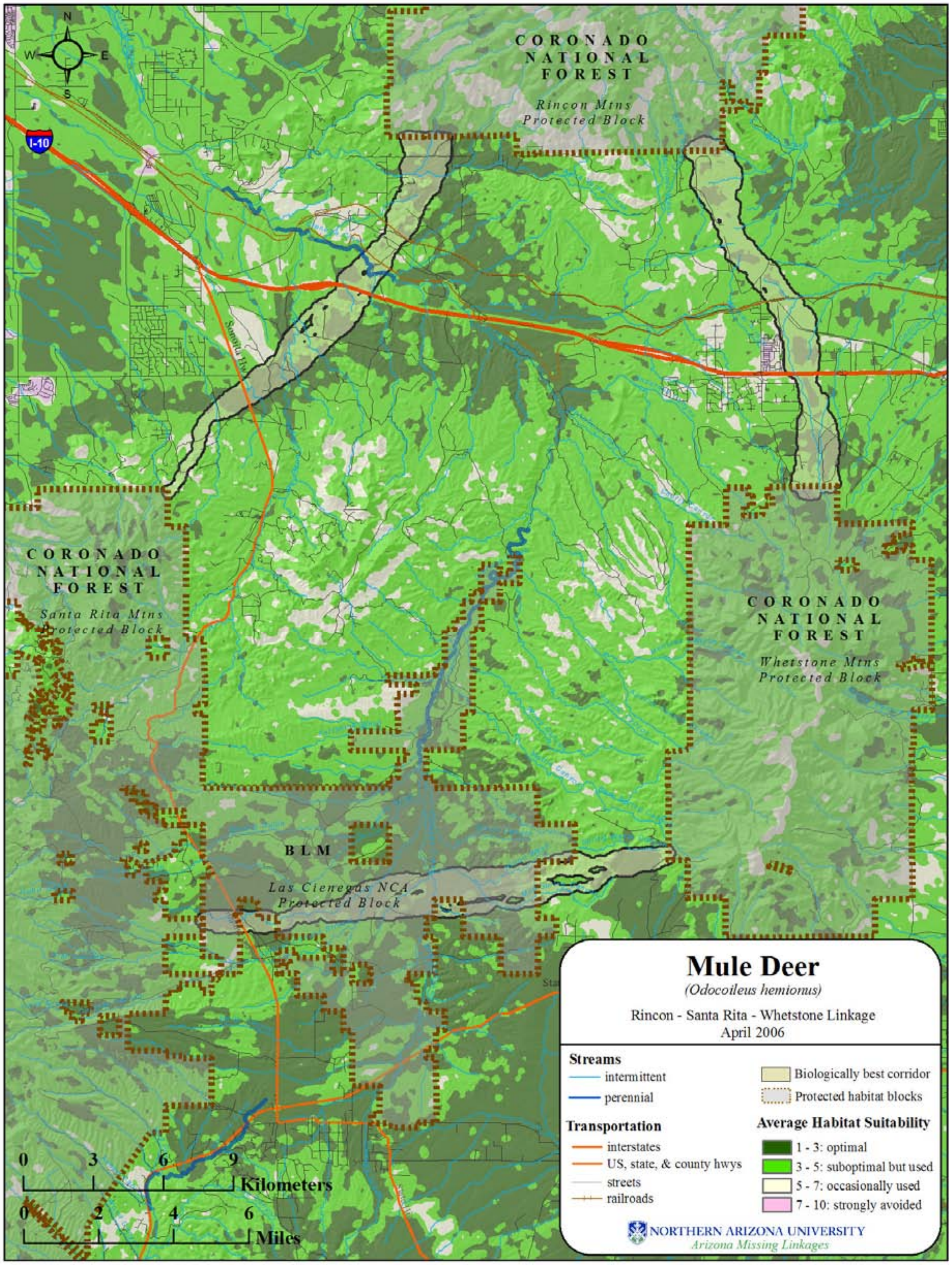

Figure 38: Modeled habitat suitability of mule deer.

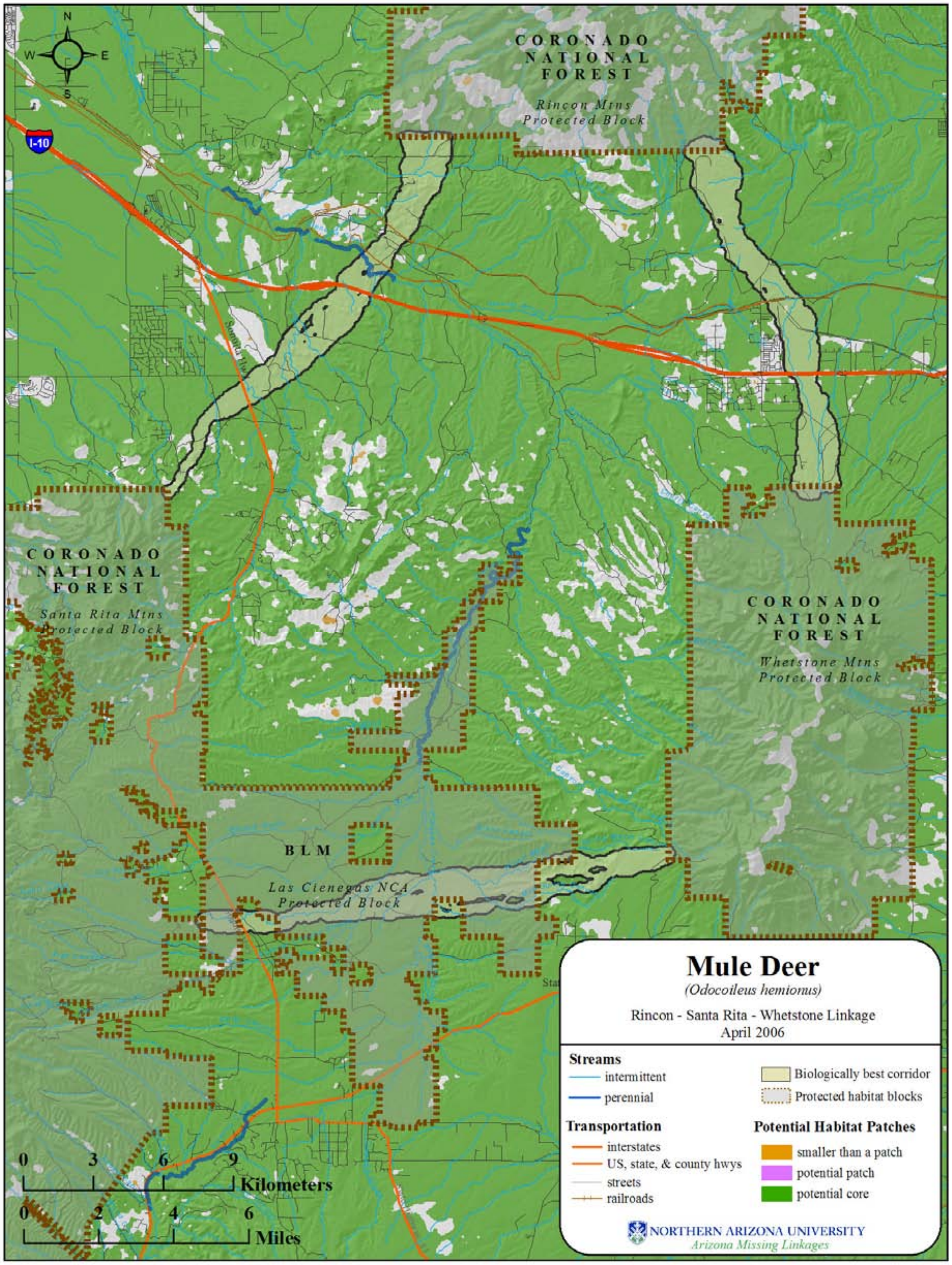

Figure 39: Potential habitat patches and cores for mule deer.

Porcupine (*Erethizon dorsatum*)

Justification for Selection

The porcupine's range has been reduced in some areas due to changes in human distribution and land use (Woods 1973). Porcupines are frequently killed by automobiles while crossing roads (Woods 1973).

Distribution

Porcupines are widespread in much of North America, from Alaska and northern Canada to parts of northern Mexico (Woods 1973). The porcupine's range includes most of Arizona in forested, mountainous regions of the state as well as riparian areas in lower elevations; they are considered absent or rare in desert areas (Hoffmeister 1986).

Habitat Associations

Porcupines inhabit montane and subalpine forests that include ponderosa pine, spruce-fir, aspen, pinyon, juniper, and oak in higher elevations. They also live in cottonwood-willow forests of riparian areas and mesquite thickets of semidesert shrublands (New Mexico Department of Game and Fish 2004). In Arizona, they also occur in grassland, chaparral or desert scrub (Hoffmeister 1986). Porcupines consume bark from trees in these areas, as well as mistletoe, pine needles, oak leaves, acorns, fungi, buckbrush, and the fruit of prickly pear cactus (New Mexico Department of Game and Fish 2004). Porcupines seek out rock piles, rocky slopes, mine shafts, and caves for shelter (Hoffmeister 1986).

Spatial Patterns

Home ranges of porcupines are restricted, with summer range larger than winter range (Woods 1973). Average summer home range is 14 hectares (Marshall et al. 1962), while winter home range is up to 5 hectares (Smith 1979). Average yearly home range has been estimated as 70 ha (Roze 1989). They will occupy the same dens for many years and even generations (Hoffmeister 1986). Individuals move an average of 1.5 kilometers to and from their winter den (Woods 1973). Dispersal among porcupines is female-biased, with juvenile female porcupines dispersing an average of 3.7km while juvenile males generally remain within their natal ranges (Sweitzer and Berger 1998).

Conceptual Basis for Model Development

Habitat suitability model – Vegetation received an importance weight of 87%, while topography and distance from roads received weights of 3% and 10%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Minimum patch size for mule deer was defined as 70 ha and minimum core size as 250 ha. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – The standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate a fair amount of suitable habitat for this species within the potential linkage area, although optimal habitat is concentrated within the wildland blocks of mountainous habitat (Figure 40). Between the Santa Rita and Rincon blocks, the average habitat suitability ranged from 1.0 to 8.7, with an average suitability of 4.7 (S.D: 1.0). Between the Santa Rita and Whetstone blocks, the average habitat suitability ranged from 1.0 to 9.0, with an average suitability of 3.6 (S.D: 1.7). Between the Rincon and Whetstone blocks, the average habitat suitability ranged from 1.0 to 8.7, with an average suitability of 4.1 (S.D: 1.2).

Union of biologically best corridors – Although majority of habitat within UBBC is suboptimal but usable, UBBC provides additional habitat throughout. Nearly all strands provide contiguous habitat that could be used by this species (Figure 41).

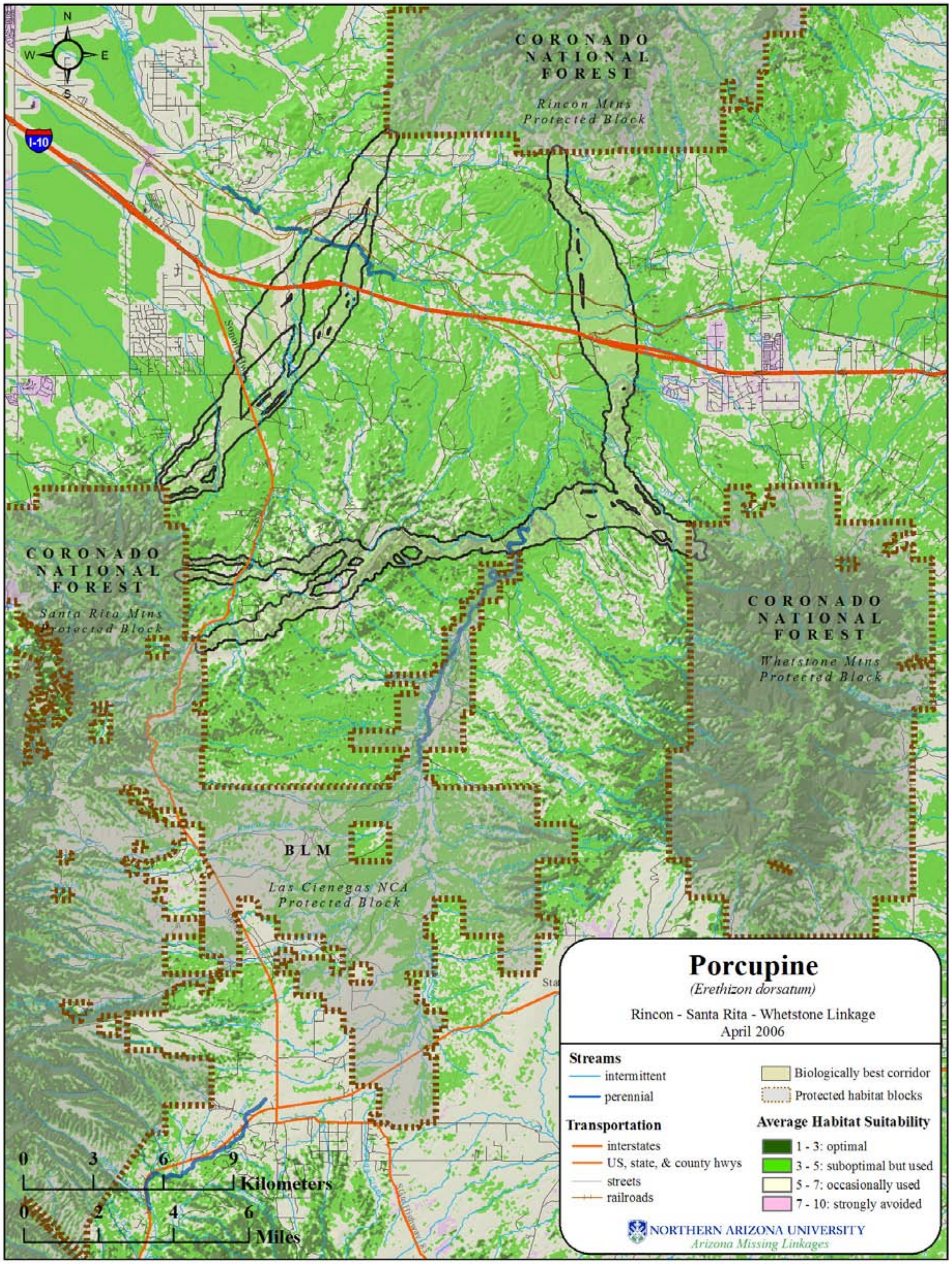

Figure 40: Modeled habitat suitability of porcupine.

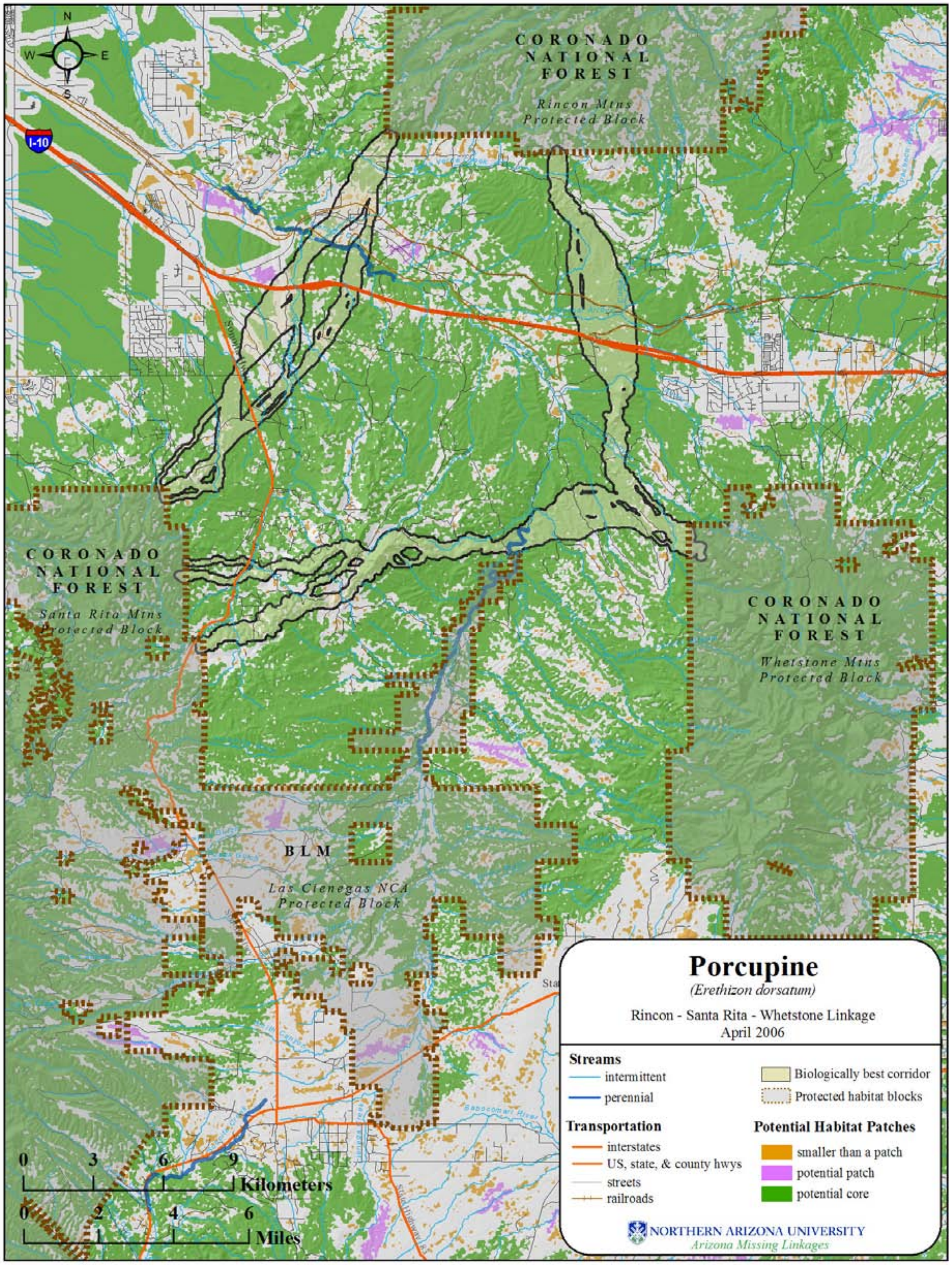

Figure 41: Potential habitat patches and cores for porcupine.

Pronghorn (*Antilocapra americana*)

Justification for Selection

Pronghorn are known to be susceptible to habitat degradation and human development (AZGFD 2002a). One example of harmful development is right of way fences for highways and railroads, which are the major factor affecting pronghorn movements across their range (Ockenfels et al. 1997). Existence of migration corridors is critical to pronghorn survival for allowing movement to lower elevation winter ranges away from high snowfall amounts (Ockenfels et al. 2002). The Sonoran pronghorn subspecies, which requires large tracts of land to obtain adequate forage, has only 25 individuals remaining due to loss of habitat and drought (AZGFD 2002b).

Distribution

Pronghorn range through much of the western United States, and are found throughout the grasslands of Arizona, except in the southeastern part of the state (Hoffmeister 1986). The Sonoran pronghorn subspecies is found in northwest Sonora, Mexico and southwestern Arizona including on the Cabeza Prieta National Wildlife Refuge, the Organ Pipe Cactus National Monument, the Barry M. Goldwater Gunnery Range (AZGFD 2002b).

Habitat Associations

Pronghorn are found in areas of grasses and scattered shrubs with rolling hills or mesas (Ticer and Ockenfels 2001; New Mexico Department of Fish and Game 2004). They inhabit shortgrass plains as well as riparian areas of sycamore and rabbitbrush, and oak savannas (New Mexico Department of Fish and Game 2004). In winter, pronghorn rely on browse, especially sagebrush (O'Gara 1978). Pronghorn prefer gentle terrain, and avoid rugged areas (Ockenfels et al. 1997). Woodland and coniferous forests are also generally avoided, especially when high tree density obstructs vision (Ockenfels et al. 2002). Also for visibility, pronghorn prefer slopes that are less than 30% (Yoakum et al. 1996). Sonoran pronghorn habitat is described as broad alluvial valleys separated by block-faulted mountains (AZGFD 2002b). Elevations for this subspecies vary from 400 to 1600 feet (AZGFD 2002b). Sonoran pronghorn are found in vegetation types that include creosote bush, bursage/palo verde-mixed cacti, and saguaro (deVos and Miller 2005).

Spatial Patterns

In northern populations, home range has been estimated to range from 0.2 to 5.2 km^2, depending on season, terrain, and available resources (O'Gara 1978). However, large variation in sizes of home and seasonal ranges due to habitat quality and weather conditions make it difficult to apply data from other studies (O'Gara 1978). Other studies report home ranges that average 88 km^2 (Ockenfels et al. 1994) and 170 km^2 in central Arizona (Bright & Van Riper III 2000), and in the 75 – 125 km^2 range (n=37) in northern Arizona (Ockenfels et al. 1997). The Sonoran pronghorn subspecies is known to require even larger tracts of land to obtain adequate forage (AZGFD 2002b). One study of collared Sonoran pronghorn found the home range of 4 males to range from 64 km^2 – 1214 km^2 (avg. 800 km^2), while females ranged from 41km^2 -1144 km^2 (avg. 465.7 km^2) (AZGFD 2002b). Another study of Sonoran pronghorn found home range to range from 43 to 2,873 km^2, with mean home range size of 511 + 665 SD km^2 (n=22), which is much larger than other pronghorn subspecies (Hervert et al. 2005). One key element in pronghorn movement is distance to water. One study found that 84% of locations were less than 6 km from water sources (Bright & Van Riper III 2000), and another reports collared pronghorn locations from 1.5 – 6.5 km of a water source (Yoakum et al. 1996). Habitats within 1 km of water appear to be key fawn bedsite areas for neonate fawns (Ockenfels et al. 1992).

Conceptual Basis for Model Development

Habitat suitability model – Vegetation received an importance weight of 45%, while topography and distance from roads received weights of 37% and 18%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Minimum patch size for pronghorn was defined as 50 km^2 and minimum core size as 250 km^2. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

Biologically best corridor analysis – Because pronghorn do not occur in the forested mountains of the Rincon, Santa Rita, and Whetstone wildland blocks, we did not create a biologically best corridor for the species. Instead, we used the standard habitat suitability model to assess potential habitat for this species within the union of biologically best corridors.

Results & Discussion

Union of biologically best corridors – Most suitable habitat for this pronghorn is concentrated in the open grasslands of Las Cienegas National Conservation Area (Figure 42). The union of least-cost corridors encompasses a fair amount of potential habitat for this species; however, habitat between the Rincon and Santa Rita/Whetstone wildland blocks is not contiguous with currently used habitat in Las Cienegas NCA (Figure 43).

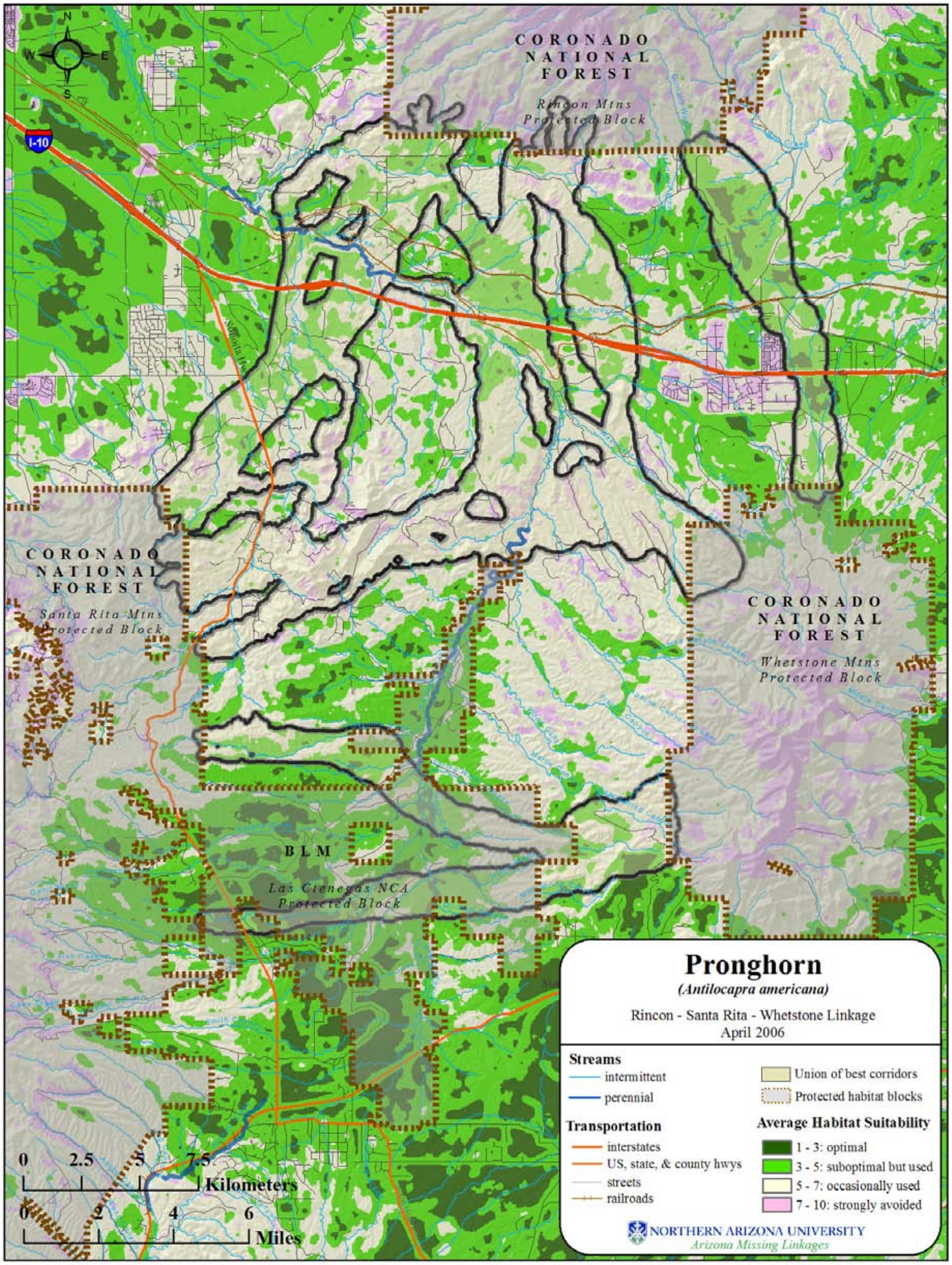

Figure 42: Modeled habitat suitability of pronghorn.

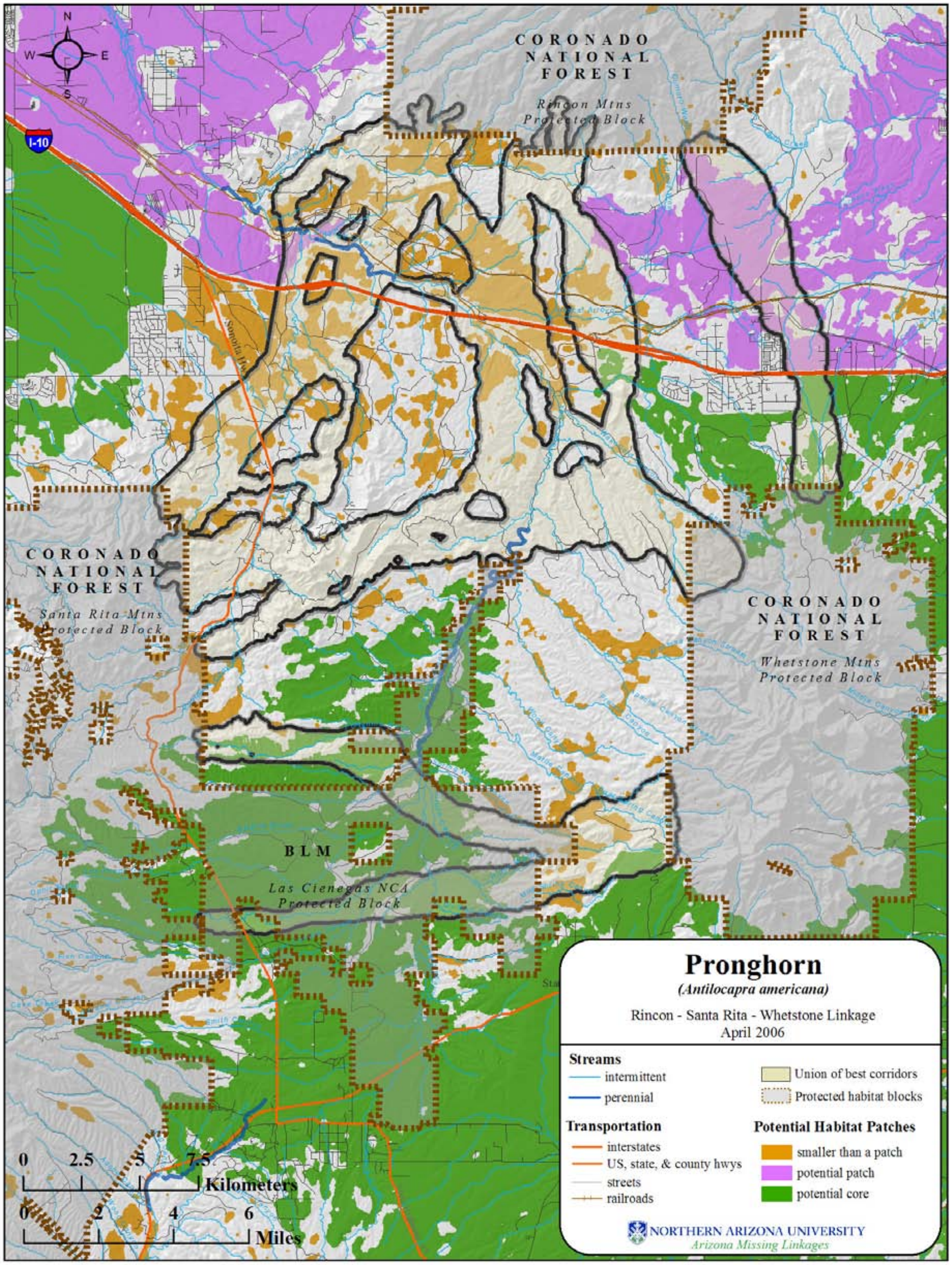

Figure 43: Potential habitat patches and cores for pronghorn.

White-nosed Coati (*Nasua narica*)

Justification for Selection
White-nosed coatis are primarily forest species, and may serve as prey for top carnivores such as mountain lion (NMDGF 2004). They also appear to be dispersal-limited, and sensitive to roads and habitat fragmentation.

Distribution
White-nosed coatis are found in southern Arizona and New Mexico, and Texas, and throughout Mexico and Central America (Gompper 1995). In Arizona, coatis are found as far north as the Gila River, and throughout southeastern Arizonan forests.

Habitat Associations
Coatis are primarily a forest species, preferring shrubby and woodland habitats with good horizontal cover (Gompper 1995; C. Hass, personal comm.). While they do not have strong topographic preferences, they are generally found within several miles of water, and prefer riparian habitats if available (Gompper 1995). In Arizona, elevation places no constraints on habitat use, as this species are found from sea level to mountains exceeding 10,000 feet. While they are not a desert species, coatis will move through desert scrub and shrublands when moving between forested areas (Hoffmeister 1986).

Spatial Patterns
Female coatis and their yearlings (both sexes) live in groups of up 25 individuals, while males are solitary most of the year (Hoffmeister 1986). In southeastern Arizona, average home range of coati troops was calculated as 13.57 km^2 (Hass 2002). Home ranges of males overlapped other males up to 61% and overlapped troops up to 67%, while home ranges of troops overlapped each other up to 80% (Hass 2002). Virtually nothing is known about dispersal distance in coatis, and radioed animals have not dispersed more than a few kilometers (Christine Hass, personal comm.). Females are philopatric, but males have been observed at large distances from known coati habitat, and tend to get hit by cars. While successful dispersal of any distance is unknown, it is thought that males may disperse up to 5 km (Christine Hass, personal comm.)

Conceptual Basis for Model Development
Habitat suitability model – Due to this species' strong vegetation preferences, vegetation received an importance weight of 95%, while distance from roads received a weight of 5%. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Minimum potential habitat patch size was defined as 13.6 km^2, the average home range observed in southeastern Arizona by Hass (2002). Minimum potential habitat core size was defined as 68 km^2, or five times minimum patch size. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the large spatial requirements for coati groups.

Biologically best corridor analysis – Most of the habitat within the linkage zone was calculated as suitable (cost <5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate a fair amount of suitable habitat for this species within the potential linkage area, although optimal habitat is concentrated within the wildland blocks of mountainous habitat (Figure 44). Between the Santa Rita and Rincon blocks, the average habitat suitability ranged from 1.1 to 9.0, with an average suitability of 4.6 (S.D: 2.0). Between the Santa Rita and Whetstone blocks, the average habitat suitability ranged from 1.1 to 8.7, with an average suitability of 4.0 (S.D: 2.5). Between the Rincon and Whetstone blocks, the average habitat suitability ranged from 1.1 to 9.0, with an average suitability of 4.2 (S.D: 2.06).

Union of biologically best corridors – The union of biologically best corridors increases the amount of suitable habitat beyond the initial biologically best corridor model for coati. Coatis tend to occupy habitat close to water, and riparian areas would provide a better movement corridor for this species that a dry wash (Christine Hass, personal comm.). The UBBC adds the entire Cienega Creek corridor and significant portions of Davidson Canyon between the Rincon and Santa Rita/Whetstone wildland blocks, as well as Spring Water Canyon, Bear Spring Canyon, Hilton Wash, and Fortynine Wash between the Santa Rita and Whetstone wildland blocks.

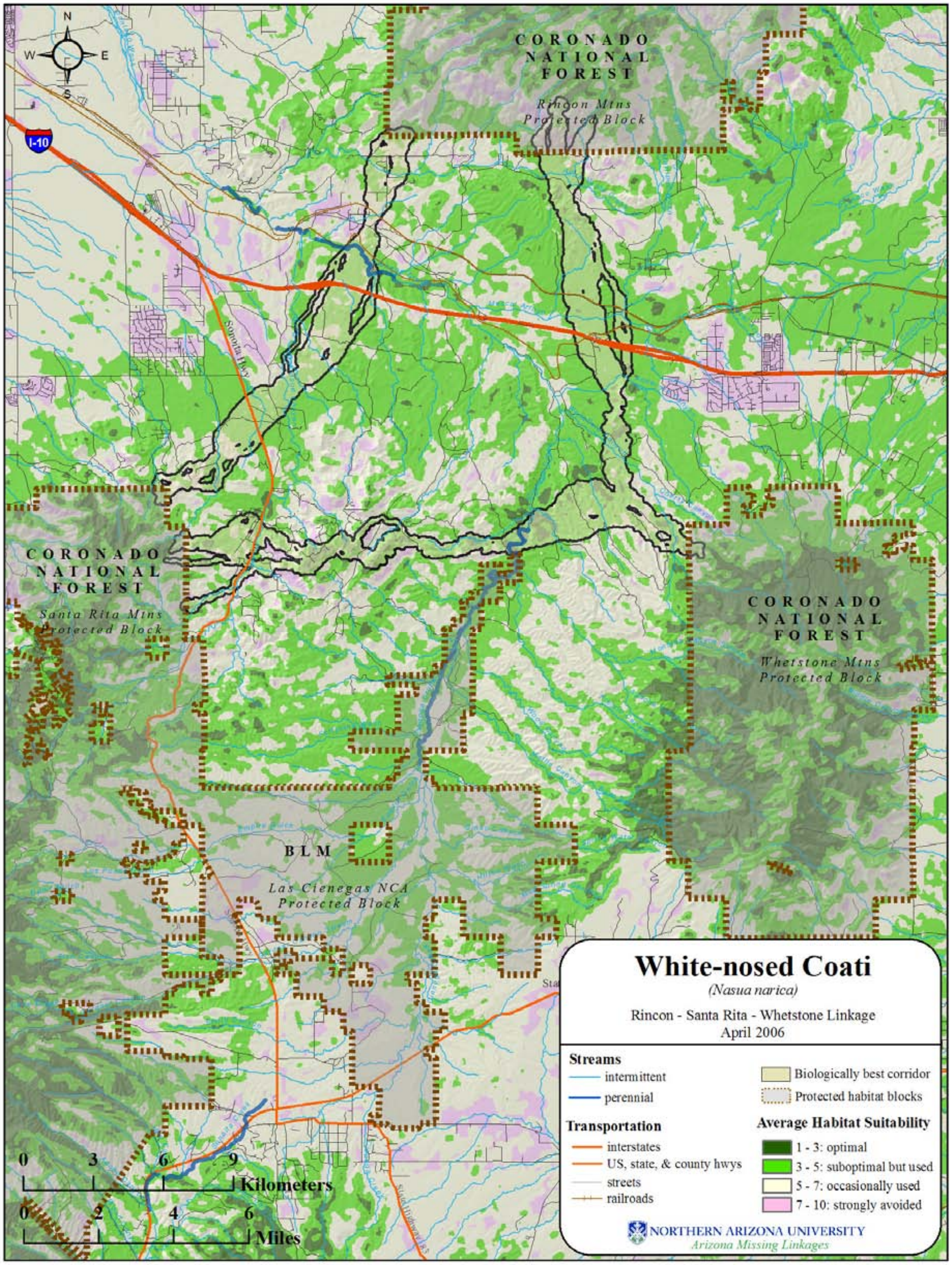

Figure 44: Modeled habitat suitability of white-nosed coati.

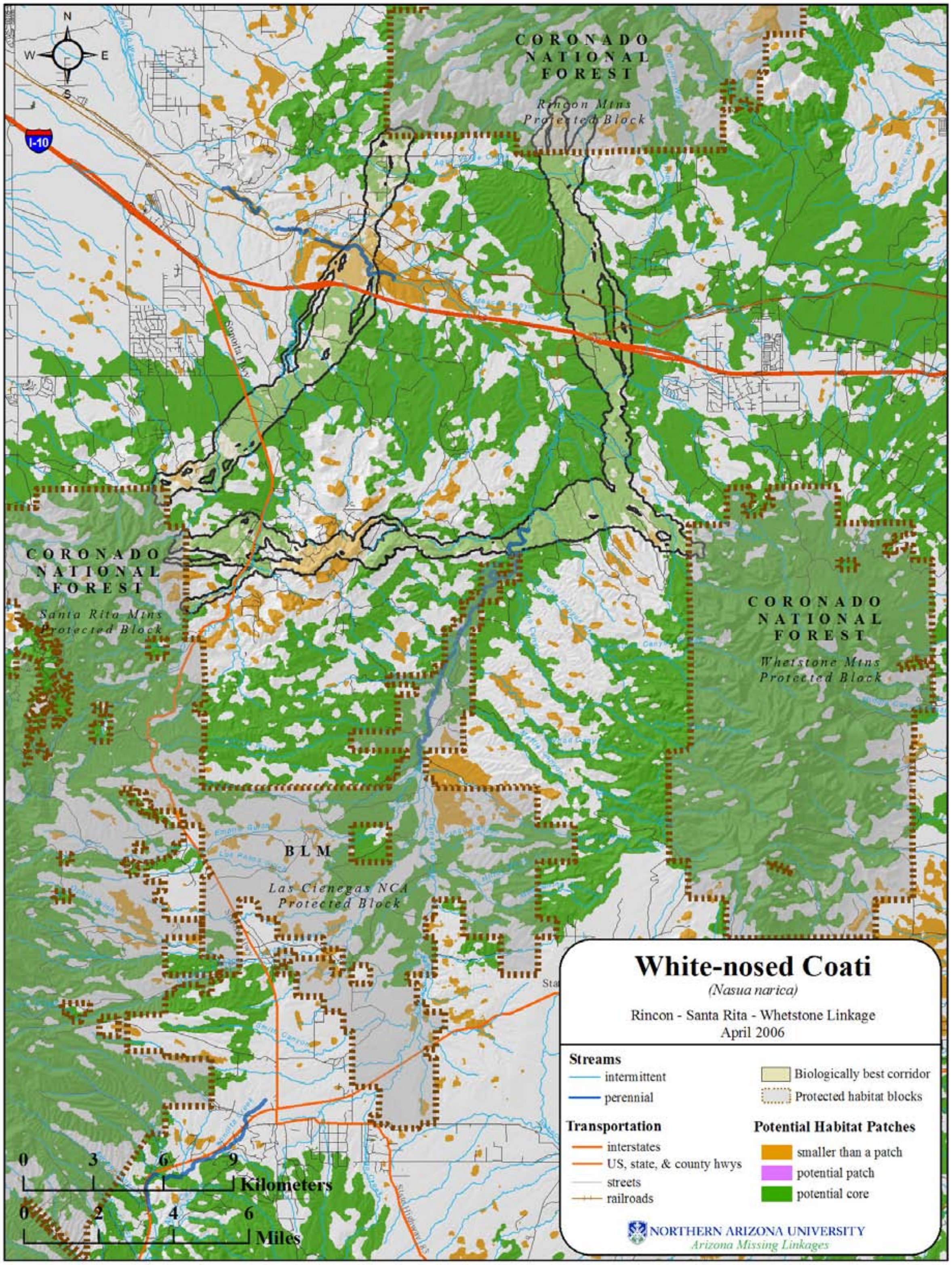

Figure 45: Potential habitat patches and cores for white-nosed coati.

Black-tailed Rattlesnake (*Crotalus molossuss*)

Justification for Selection
Ecologically, the black-tailed rattlesnake is a generalist, able to live in a variety of habitats, making this species an important part of many ecosystems throughout Arizona. This rattlesnake requires various habitat types during different times of the year (Beck 1995), and relies on connectivity of these habitat types during its life cycle.

Distribution
This rattlesnake is found from central and west-central Texas northwest through the southern two-thirds of New Mexico to northern and extreme western Arizona, and southward to the southern edge of the Mexican Plateau and Mesa del Sur, Oaxaca (Degenhardt et. al 1996).

Habitat Associations
Black-tailed rattlesnakes are known as ecological generalists, occurring in a wide variety of habitats including montane coniferous forests, talus slopes, rocky stream beds in riparian areas, and lava flows on flat deserts (Degenhardt et. al 1996). In a radiotelemetry study conducted by Beck (1995), these snakes frequented rocky areas, but used arroyos and creosotebush flats during late summer and fall. Pine-oak forests, boreal forests, mesquite-grasslands, chaparral, tropical deciduous forests, and thorn forests are also included as habitats for this species (New Mexico Department of Game and Fish 2004). In New Mexico, black-tailed rattlesnakes occur between 1000 and 3,150 meters in elevation (New Mexico Department of Game and Fish 2004).

Spatial Patterns
The home range size for black-tailed rattlesnakes has been reported as 3.5 hectares, in a study within the Sonoran desert of Arizona (Beck 1995). These snakes traveled a mean distance of 15 km throughout the year, and moved an average of 42.9 meters per day (Beck 1995). No data is available on dispersal distance for this species, but a similar species, Tiger rattlesnake (*Crotalus tigris*), has been found to disperse up to 2 km (Matt Goode & Phil Rosen, personal comm.).

Conceptual Basis for Model Development
Habitat suitability model – While this species is a vegetation generalist, it is strongly associated with rocks and outcrops on mountain slopes, and rarely seen at any distance from these environments (Matt Goode & Phil Rosen, personal comm.). Because of this strong topographic association, topography received an importance weight of 90%, while distance from roads received a weight of 10%. For specific scores of classes within each of these factors, see Table 4. To ensure that suitable habitat was restrained to locations close to rocky areas, habitat suitability beyond 500 meters from rocky areas mapped in the ReGAP vegetation layer were reclassified to suitability scores between 5 and 10.

Patch size & configuration analysis – Beck (1995) found home ranges from 3-4 ha in size; however, it is thought that home ranges for most black-tailed rattlesnakes are slightly larger (Phil Rosen, personal comm.), so minimum patch size was defined as 10 ha. Minimum core size was defined as 100 ha. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – The standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate a minimal amount of suitable habitat within the linkage area, due to the topography of the linkage area (Figure 46); however, the biologically best corridor for this species is nearly completely composed of potential habitat patches (Figure 47). Between the Santa Rita and Rincon blocks, the average habitat suitability ranged from 1.0 to 9.1, with an average suitability of 3.6 (S.D: 3.4). Between the Santa Rita and Whetstone blocks, the average habitat suitability ranged from 1.0 to 9.1, with an average suitability of 2.3 (S.D: 2.7). Between the Rincon and Whetstone blocks, the average habitat suitability ranged from 1.0 to 9.1, with an average suitability of 3.9 (S.D: 3.5).

Union of biologically best corridors – Strand 1 of the UBBC best serves this species between the Rincon and Santa Rita wildland blocks, strand 3 best serves the connection between the Rincon and Whetstone wildland blocks, and strand 5 best serves this species between the Santa Rita and Whetstone wildland blocks. The shortest distance between potential patches in strand 1 is approximately 1 km, potential habitat patches in strand 5 are nearly contiguous, and the shortest distance between patches between the Whetstone – Rincon blocks is distance is approximately 2 km along Cienega Creek and approximately 5 km in strand 2, and 4 km in strand 3.

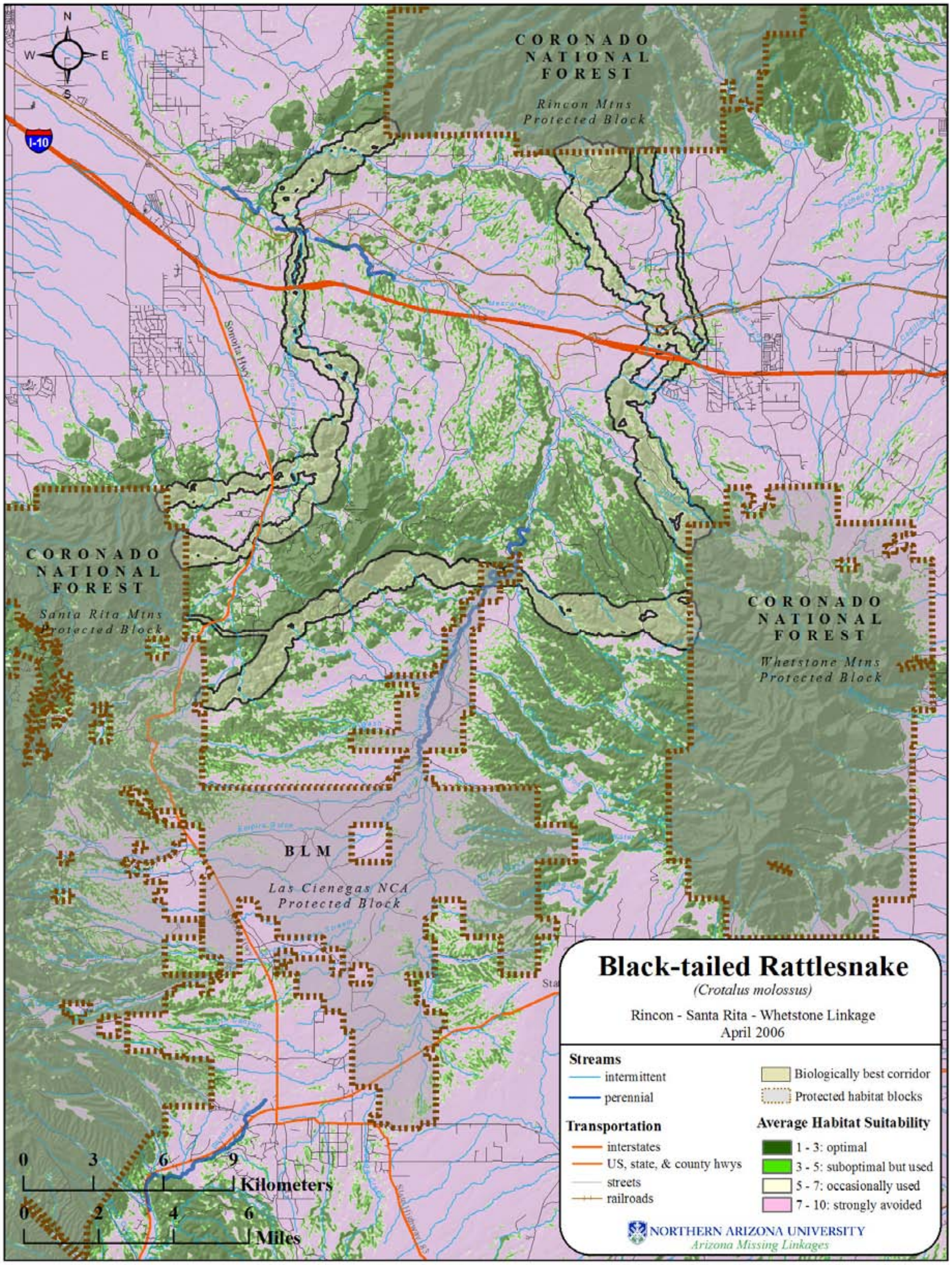

Figure 46: Modeled habitat suitability of black-tailed rattlesnake.

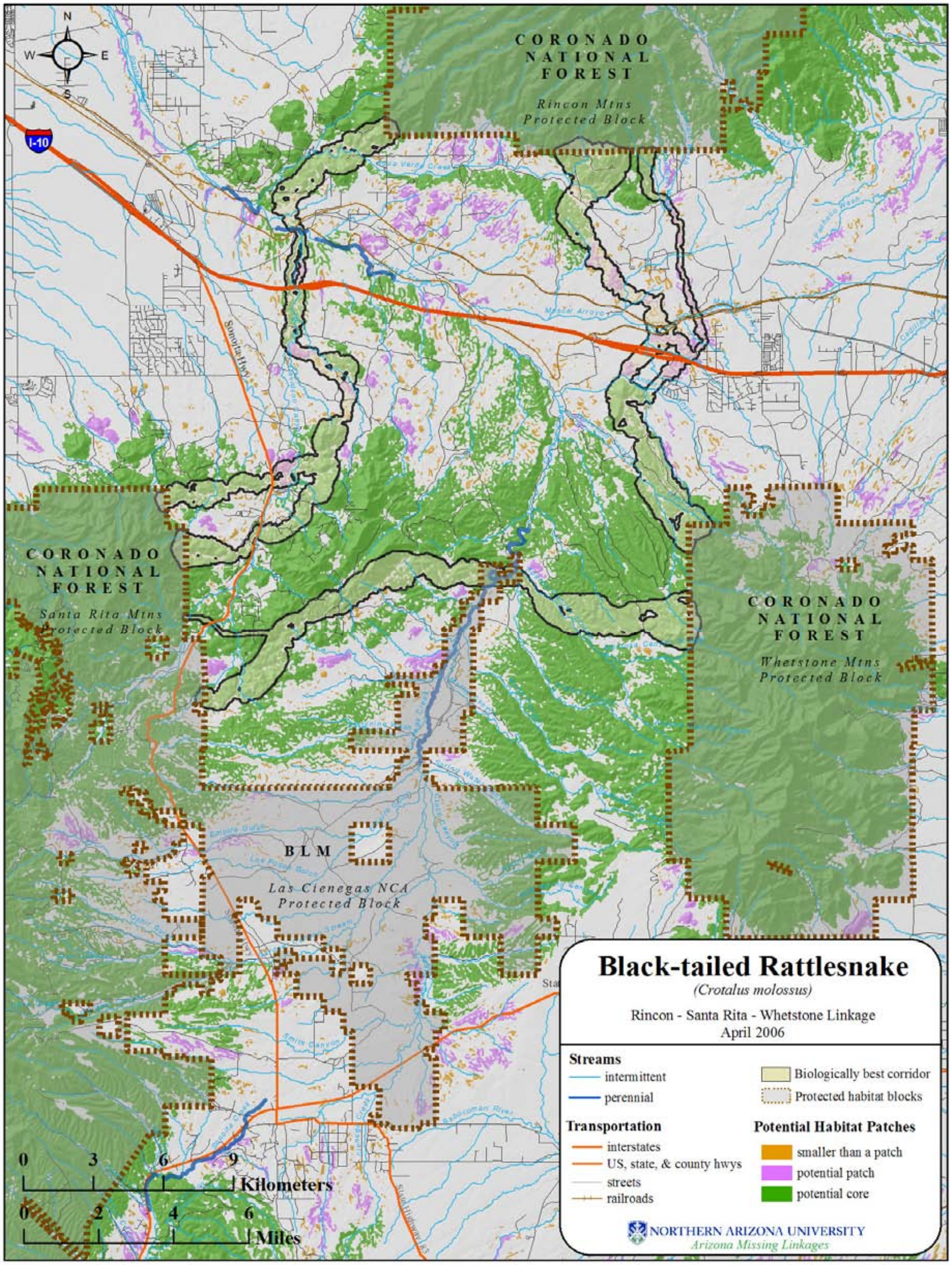

Figure 47: Potential habitat patches and cores for black-tailed rattlesnake.

Desert Box Turtle (*Terrapene ornata luteola*)

Justification for Selection
The desert grassland box turtle is uncommon in Arizona, and its habitat continues to be limited by recent residential developments (Pima Co., Arizona 2001). Habitat alterations from agriculture also may be eliminating populations in some areas of its range (New Mexico Department of Game and Fish 2004). This turtle is sensitive to highway traffic, and automobiles are considered a significant cause of mortality (Pima Co., Arizona 2001).

Distribution
The desert box turtle's range encompasses south-central New Mexico south to central Chihuahua and Sonora, Mexico, and from west Texas across southern New Mexico to the eastern base of the Baboquivari Mountains (Pima Co., Arizona 2001). In Arizona, the desert box turtle occurs in Pima and Santa Cruz counties (New Mexico Department of Game and Fish 2004). This species has historically occurred in the Santa Cruz Valley, but may have been extirpated (Phil Rosen, personal comm.).

Habitat Associations
This species is associated with arid and semiarid regions, and is found in grasslands, plains, and pastures (New Mexico Department of Game and Fish 2004). It prefers open prairies with herbaceous vegetation and sandy soil (New Mexico Department of Game and Fish 2004). This turtle also occurs in rolling grass and shrub land, as well as open woodlands with herbaceous understory (Pima Co., Arizona 2001). Specifically, it is common to mesquite-dominated bajada and abundant in bajada grasslands, grassland flats, and mesquite-dominated flats, but uncommon in rocky slopes and bajada desertscrub (New Mexico Department of Game and Fish 2004). This turtle has been observed taking refuge in subterranean mammal burrows, especially those of the kangaroo rat (Plummer 2004). Elevation range for this species is 0 to 2000 meters, but elevations of 1,200 to 1,600 meters are most suitable (Pima Co., Arizona 2001). In arid regions such as the linkage planning area, this species is dependent on inhabitable sections of riparian bottoms (Phil Rosen, personal comm.)

Spatial Patterns
Due to extended periods of unfavorable weather conditions within its range, the desert box turtle is active only a few weeks out of the year (Plummer 2004). During activity, it requires up to 12 ha for its home range, including land with moist soil that is not compacted (Pima Co., Arizona 2001). One study in Cochise County, Arizona reported average home ranges of 1.1 ha in a dry year and 2.5 ha in a wet year (Pima Co., Arizona 2001). Another study at Fort Huachuca found home ranges that varied from 1.6 ha to 12.4 ha, with an average of 8.5 ha (Pima Co., Arizona 2001). Daily movements include early morning and late afternoon excursions to flat water sites, including cattle tanks (New Mexico Department of Game and Fish 2004; Plummer 2004).

Conceptual Basis for Model Development
Habitat suitability model – Vegetation received an importance weight of 40%, while elevation, topography, and distance from roads received weights of 15%, 20%, and 25%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Minimum potential habitat patch size was defined as 5 ha, and minimum potential core size was defined as 50 ha (Phil Rosen, personal comm.). To determine potential

habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.
Biologically best corridor analysis – Nearly all habitat within the linkage zone was calculated as suitable (cost < 5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – The biologically best corridor model for this species appears to include significant amounts of suitable habitat (Figure 48); however, this species is mainly known to only currently occur within the Cienega Creek corridor (Phil Rosen, personal comm.). Between the Las Cienegas and Rincon blocks, the average habitat suitability ranged from 1.5 to 10.0, with an average suitability of 3.0 (S.D: 1.1). While it appears that the entire BBC for this species is a potential habitat core (Figure 49), suitable habitat is likely over-predicted.

Union of biologically best corridors – While the biologically best corridor for this species does not capture the entire Cienega Creek corridor where this desert box turtle likely occurs, the UBBC contains the portions of Cienega Creek that fall within the linkage planning area, as well as other important riparian areas such as Davidson Canyon.

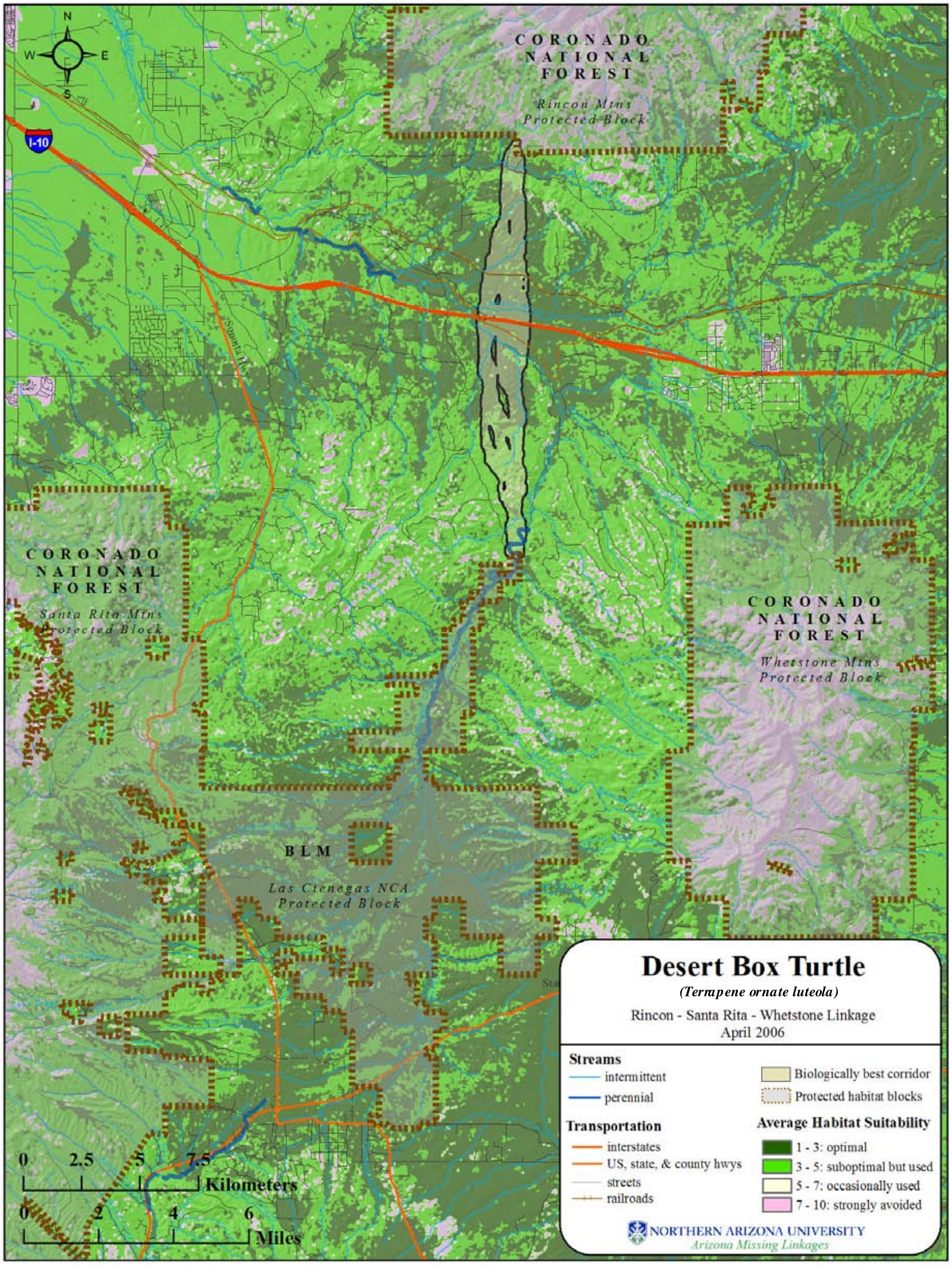

Figure 48: Modeled habitat suitability of desert box turtle.

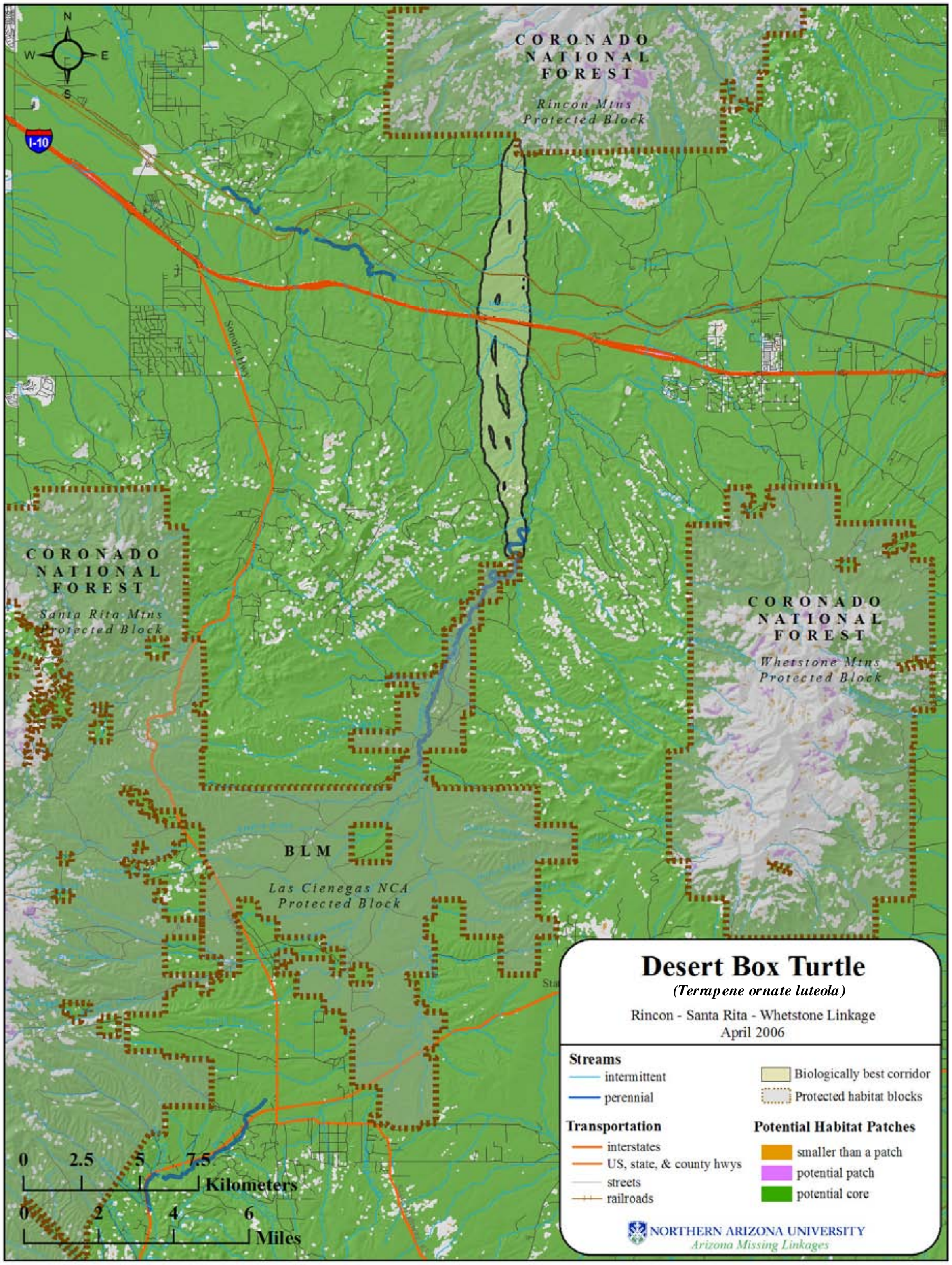

Figure 49: Potential habitat patches and cores for desert box turtle.

Giant Spotted Whiptail (*Aspidoscelis burti stictogrammus*)

Justification for Selection

The giant spotted whiptail is thought to be stable; however, little is known of its population trends (Arizona Game and Fish Department 2001). This species has a limited distribution, and is listed as Forest Service Sensitive (1999) and Bureau of Land Management Sensitive (2000; Arizona Game and Fish Department 2001). Although the giant spotted whiptail is not considered to be migratory, corridors are needed to connect disjunct populations (Pima Co., Arizona 2001). They are adversely impacted by habitat alteration due to overgrazing of riparian vegetation (Pima Co., Arizona 2001).

Distribution

This lizard's range is limited to southeastern Arizona including the Santa Catalina, Santa Rita, Pajarito, and Baboquivari Mountains. It is also known to exist in the vicinity of Oracle, Pinal County, and Mineral Hot Springs, Cochise County. Outside of Arizona, the giant spotted whiptail is found in Guadalupe Canyon in extreme southwest New Mexico and northern Sonora, Mexico (Arizona Game and Fish Department 2001).

Habitat Associations

Giant spotted whiptails are found in the riparian areas of lower Sonoran life zones, as well as mountain canyons, arroyos, and mesas in arid and semi-arid regions (Pima Co., Arizona 2001). These lizards inhabit dense shrubby vegetation, often among rocks near permanent and intermittent streams, as well as open areas of bunch grass within these riparian habitats (Arizona Game and Fish Department 2001). They are able to access lowland desert along stream courses (Pima Co., Arizona 2001). Elevation ranges of suitable habitat are from 2,200 to 5,000 feet (670 to 1,500m) (Pima Co., Arizona 2001).

Spatial Patterns

Giant spotted whiptails require only 2-4 ha for their home range (Rosen et al. 2002). Within this area, they rely on a mosaic of open spaces and cover of dense thickets of thorny scrub while foraging (Pima Co., Arizona 2001). These lizards are not migratory, and hibernate in winter.

Conceptual Basis for Model Development

Habitat suitability model – Vegetation received an importance weight of 70%, while elevation received a weight of 30%.

Patch size & configuration analysis – Minimum patch size was defined as 4 ha, while minimum core size was defined as 25 ha. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – Because this species do not occur in the forested mountains of the Rincon, Santa Rita, and Whetstone wildland blocks, we did not create a biologically best corridor for the species. Instead, we used the standard habitat suitability model to assess potential habitat for this species within the union of biologically best corridors.

Results & Discussion

Habitat suitability model – The habitat suitability model may not accurately reflect the Giant Spotted Whiptail's habitat, because thornscrub, as mapped by the ReGAP project, includes much more arid aspects of vegetation than can be utilized by this species, and the thornscrub which can be occupied by this species is typically localized near major drainages (Phil Rosen, personal comm.)

Union of biologically best corridors – The union of biologically best corridors encompasses riparian woodland and shrubland and thornscrub along Davidson Canyon which is important habitat for this species. The UBBC also encompasses other important riparian areas which could be valuable in maintaining connectivity for this species, such as Cienega Creek, where this species has recently been discovered in mid-valley locations (Phil Rosen, personal comm.).

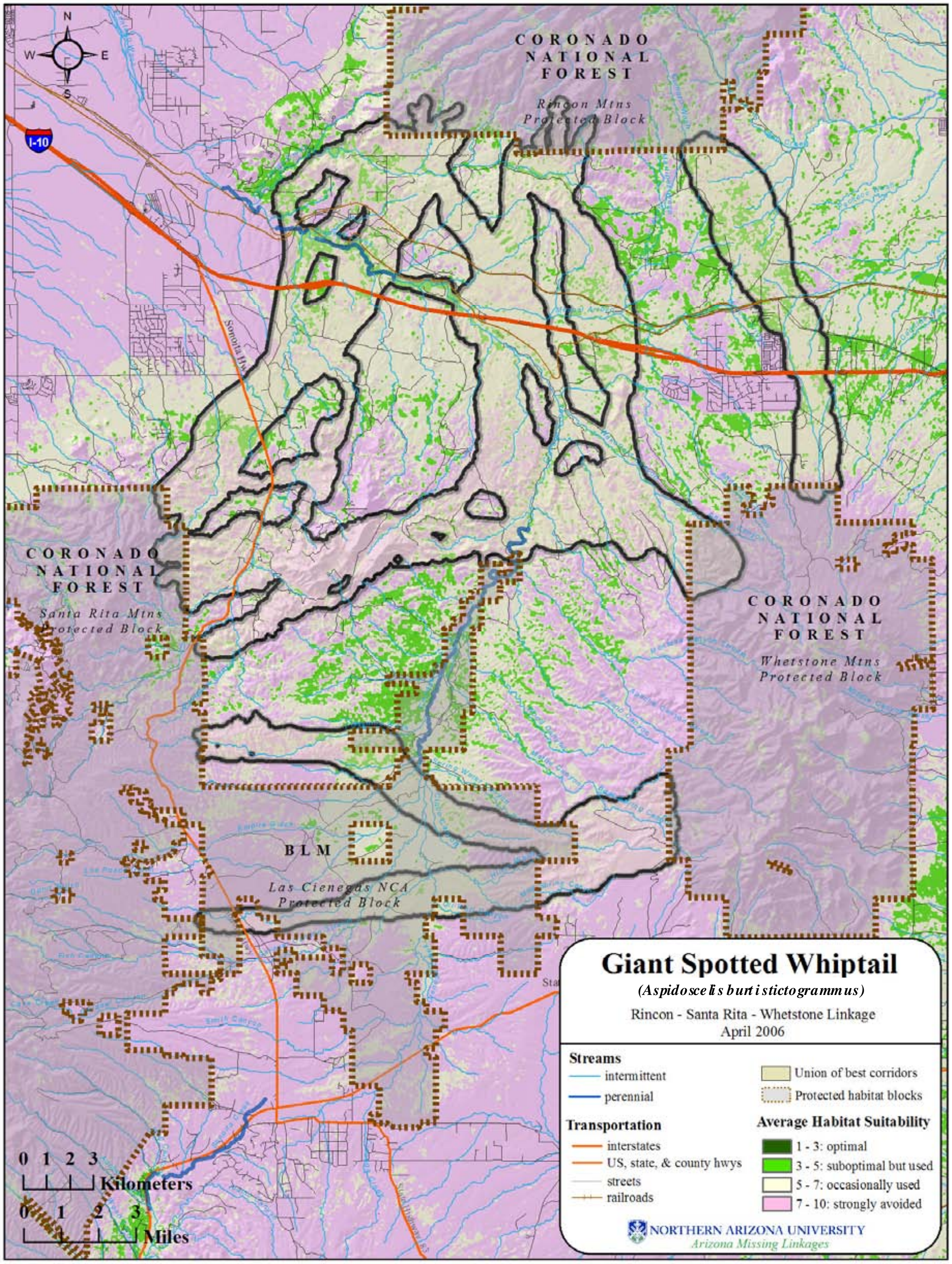

Figure 50: Modeled habitat suitability of giant spotted whiptail.

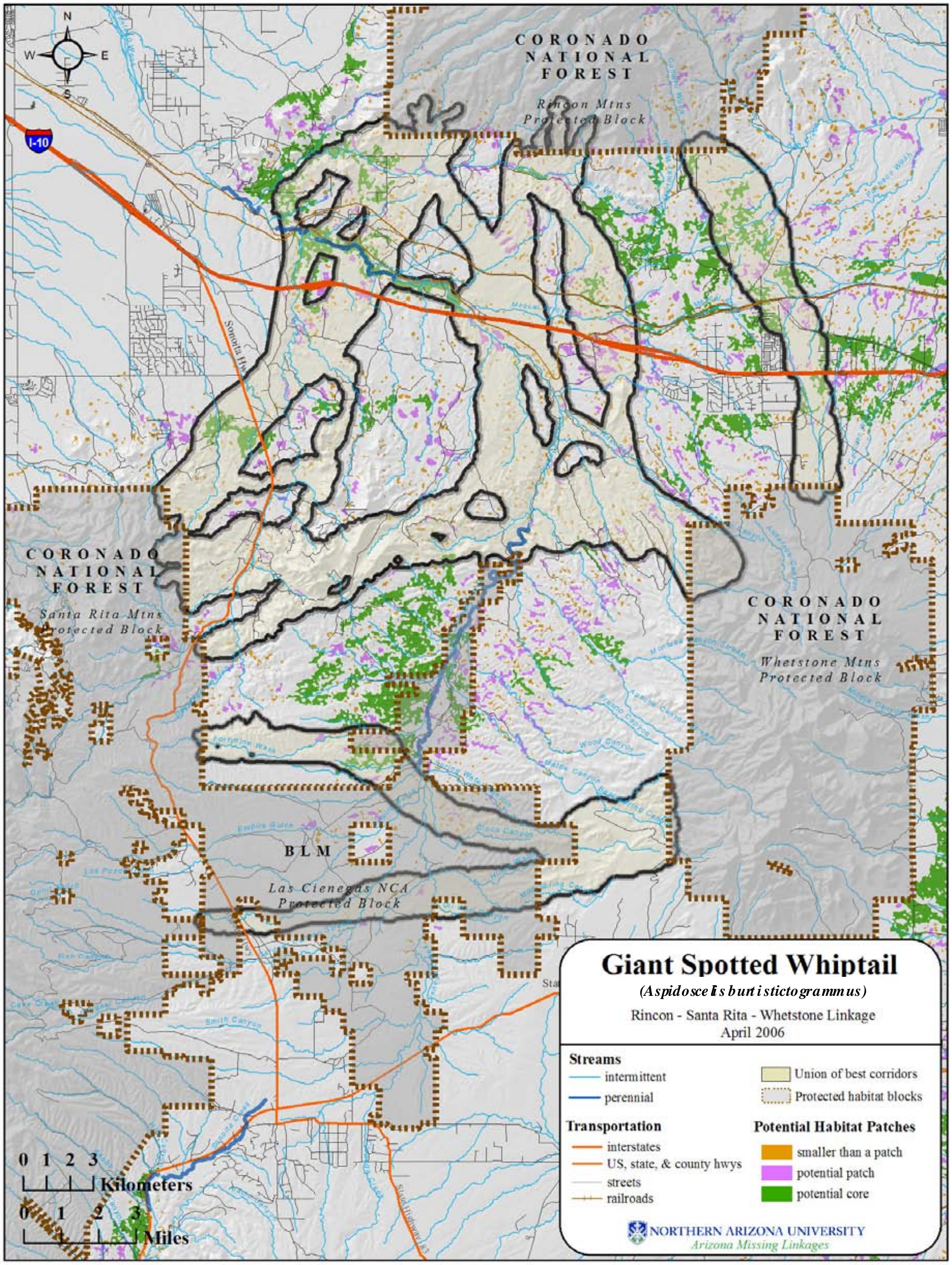

Figure 51: Potential habitat patches and cores for giant spotted whiptail.

Mexican Garter Snake (*Thamnophis eques megalops*)

Justification for Selection

The Mexican garter snake is designated a Species of Concern by the U.S. Fish and Wildlife Service, and a Species of Special Concern by the Arizona Game and Fish Department (Pima Co., Arizona 2001). This species is vulnerable to urbanization and lowered water tables, habitat destruction, overgrazing, and predation by introduced bullfrogs and predatory fishes (Arizona Game and Fish Department 2001).

Distribution

The Mexican garter snake's current range extends from southeastern Arizona and extreme southwestern New Mexico southward to Oaxaca, Mexico (Arizona Game and Fish Department 2001). Specifically within Arizona, this snake is found from the Santa Cruz Valley east and south of the Gila River. Recent sightings have been recorded in the San Rafael and Sonoita grasslands, Arivaca, the Aqua Fria, Verde, and Salt/Black River, and Oak Creek (Arizona Game and Fish Department 2001).

Habitat Associations

This snake species requires intact riparian vegetation communities along permanent water that is free of bullfrogs (Pima Co., Arizona 2001). In Arizona, it is associated with densely vegetated habitat surrounding cinegas, cinega streams, and stock tanks, and also in or near water along streams in valley floors and open areas of elevations up to 8,500 feet, but not in steep mountain canyon stream habitats (Arizona Game and Fish Department 2001).

Spatial Patterns

The Mexican garter snake requires a home range of slightly more than 2 acres (Pima Co., Arizona 2001). This species requires large habitat areas of dense vegetation habitat and interconnected areas of ponds, springs, and streams to assure survival (Pima Co., Arizona 2001).

Conceptual Basis for Model Development

Habitat suitability model – Vegetation received an importance weight of 40%, while elevation, topography, and distance from roads received weights of 15%, 40%, and 5%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Minimum patch size for Mexican garter snake was defined as 0.5 ha and minimum core size as 1 ha (Phil Rosen, personal comm.). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – Because Mexican garter snakes are an aquatic species that do not occur in the forested mountains of the Rincon, Santa Rita, and Whetstone wildland blocks, we did not create a biologically best corridor for the species. Instead, we used the standard habitat suitability model to assess potential habitat for this species within the union of biologically best corridors. According to Phil Rosen (personal comm.), the most probable corridor for this species would be Cienega Creek, as no populations have formerly existed in the montane wildland blocks.

Results & Discussion

Union of biologically best corridors –While the modeled habitat suitability map for this species shows a fair amount of habitat in the plains between protected wildland blocks (Figure 52), as noted above, habitat for this species is concentrated in the Cienega Creek corridor. The linkage design adequately captured Cienega Creek, providing potential habitat cores for this species (Figure 53).

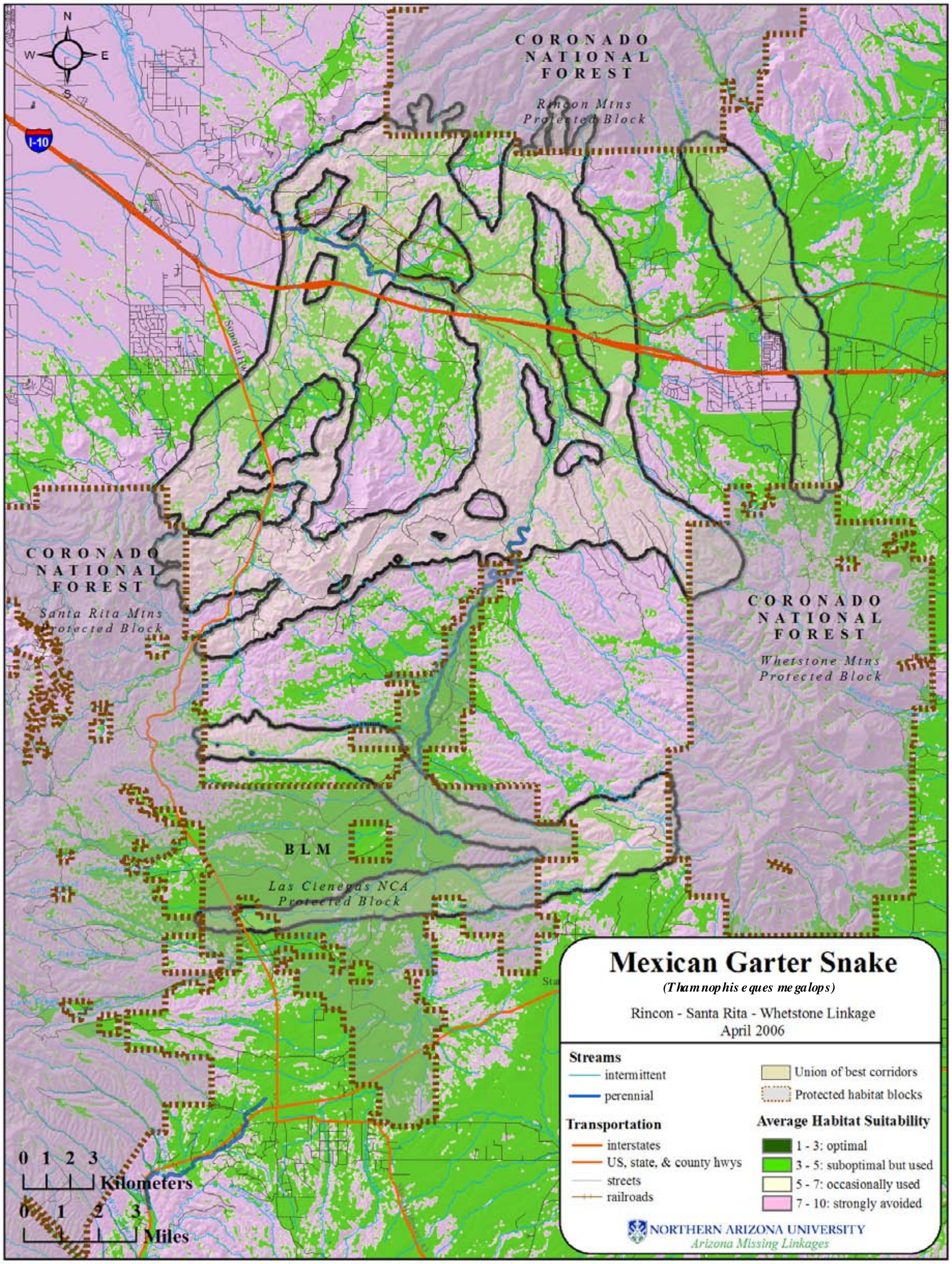

Figure 52: Modeled habitat suitability of Mexican garter snake.

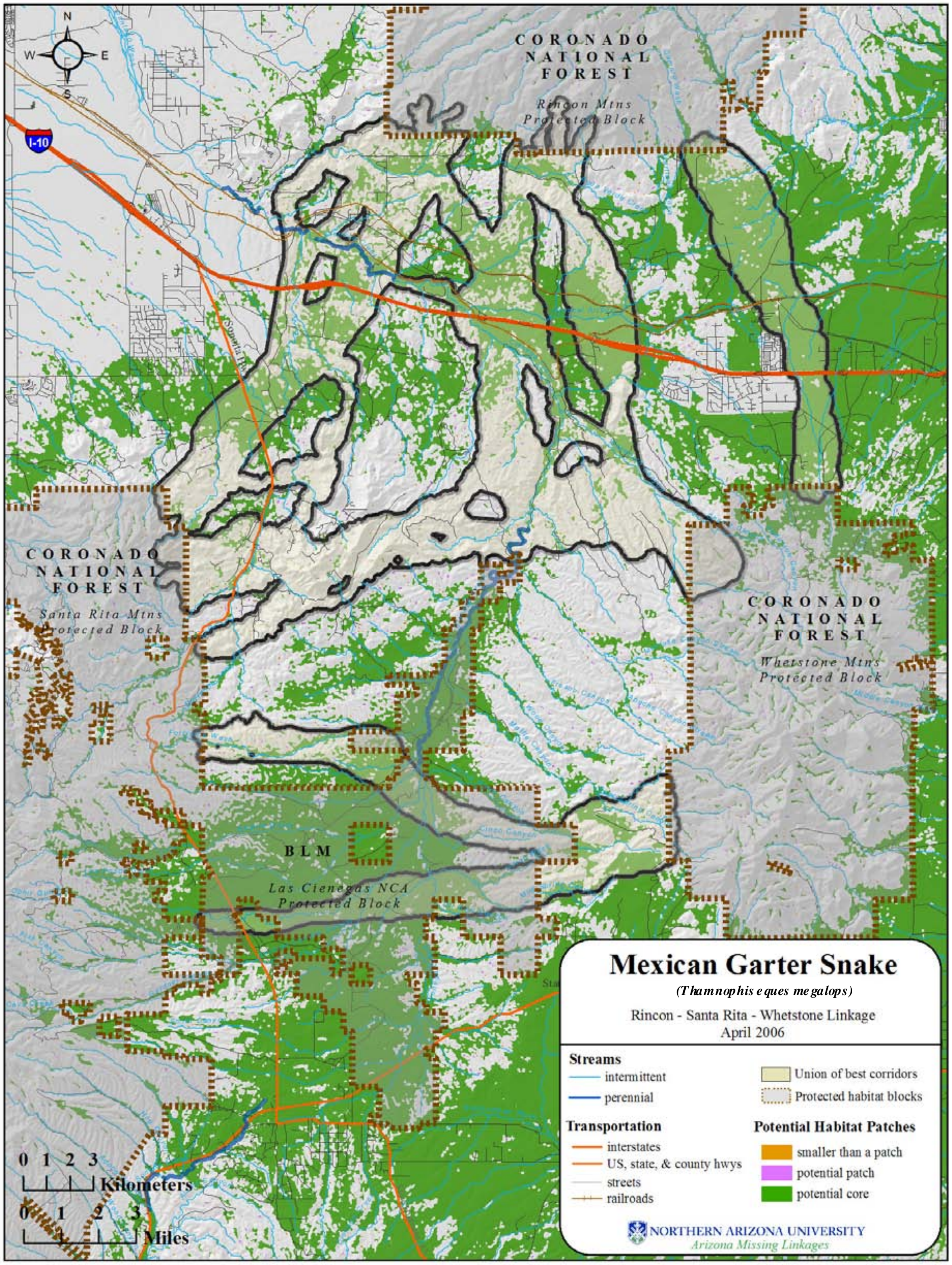

Figure 53: Potential habitat patches and cores for Mexican garter snake.

Sonoran Desert Toad (*Bufo alvarius*)

Justification for Selection
This species is thought to be potentially susceptible to extirpation or demographic impact from road mortality due to its large size, conspicuous activity, numerous observations of road-killed adults, presumed long natural lifespan, and apparent declines in road-rich urban zones. However, in at least one place, a population is thriving in central Tucson (Rosen and Mauz (2001).

Distribution
Sonoran desert toads range from southeastern California to southwestern New Mexico (New Mexico Department of Game & Fish 2002).

Habitat Associations
Breeding is naturally concentrated in canyons and upper bajada intermittant streams, and on valley floors in major pools, but not naturally frequent on intervening bajadas. With stock ponds, breeding can occur anywhere on the landscape, but valley centers and canyons likely remain as the core areas (Phil Rosen, personal comm.).

Spatial Patterns
Little is know about spatial patterns for this species. Rosen (personal comm.) estimates the smallest area of suitable habitat necessary to support a breeding group for 1 breeding season to be 25 ha, based on limited knowledge of movements and smallest occupied patches in Tucson. Based on unpublished data by Cornejo, adults appear to be highly mobile, and long distance movements (5 km to be conservative) seem likely (P. Rosen, personal comm).

Conceptual Basis for Model Development
Habitat suitability model – Sonoran desert toads appear capable of occupying any vegetation type, from urbanized park to their maximum elevation. Roads can have a massive mortality impact and presumed population impact, but some populations live near roads that may be peripheral or marginal to the core habitat (Phil Rosen, personal comm.). Vegetation received an importance weight of 5%, while elevation, topography, and distance from roads received weights of 50%, 25%, and 20%, respectively. For specific scores of classes within each of these factors, see Table 4.

Patch size & configuration analysis – Minimum potential habitat patch size was defined as 25 ha, and minimum potential core size was defined as 100 ha (Rosen & Mauz 2001; Phil Rosen, personal comm.). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – Nearly all habitat within the linkage zone was calculated as suitable (cost < 5), so the standard habitat suitability model was used in the corridor analysis.

Results & Discussion

Initial biologically best corridor – Modeling results indicate ample suitable habitat for this species within the potential linkage area (Figure 54). Between the Las Cienegas and Rincon blocks, the average habitat suitability ranged from 1.2 to 10, with an average suitability of 2.2 (S.D: 0.8).

Union of biologically best corridors – The union of biologically best corridors adds additional optimal habitat to the biologically best corridor for the Sonoran desert toad. While the entire linkage area was modeled as a potential habitat core (Figure 55), it is important to note that because breeding is naturally concentrated in canyons, upper bajada intermittent streams, and on valley floors in major pools, but not naturally frequent on intervening bajadas, these areas are particularly important for this species. With stock ponds, breeding can occur anywhere on the landscape, but valley centers and canyons likely remain as the core areas.

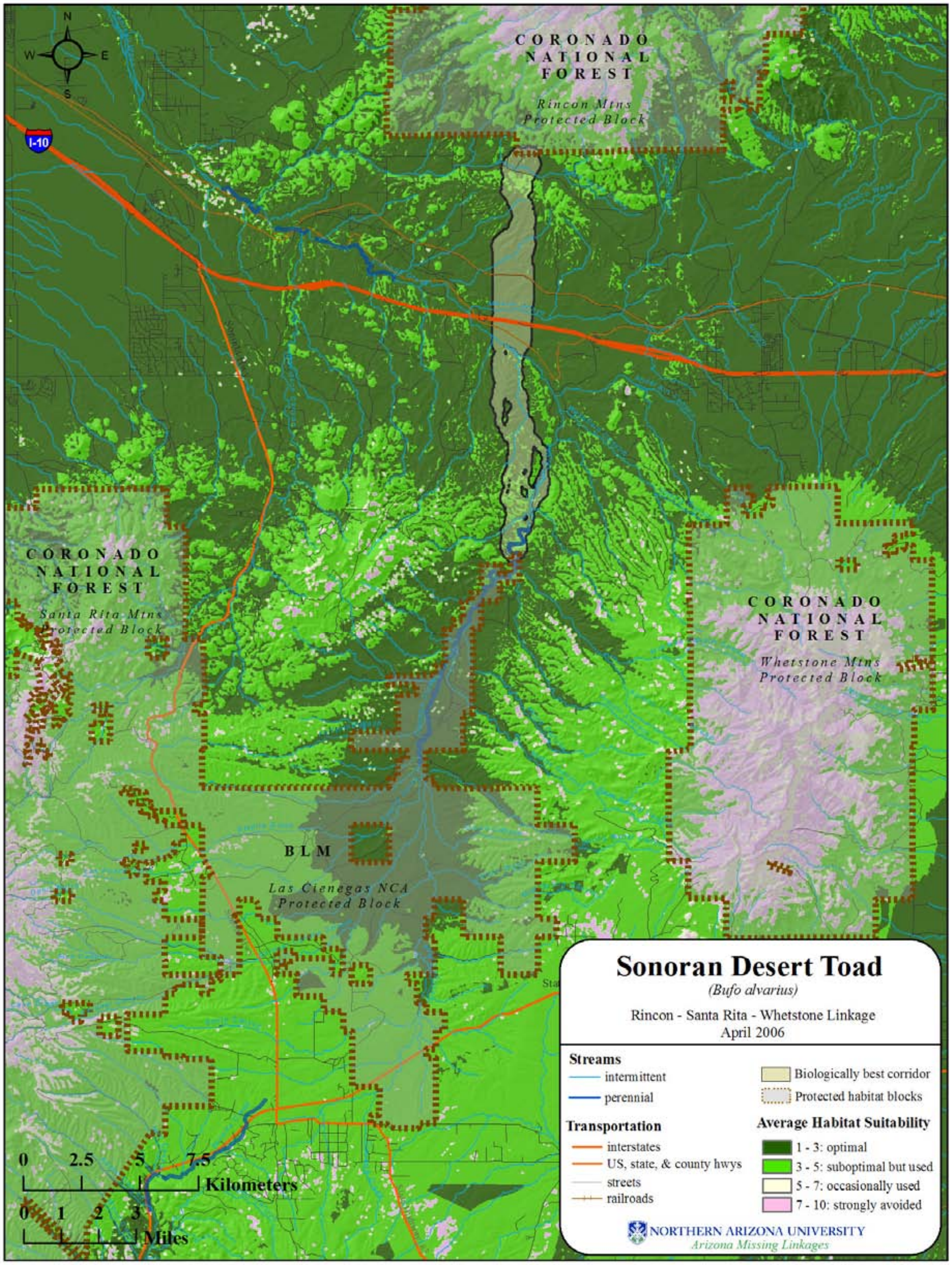

Figure 54: Modeled habitat suitability of Sonoran desert toad.

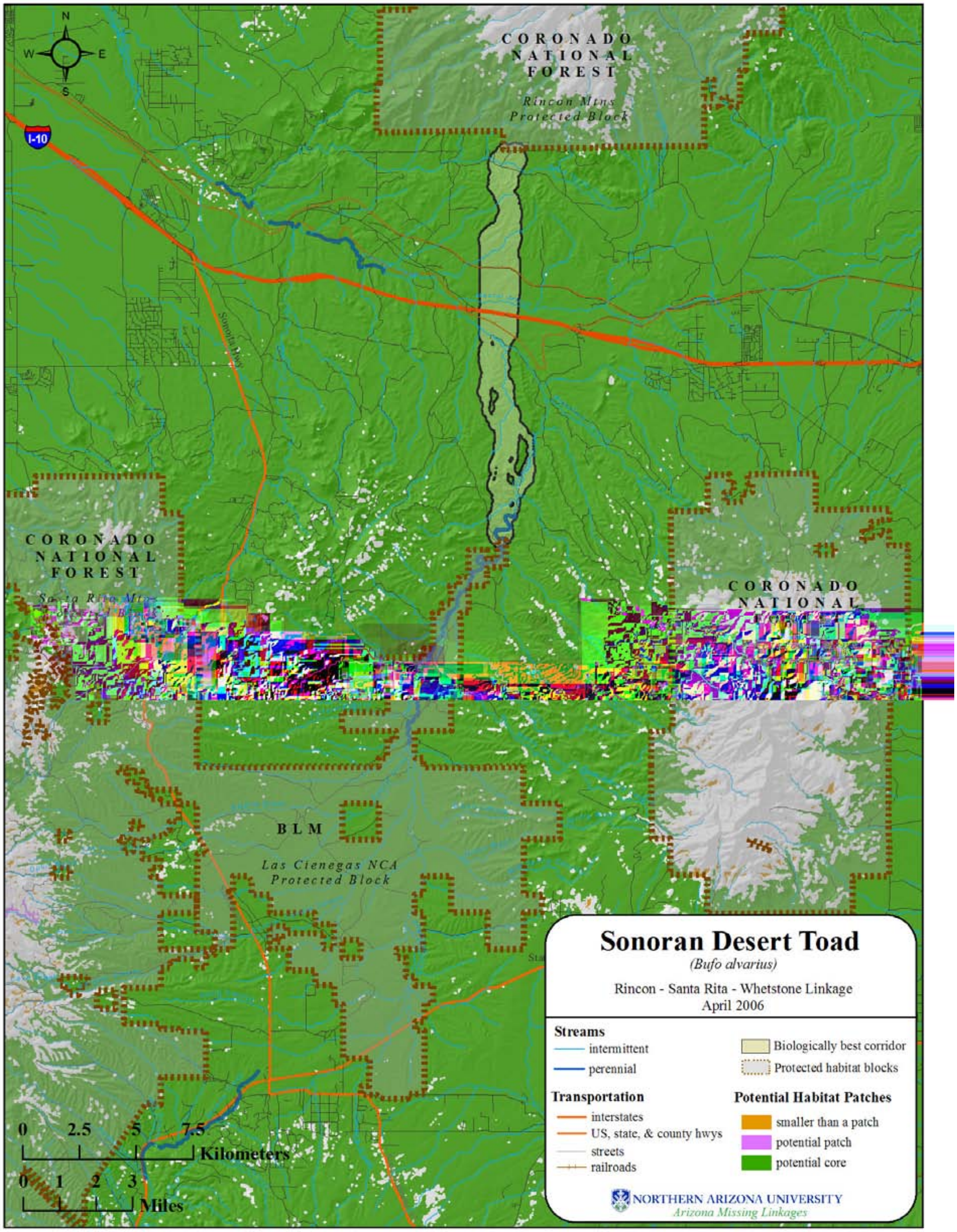

Figure 55: Potential habitat patches and cores for Sonoran desert toad.

Tiger Rattlesnake (*Crotalus tigris*)

Justification for Selection
Tiger rattlesnakes are a rare species in Arizona, and rely on the ability to move across varied habitats and elevations for migration. Radio telemetry research suggests they avoid busy roads (M. Goode, pers. comm.), possibly fragmenting their habitat and impeding their movement requirements.

Distribution
The tiger rattlesnake has a limited distribution, encompassing south-central Arizona to the New Mexico border and south into Sonora, Mexico (Lowe 1978; Degenhardt et al. 1996).

Habitat Associations
Tiger rattlesnakes are most common in Arizona Upland habitats of saguaro, palo verde, and mixed cactus, but also can be found in lower elevations of oak grassland and creosote flats on the lower bajada if rocky washes are present (M. Goode, pers. comm.). They have a known elevational range in Arizona of 300-1,700 m, and are never found far from rock outcrops (M. Goode, pers. comm.).

Spatial Patterns
There is considerable variation in movement patterns of tiger rattlesnakes among individuals, sexes, age classes, seasons, and years (M. Goode, pers. comm.). Male home ranges vary from 5 to 25 hectares, depending on landscape patterns and year. Occasionally, rogue males may have home ranges as large as 125 hectares (M. Goode, pers. comm.). Female home ranges are generally smaller, averaging from 1 to 5 hectares (M. Goode, pers. comm.). In general, tiger rattlesnakes are elevational migrants, moving from rocky slopes in spring to xeroriparian washes in summer and back to slopes in fall (M. Goode, pers. comm.). Preliminary genetic data (microsatellite markers) indicate that tiger rattlesnakes moved between mountain ranges, but radiotelemetry data suggest that this no longer happens (M. Goode, pers. comm.).

Conceptual Basis for Model Development
Habitat suitability model – Tiger rattlesnakes have a known elevational range in Arizona (300-1,700 m), and they are never found far from rock outcrops. Although mostly in Arizona Upland (saguaro/palo verde/mixed cactus), they can be found at the lower elevations of oak grassland and out into creosote flats on the lower bajada if rocky washes are present (Matt Goode, personal comm.). Vegetation received an importance weight of 20%, while elevation, topography, and distance from roads received weights of 30%, 40%, and 10%, respectively. For specific scores of classes within each of these factors, see Table 4. Because this species does not occur above 5,100 ft, all habitat above 5,100 ft was reclassified to a score of 10, 'strongly avoided.'

Patch size & configuration analysis – Minimum potential habitat patch size was defined as 25 ha, and minimum potential core size was defined as 100 ha. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Biologically best corridor analysis – Because tiger rattlesnakes do not occur in the forested mountains of the Rincon, Santa Rita, and Whetstone wildland blocks, we did not create a biologically best corridor for the species. Instead, we used the standard habitat suitability model to assess potential habitat for this species within the union of biologically best corridors.

Results & Discussion

Union of biologically best corridors –Modeling results indicate a fair amount of suitable habitat within the linkage area, due to the topography of the linkage area (Figure 56). Nearly the entire UBBC is a potential habitat core for this species (Figure 57). Because tiger rattlesnakes are rarely found more than a few hundred meters from rock outcrops, this habitat model most likely overestimates potential habitat for this species.

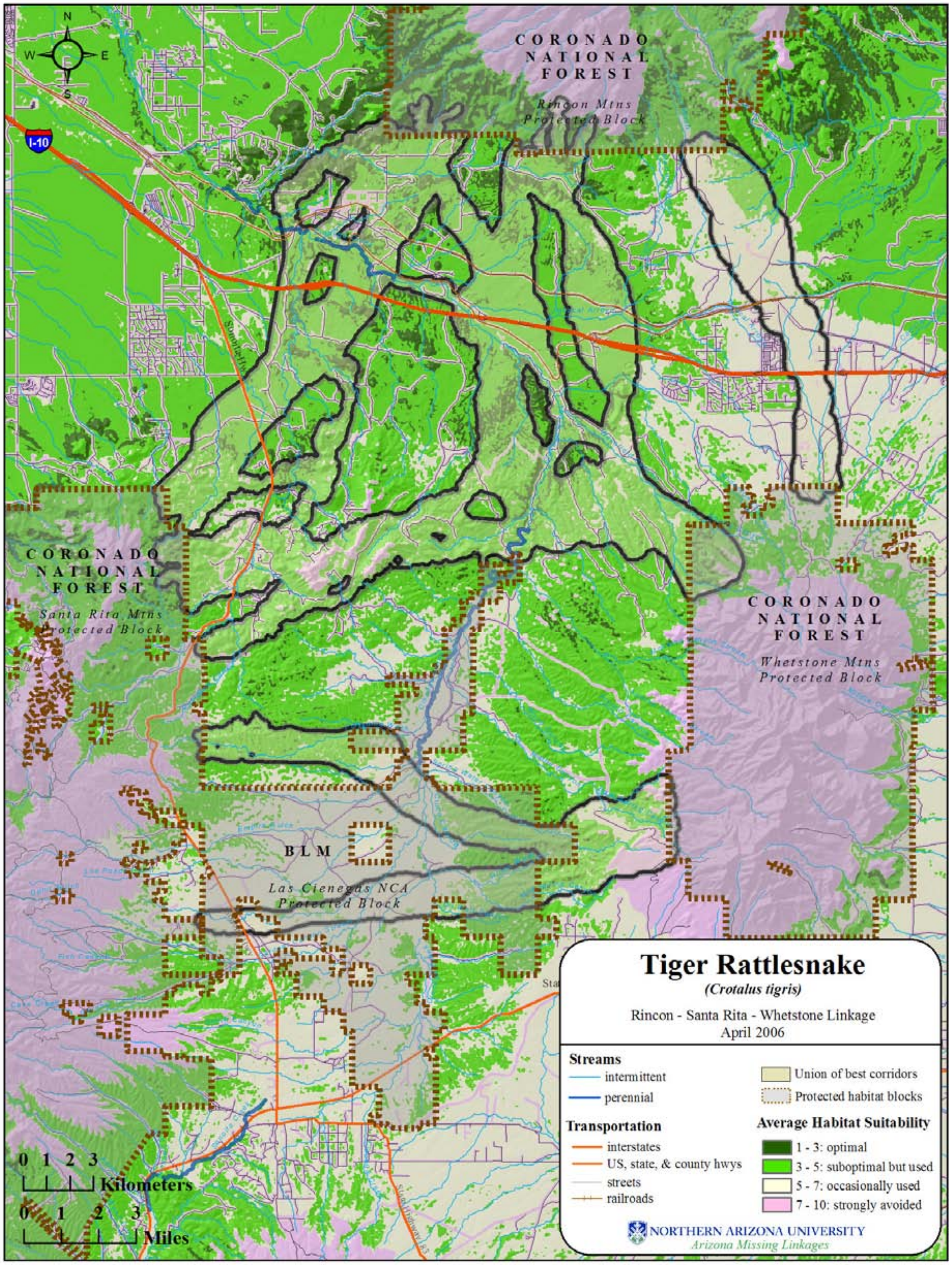

Figure 56: Modeled habitat suitability of tiger rattlesnake.

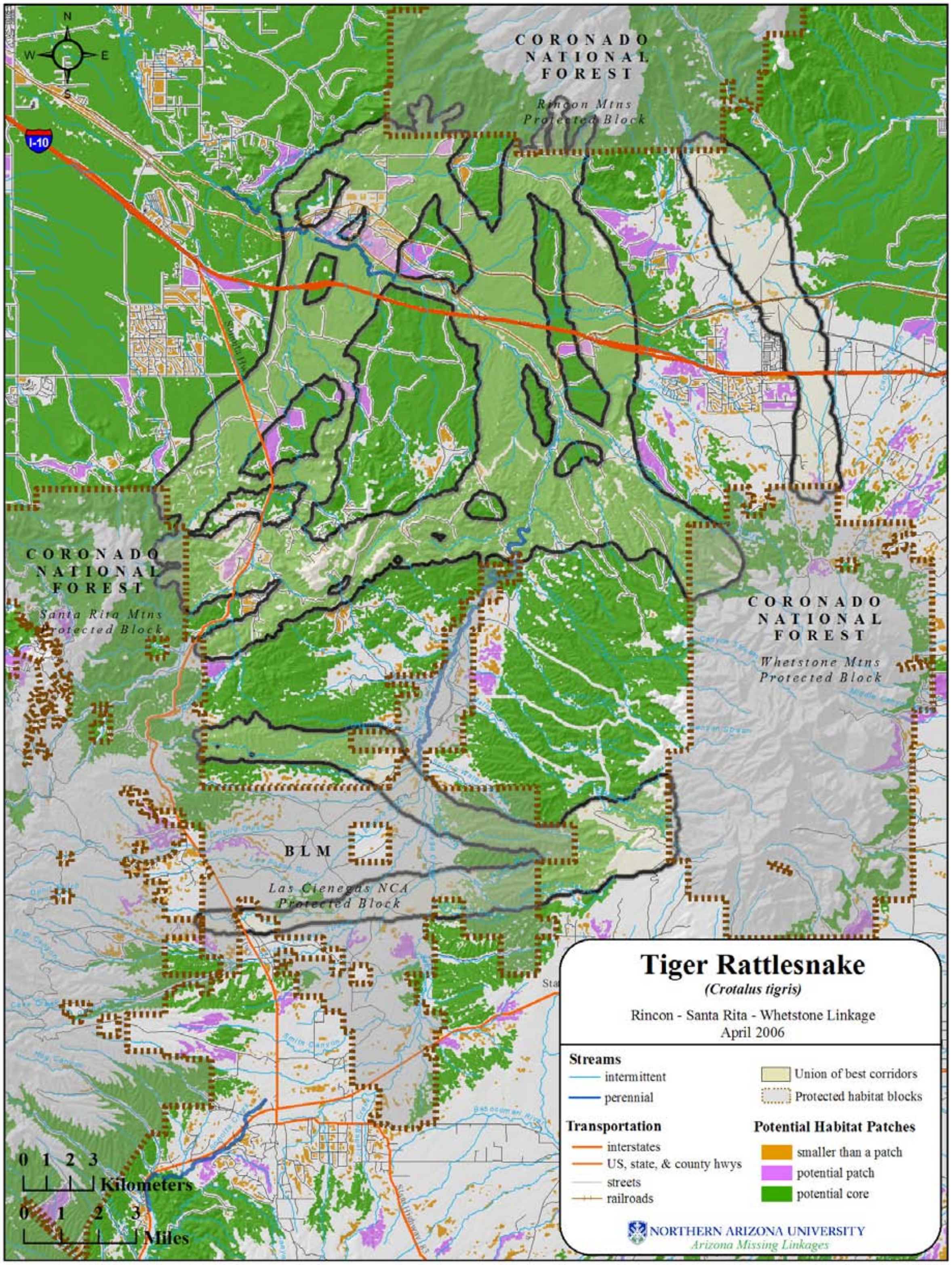

Figure 57: Potential habitat patches and cores for tiger rattlesnake.

Riparian and Aquatic Obligates

Several fish, amphibians, reptiles, and birds associated with riparian or aquatic habitats were suggested as focal species for this linkage design. Although we could not model their habitat requirements using the same analyses employed for terrestrial species, we ensured that the riparian and aquatic habitats in the linkage design along Cienega Creek were adequately incorporated in the linkage design (Figure 58). The linkage design was expanded to include all perennial flowing waters of Cienega Creek in the linkage planning area, as well as riparian woodland and riparian mesquite bosque habitats along the river. A list of important riparian and aquatic obligate species follows:

Fish

- **Gila Topminnow** (*Poeciliopsis occidentalis occidentalis*) – The Gila topminnow is listed as endangered by the U.S. Fish and Wildlife Service, and is a Wildlife of Special Concern in Arizona (U.S. Fish and Wildlife Service 2001; Arizona Game and Fish Department 2001). Gila topminnow has gone from being one of the most common fishes of the Gila basin to one that exists at not more than 30 localities (12 natural and 18 stocked). The original recovery plan for Gila topminnow listed 10 extant natural populations; Monkey Spring, Cottonwood Spring, Sheehy Spring, Sharp Spring, Santa Cruz River near Lochiel, Redrock Canyon, Cienega Creek, Sonoita Creek (presumably including localities above and below Patagonia Lake), Salt Creek, and Bylas Springs (USFWS 1984). Threats to this species include habitat modification and destruction from groundwater pumping, water impoundment and diversion, water pollution, and, stream channelization (U.S. Fish and Wildlife Service 2001; Arizona Game and Fish Department 2001). Gila topminnows live in shallow, warm water areas of small streams, cienegas, and springs that have aquatic vegetation and debris for cover (U.S. Fish and Wildlife Service 2001). They are also able to exist in backwater areas of intermittent streams and marshes (Arizona Game and Fish Department 2001, NatureServe 2005). Associated plant communities include cottonwood, willow, and burrobrush riparian areas of deserts and grasslands (Arizona Game and Fish Department 2001; NatureServe 2005). The Gila topminnow occurs at elevations from 1,320 – 7,510 feet (403-2291 m), but prefers elevations below 5,000 feet (Arizona Game and Fish Department 2001). They have been found on Upper Cienega Creek and Mattie Canyon, a tributary to Cienega Creek.
- **Longfin Dace** (*Agosia chrysogaster*) – The longfin dace is listed as BLM Sensitive, and is threatened in Mexico (Arizona Game and Fish Department 2002). The longfin dace is vulnerable to human activities that alter the quality or flow of water, especially flood control and irrigation practices; changes in water flow can cause massive mortalities amongst individual populations (Arizona Game and Fish Department 2002). Longfin daces live in varied habitats, from intermittent hot low-desert streams to clear, cool brooks at higher elevations, and tend to occupy small streams with gravelly or sandy bottoms (Arizona Game and Fish Department 2002). Adjacent plant communities to streams occupied by longfin dace are varied, from desert scrub to the lower end of conifer woodlands (Arizona Game and Fish Department 2002). They have been recorded on lower and upper Cienega Creek and Davidson Canyon.

Herpetofauna

- **Chiricahua Leopard Frog** (*Rana chiricahuensis*) – The Chiricahua leopard frog's population is declining in Arizona, and has been extirpated from about 75 percent of its historic range in Arizona and New Mexico (U.S. Fish and Wildlife Service 2002). Reasons for decline include habitat fragmentation, major water manipulations, water pollution, and heavy grazing (Arizona Game and Fish Department 2001). The Chiricahua leopard frog has been listed as a threatened species by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 2002), and is also Forest Service Sensitive and a Species of Special Concern in Arizona (Arizona Game and Fish Department 2001). The Chiricahua leopard frog's primary habitat is oak, mixed oak, and pine woodlands, but also is found in areas of chaparral, grassland, and even desert (Arizona Game and Fish Department 2001). Within these habitats, this frog is an aquatic species that uses a variety of water sources including thermal springs and seeps, stock tanks, wells, intermittent rocky creeks, and main-stream river reaches (Degenhardt 1996). According to Phil Rosen, Chircahua leopard frogs do not occur in the Rincon Mountains (only Lowland Leopard Frog occurs there, although both are in the Galiuro Mts), and the connectivity between the Santa Ritas and Whetstones would probably best be achieved by connecting major canyons from the Santa Rita and Whetstone Mountains to the Cienega Creek corridor running north-south, or a corridor constructed with managed stock tanks.

- **Lowland Leopard Frog** (*Rana yavapaiensis*) – Lowland leopard frogs have a limited distribution, and are susceptible to road mortality. This species is 100% dependent on aquatic habitat. They can occur in aquatic systems ranging from desert grasslands to pinyon-juniper. Generally, effective corridors would tend to be in stream bottoms (like Cienega Creek, where it still occurs) and connecting to stock ponds and mountain springs or tinajas via major washes, especially those with intermittent, rather than ephemeral flow (Phil Rosen, personal comm.). Specifics sites in these areas would need to be considered (e.g., Wakefield Canyon and its springs in the Whetstone Mountains) for there to be any real chance of establishing connectivity without large scale management action like that needed for connectivity to be conceivable for the Chiricahua Leopard Frog. Optimal elevation for this species is from 900 to 4000 ft, although it can be found at higher elevations (Lannoo 2005; P. Rosen, personal comm.)
- **Mexican Garter Snake** (*Thamnophis eques megalops*) – The Mexican Garter Snake is designated a Species of Concern by the U.S. Fish and Wildlife Service, and a Species of Special Concern by the Arizona Game and Fish Department (Pima Co., Arizona 2001). A habitat suitability model was created for this species – see its species account above.

Birds

- **Southwestern Willow Flycatcher** (*Empidonax traillii extimus*) – Southwestern willow flycatchers are listed as endangered by the U.S. Fish and Wildlife Service, Forest Service Sensitive, and a Species of Special Concern in Arizona. Major causes of decline include loss and modification of riparian habitat as a result of agricultural and urban development, river and stream impoundments, ground water pumping, and flood control projects (U.S. Fish and Wildlife Service 2004). The southwestern willow flycatcher's habitat is also threatened by diversion of water from streams, draining of wetlands, canal construction, livestock grazing, off-road vehicle use, and invasion of exotic tamarisk (Arizona Game and Fish Department 2002). They occur in dense riparian habitats along rivers, streams, and wetlands where cottonwood, willow, boxelder, tamarisk, Russian olive, arrowweed, and buttonbrush are present. They prefer dense canopy cover, a large volume of foliage, and surface water during midsummer, but avoid steep, closed canyons (Arizona Game and Fish Department 2002). Southwestern willow flycatchers are found at elevations up to 9,180 feet in Arizona (Arizona Game and Fish Department 2002).

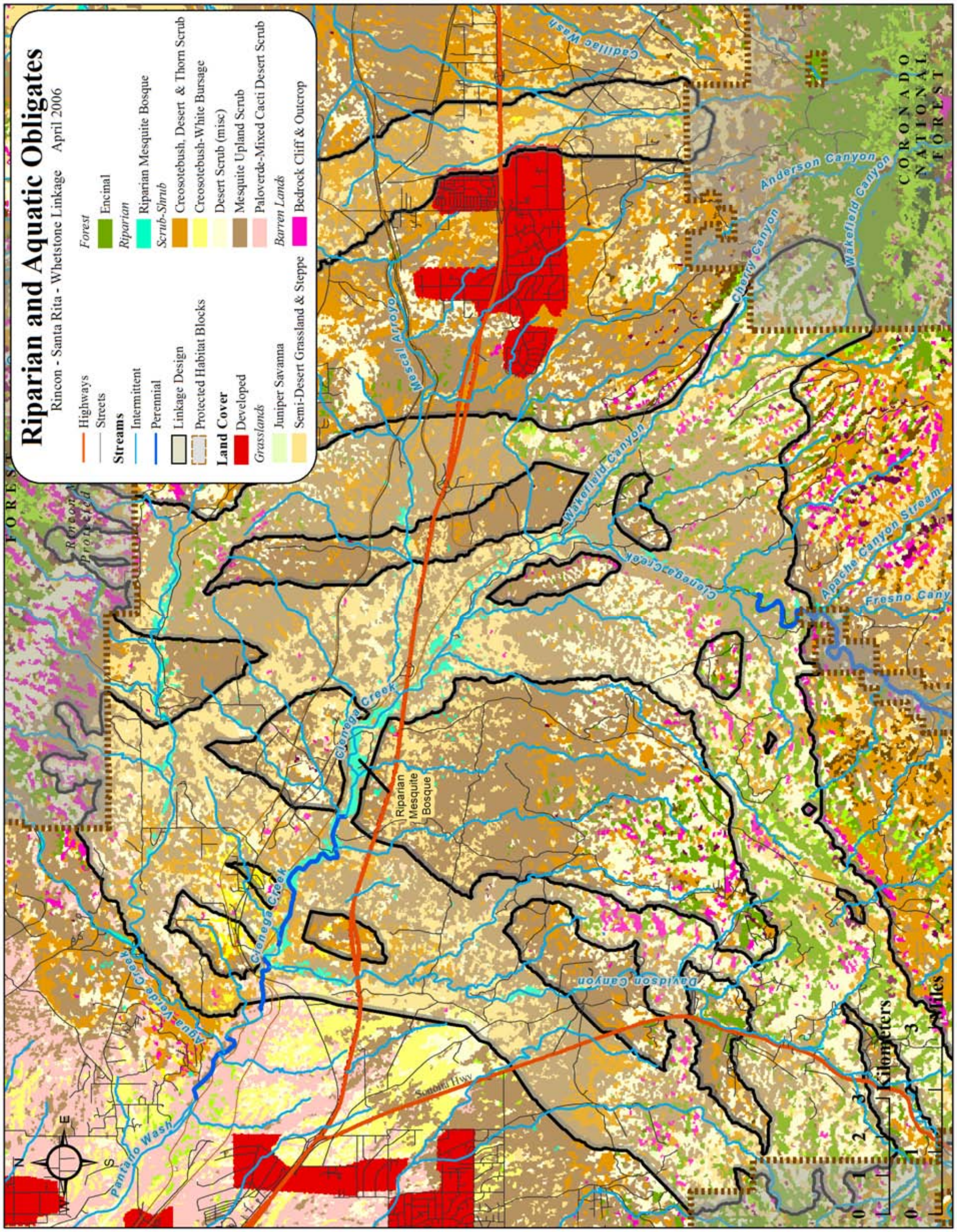

Figure 58: Important riparian and aquatic habitat in the linkage design.

Appendix C: Creation of Final Linkage Design

To create the final Linkage Design, we combined biologically best corridors for all focal species modeled, and made several minor edits to the union of biologically best corridors (Figure 59). We aimed to create a concise linkage design that adequately supports the suite of focal species by identifying the biologically best corridor for an individual species that differed most radically from the other corridors. We then studies the map to determine if that species would be equally well-served by the remaining union of corridors. To do so, we compared the average habitat suitability score, and the distribution of patches of breeding habitat, in the original single-species corridor with the scores and distribution of breeding habitat in the remaining union of corridors. If the species was well served, the disparate corridor model was removed from the union of biologically best corridors. Our goal in trimming these areas was to reduce the need for the corridor to include private land, reduce the total amount of edge, and minimize the area that would have to be managed for connectivity. In this trimming operation, however, we never compromised the biological goals; that is, we did not omit part of the corridor if the individual species would experience more than a small percentage decrease in habitat suitability.

We then added habitat to the union of least-cost corridors to expand each of the 6 major strands to a minimum width of 1500 meters, and to capture important riparian habitat that was not selected by individual biologically best corridors[12]. An explanation of specific steps taken to create the final linkage design follows:

<u>Rincon – Santa Rita Mtns Linkage Strand</u>

- We removed the Arizona gray squirrel corridor model from the UBBC because the model for black bear included equally-good habitat for gray squirrels.
- We removed mountain lion corridor model because it was served equally well by remaining species.

<u>Rincon – Cienega Creek Linkage Strand</u>

- We removed the javelina corridor model because nearly the entire linkage planning area was optimal habitat for javelina, so connectivity needs for this species were equally covered by the remaining union of corridor models.
- We removed the Antelope jackrabbit corridor model because this species was equally covered by the remaining union of corridor models.
- We removed a portion of the corridor for badger south of the Rincon wildland block because it provided redundant protection for this species.

<u>Rincon – Whetstone Mtns Linkage Strand</u>

- We removed the model for black-tailed rattlesnake model because it passed through a large portion of developed non-habitat, and was probably equally served by the connection through Cienega Creek.
- Little suitable habitat was captured by the corridor models for Arizona gray squirrels and black bear between the Rincon and Whetstone wildland blocks, and equivalent habitat was found in the remaining UBBC, so we removed the corridor models for both species.

<u>Santa Rita Mtns – Whetstone Mtns Linkage Strand</u>

- A small portion of the model for Coues white-tailed deer which was disparate from the remaining corridors was removed because this disparate fragment did not capture uniquely suitable habitat for the species.

[12] We widened the Santa Rita-Whetstones linkage around Fortynine wash and buffered the Cienega Creek corridor because it provides important riparian habitat and steep diverse topography for species such as tiger rattlesnakes and black-tailed rattlesnakes.

- The corridor model for black-tailed rattlesnake was removed because it was sufficiently covered by the remaining northernmost strand of the Santa Rita-Whetstone linkage.
- The corridor model for badger between Las Cienegas NCA and the Whetstone wildland block was removed because the remaining corridors provided adequate amounts of suitable habitat.

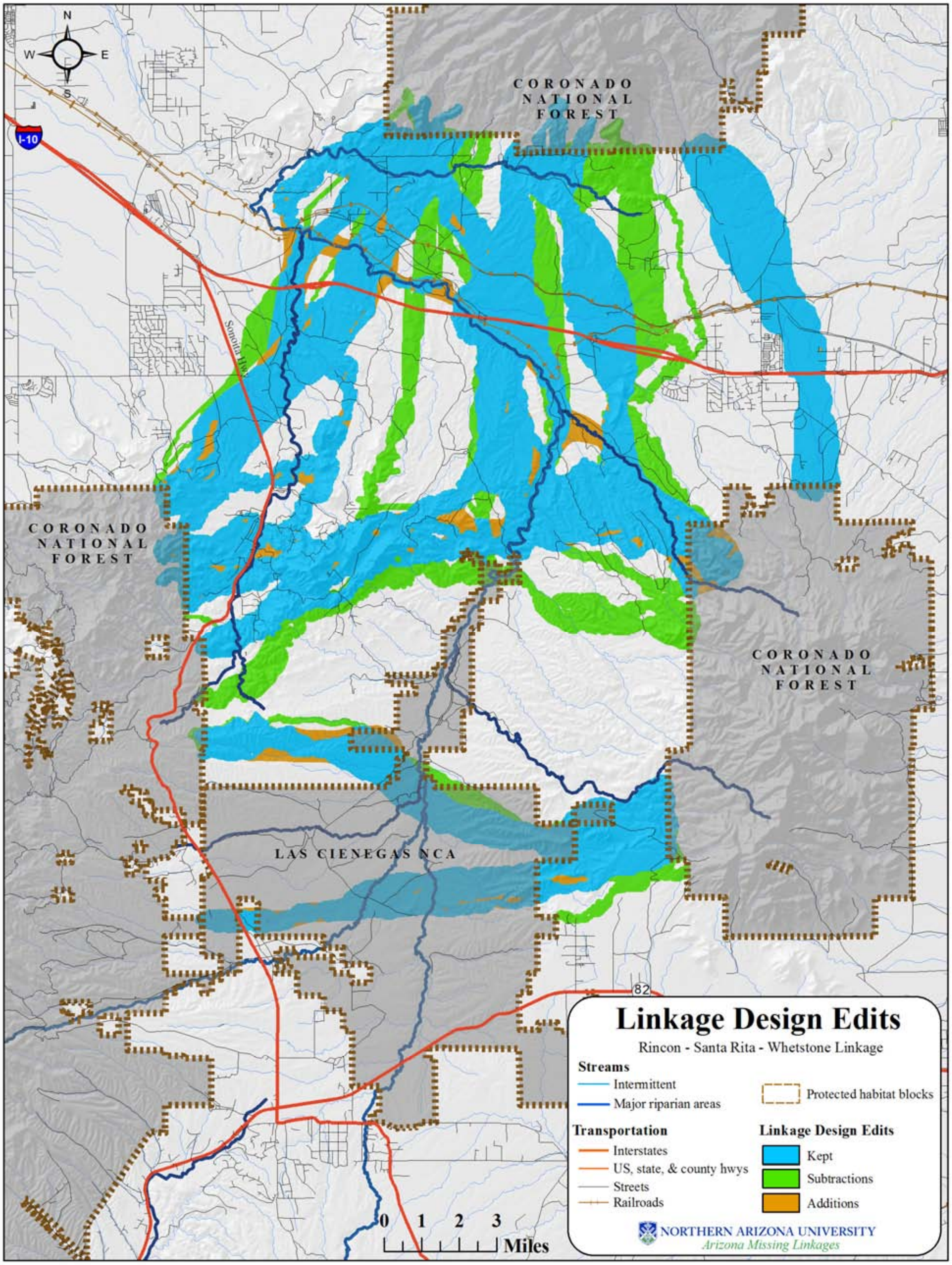

Figure 59: Edits made to union of biologically best corridors to create final linkage design.

Appendix D: Description of Land Cover Classes

Vegetation classes have been derived from the Southwest Regional GAP analysis (ReGAP) land cover layer. To simplify the layer from 77 to 46 classes, we grouped similar vegetation classes into slightly broader classes by removing geographic and environmental modifiers (e.g. Chihuahuan Mixed Salt Desert Scrub and Inter-Mountain Basins Mixed Salt Desert Scrub got lumped into "Desert Scrub"; Subalpine Dry-Mesic Spruce-Fir Forest and Woodland was simplified to Spruce-Fir Forest and Woodland). What follows is a description of each class in this linkage zone, taken largely from the document, Landcover Descriptions for the Southwest Regional GAP Analysis Project (Available from http://earth.gis.usu.edu/swgap)

EVERGREEN FOREST (5 CLASSES) – Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

Conifer-Oak Forest and Woodland – This system occurs at the upper elevations in the Sierra Madre Occidentale and Sierra Madre Orientale. In the U.S., it is restricted to north and east aspects at high elevations (1980-2440 m) in the Sky Islands (Chiricahua, Huachuca, Pinaleno, Santa Catalina, and Santa Rita mountains) and along the Nantanes Rim. The vegetation is characterized by large- and small-patch forests and woodlands dominated by *Pseudotsuga menziesii, Abies coahuilensis*, or *Abies concolor* and Madrean oaks such as *Quercus hypoleucoides* and *Quercus rugosa*. It is similar to Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland

Encinal (Oak Woodland) – Madrean Encinal occurs on foothills, canyons, bajadas and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, extending north intoTrans-Pecos Texas, southern New Mexico and sub-Mogollon Arizona. These woodlands are dominated by Madrean evergreen oaks along a low-slope transition below Madrean Pine-Oak Forest and Woodland and Madrean Pinyon-Juniper Woodland. Lower elevation stands are typically open woodlands or savannas where they transition into desert grasslands, chaparral or is some case desert scrub.

Pine-Oak Forest and Woodland – This system occurs on mountains and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, Trans-Pecos Texas, southern New Mexico and southern and central Arizona, from the the Mogollon Rim southeastward to the Sky Islands. These forests and woodlands are composed of Madrean pines (*Pinus arizonica, Pinus engelmannii, Pinus leiophylla* or *Pinus strobiformis*) and evergreen oaks (*Quercus arizonica, Quercus emoryi,* or *Quercus grisea*) intermingled with patchy shrublands on most mid-elevation slopes (1500-2300 m elevation). Other tree species include *Cupressus arizonica, Juniperus deppeana.*

Pinyon-Juniper Woodland – These woodlands occur on warm, dry sites on mountain slopes, mesas, plateaus, and ridges. Severe climatic events occurring during the growing season, such as frosts and drought, are thought to limit the distribution of pinyon-juniper woodlands to relatively narrow altitudinal belts on mountainsides. In the southern portion of the Colorado Plateau in northern Arizona and northwestern New Mexico, *Juniperus monosperma* and hybrids of *Juniperus* spp may dominate or codominate tree canopy. *Juniperus scopulorum* may codominate or replace *Juniperus osteosperma* at higher elevations. In transitional areas along the Mogollon Rim and in northern New Mexico, *Juniperus deppeana* becomes common. In the Great Basin, Woodlands dominated by a mix of *Pinus monophylla* and *Juniperus osteosperma*, pure or nearly pure occurrences of *Pinus monophylla*, or woodlands dominated solely by *Juniperus osteosperma* comprise this system.

Ponderosa Pine Woodland – These woodlands occur at the lower treeline/ecotone between grassland or shrubland and more mesic coniferous forests typically in warm, dry, exposed sites. Elevations range from less than 500 m in British Columbia to 2800 m in the New Mexico mountains. Occurrences are found on all slopes and aspects, however, moderately steep to very steep slopes or ridgetops are most common. *Pinus ponderosa* is the predominant conifer; *Pseudotsuga menziesii, Pinus edulis*, and *Juniperus* spp. may be present in the tree canopy.

DECIDUOUS FOREST (1 CLASS) – Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

Aspen Forest and Woodland – Elevations generally range from 1525 to 3050 m (5000-10,000 feet), but occurrences can be found at lower elevations in some regions. Distribution of this ecological system is primarily limited by adequate soil moisture required to meet its high evapotranspiration demand, and secondarily is limited by the length of the growing season or low temperatures. These are upland forests and woodlands dominated by *Populus tremuloides* without a significant conifer component (<25% relative tree cover).

GRASSLANDS-HERBACEOUS (2 CLASSES) – Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

Juniper Savanna – The vegetation is typically open savanna, although there may be inclusions of more dense juniper woodlands. This savanna is dominated by *Juniperus osteosperma* trees with high cover of perennial bunch grasses and forbs, with *Bouteloua gracilis* and *Pleuraphis jamesii* being most common. In southeastern Arizona, these savannas have widely spaced mature juniper trees and moderate to high cover of graminoids (>25% cover). The presence of Madrean *Juniperus* spp. such as *Juniperus coahuilensis, Juniperus pinchotii*, and/or *Juniperus deppeana* is diagnostic.

Semi-Desert Grassland and Shrub Steppe – Comprised of *Semi-Desert Shrub Steppe* and *Piedmont Semi-Desert Grassland and Steppe*. Semi-Desert Shrub is typically dominated by graminoids (>25% cover) with an open shrub layer, but includes sparse mixed shrublands without a strong graminoid layer. Steppe Piedmont Semi-Desert Grassland and Steppe is a broadly defined desert grassland, mixed shrub-succulent or xeromorphic tree savanna that is typical of the Borderlands of Arizona, New Mexico and northern Mexico [Apacherian region], but extends west to the Sonoran Desert, north into the Mogollon Rim and throughout much of the Chihuahuan Desert. It is found on gently sloping bajadas that supported frequent fire throughout the Sky Islands and on mesas and steeper piedmont and foothill slopes in the Chihuahuan Desert. It is characterized by a typically diverse perennial grasses. Common grass species include *Bouteloua eriopoda, B. hirsuta,B. rothrockii, B. curtipendula, B. gracilis, Eragrostis intermedia, Muhlenbergia porteri, Muhlenbergia setifolia, Pleuraphis jamesii, Pleuraphis mutica*, and *Sporobolus airoides*, succulent species of *Agave, Dasylirion*, and *Yucca*, and tall shrub/short tree species of *Prosopis* and various oaks (e.g., *Quercus grisea, Quercus emoryi, Quercus arizonica*).

SCRUB-SHRUB (7 CLASSES) – Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

Chaparral – This ecological system occurs across central Arizona (Mogollon Rim), western New Mexico and southwestern Utah and southeast Nevada. It often dominants along the mid-elevation transition from the Mojave, Sonoran, and northern Chihuahuan deserts into mountains (1000-2200 m). It occurs on foothills, mountain slopes and canyons in dryer habitats below the encinal and *Pinus ponderosa* woodlands. Stands are often associated with more xeric and coarse-textured substrates such as limestone, basalt or alluvium, especially in transition areas with more mesic woodlands.

Creosotebush, Mixed Desert and Thorn Scrub – This widespread Chihuahuan Desert land cover type is composed of two ecological systems: the Chihuahuan Creosotebush Xeric Basin Desert Scrub and the Chihuahuan Mixed Desert and Thorn Scrub. This cover type includes xeric creosotebush basins and plains and the mixed desert scrub in the foothill transition zone above, sometimes extending up to the lower montane woodlands. Vegetation is characterized by *Larrea tridentata* alone or mixed with thornscrub and other desert scrub such as *Agave lechuguilla, Aloysia wrightii, Fouquieria splendens, Dasylirion leiophyllum, Flourensia cernua, Leucophyllum minus, Mimosa aculeaticarpa var. biuncifera, Mortonia* *scabrella (= Mortonia sempervirens ssp. scabrella), Opuntia engelmannii, Parthenium incanum, Prosopis glandulosa*, and *Tiquilia greggii*.

Creosotebush-White Bursage Desert Scrub – This ecological system forms the vegetation matrix in broad valleys, lower bajadas, plains and low hills in the Mojave and lower Sonoran deserts. This desert scrub is characterized by a sparse to moderately dense layer (2-50% cover) of xeromorphic microphyllous and broad-leaved shrubs. *Larrea tridentata* and *Ambrosia dumosa* are typically dominants, but many different shrubs, dwarf-shrubs, and cacti may codominate or form typically sparse understories.

Desert Scrub (misc) – Comprised of Succulent Desert Scrub, Mixed Salt Desert Scrub, and Mid-Elevation Desert Scrub. Vegetation is characterized by a typically open to moderately dense shrubland.

Mesquite Upland Scrub – This ecological system occurs as upland shrublands that are concentrated in the extensive grassland-shrubland transition in foothills and piedmont in the Chihuahuan Desert. Vegetation is typically dominated by *Prosopis glandulosa* or *Prosopis velutina* and succulents. Other desert scrub that may codominate or dominate includes *Acacia neovernicosa, Acacia constricta, Juniperus monosperma*, or *Juniperus coahuilensis*. Grass cover is typically low.

Paloverde-Mixed Cacti Desert Scrub - This ecological system occurs on hillsides, mesas and upper bajadas in southern Arizona. The vegetation is characterized by a diagnostic sparse, emergent tree layer of *Carnegia gigantea* (3-16 m tall) and/or a sparse to moderately dense canopy codominated by xeromorphic deciduous and evergreen tall shrubs *Parkinsonia microphylla* and *Larrea tridentata* with *Prosopis* sp., *Olneya tesota*, and *Fouquieria splendens* less prominent. The sparse herbaceous layer is composed of perennial grasses and forbs with annuals seasonally present and occasionally abundant. On slopes, plants are often distributed in patches around rock outcrops where suitable habitat is present.

Stabilized Coppice Dune and Sand Flat Scrub – This ecological system includes the open shrublands of vegetated coppice dunes and sandsheets found in the Chihuahuan Desert. Usually dominated by *Prosopis glandulosa* but includes *Atriplex canescens, Ephedra torreyana, Ephedra trifurca, Poliomintha incana*, and *Rhus microphylla* coppice sand scrub with 10-30% total vegetation cover. *Yucca elata, Gutierrezia sarothrae*, and *Sporobolus flexuosus* are commonly present.

WOODY WETLAND (2 CLASSES) – Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Riparian Mesquite Bosque – This ecological system consists of low-elevation (<1100 m) riparian corridors along intermittent streams in valleys of southern Arizona and New Mexico, and adjacent Mexico. Dominant trees include *Prosopis glandulosa* and *Prosopis velutina*. Shrub dominants include *Baccharis salicifolia, Pluchea sericea*, and *Salix exigua*.

Riparian Woodland and Shrubland – This system is dependent on a natural hydrologic regime, especially annual to episodic flooding. Occurrences are found within the flood zone of rivers, on islands, sand or cobble bars, and immediate streambanks. In mountain canyons and valleys of southern Arizona, this system consists of mid- to low-elevation (1100-1800 m) riparian corridors along perennial and seasonally intermittent streams. The vegetation is a mix of riparian woodlands and shrublands. Throughout the Rocky Mountain and Colorado Plateau regions, this system occurs within a broad elevation range from approximately 900 to 2800 m., as a mosaic of multiple communities that are tree-dominated with a diverse shrub component.

EMERGENT HERBACEOUS WETLAND (1 CLASS) – Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Arid West Emergent Marsh – This widespread ecological system occurs throughout much of the arid and semi-arid regions of western North America. Natural marshes may occur in depressions in the landscape (ponds, kettle ponds), as fringes around lakes, and along slow-flowing streams and rivers (such riparian marshes are also referred to as sloughs). Marshes are frequently or continually inundated, with water depths up to 2 m.

BARREN LANDS (5 CLASSES) – Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulation of earthen material. Generally, vegetation accounts for less than 15% of total cover.

Barren Lands, Non-specific – Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulation of earthen material. Generally, vegetation accounts for less than 15% of total cover.

Bedrock Cliff and Outcrop – This ecological system is found from subalpine to foothill elevations and includes barren and sparsely vegetated landscapes (generally <10% plant cover) of steep cliff faces, narrow canyons, and smaller rock outcrops of various igneous, sedimentary, and metamorphic bedrock types. Also included are unstable scree and talus slopes that typically occur bellow cliff faces. Species present are diverse and may include *Bursera microphylla, Fouquieria splendens, Nolina bigelovii, Opuntia bigelovii*, and other desert species, especially succulents. Lichens are predominant lifeforms in some areas. May include a variety of desert shrublands less than 2 ha (5 acres) in size from adjacent areas.

Mixed Bedrock Canyon and Tableland – The distribution of this ecological system is centered on the Colorado Plateau where it is comprised of barren and sparsely vegetated landscapes (generally <10% plant cover) of steep cliff faces, narrow canyons, and open tablelands of predominantly sedimentary rocks, such as sandstone, shale, and limestone. Some eroding shale layers similar to Inter-Mountain Basins Shale Badland (CES304.789) may be interbedded between the harder rocks. The vegetation is characterized by very open tree canopy or scattered trees and shrubs with a sparse herbaceous layer.

Volcanic Rock Land and Cinder Land – This ecological system occurs in the Intermountain western U.S. and is limited to barren and sparsely vegetated volcanic substrates (generally <10% plant cover) such as basalt lava (malpais), basalt dikes with associated colluvium, basalt cliff faces and uplifted "backbones," tuff, cinder cones or cinder fields. It may occur as large-patch, small-patch and linear (dikes) spatial patterns. Vegetation is variable and includes a variety of species depending on local environmental conditions, e.g., elevation, age and type of substrate. At montane and foothill elevations scattered *Pinus ponderosa, Pinus flexilis*, or *Juniperus* spp. trees may be present.

Warm Desert Pavement – This ecological system occurs throughout much of the warm deserts of North America and is composed of unvegetated to very sparsely vegetated (<2% plant cover) landscapes, typically flat basins where extreme temperature and wind develop ground surfaces of fine to medium gravel coated with "desert varnish." Very low cover of desert scrub species such as *Larrea tridentata* or *Eriogonum fasciculatum* is usually present. However, ephemeral herbaceous species may have high cover in response to seasonal precipitation, including *Chorizanthe rigida, Eriogonum inflatum*, and *Geraea canescens*.

ALTERED OR DISTURBED (1 CLASS) –

Recently Mined or Quarried – 2 hectare or greater, open pit mining or quarries visible on imagery.

DEVELOPED AND AGRICULTURE (3 CLASSES) –

Agriculture

Developed, Medium - High Intensity – *Developed, Medium Intensity*: Includes areas with a mixture of constructed materials and vegetation. Impervious surface accoutns for 50-79 percent of the total cover. These areas most commonly include single-family housing units. *Developed, High Intensity*: Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.

Developed, Open Space - Low Intensity – *Open Space:* Includes areas with a mixture of some construction materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed sesttings for recreation, erosion control, or aesthetic purposes. *Developed, Low intensity*: Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

OPEN WATER (1 CLASS) – All areas of open water, generally with less than 25% cover of vegetation or soil.

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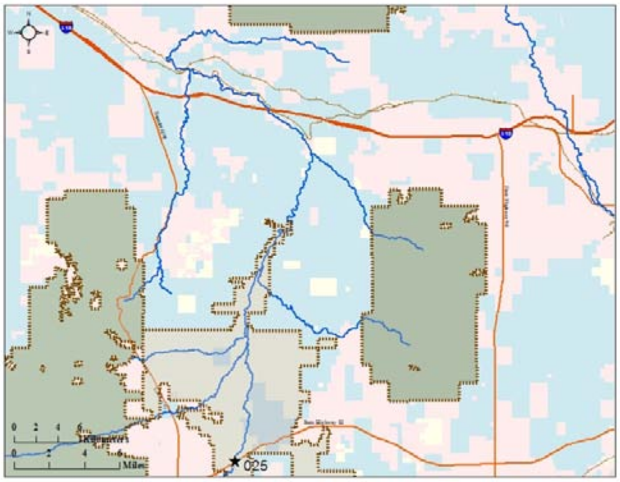
Appendix F: Database of Field Investigations

Attached is a database of field notes, GPS coordinates, and photos collected as part of our field investigations of this linkage zone. The database is found as an MS Access database on the CD-ROM accompanying this report. This database is also an ArcGIS 9.1 Geodatabase which contains all waypoints within it as a feature class. Additionally, all waypoints can be found as a shapefile in the /gis directory, and all photographs within the database are available in high resolution in the /FieldDatabase/high-res_photos/ directory.

Linkage #:	94	**Waypoint #:**	025		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.69629978	**Longitude:**	-110.600117
Observers:	Paul Beier, Dan Majka	**UTM X:**	537895.1859	**UTM Y:**	3506843.103
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



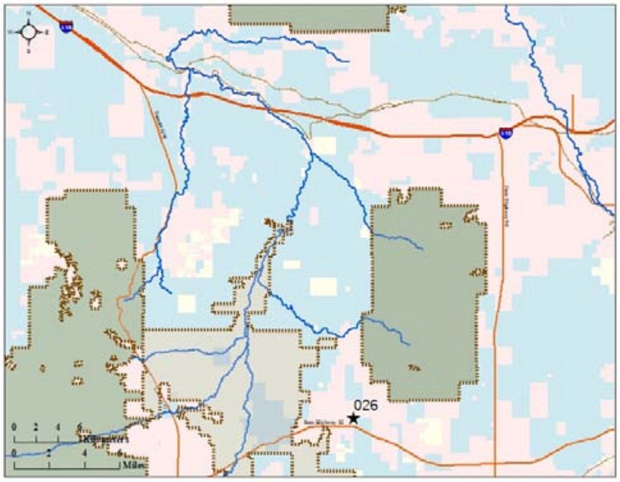
Waypoint Notes

This waypoint is surrounded by semidesert grassland and steppe.

Site Photographs

Linkage #:	94	**Waypoint #:**	026		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.73120898	**Longitude:**	-110.486292
Observers:	Paul Beier, Dan Majka	**UTM X:**	548663.7938	**UTM Y:**	3510757.606
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Areas to the north seem to have a very low threat of development.

Site Photographs

Name: DSCF0073.jpg

Azimuth: 0 **Zoom:** 1x

Notes: Photo taken from Granite Rd. Gate to Sanos Ranch

Name: DSCF0074.jpg

Azimuth: 270 **Zoom:** 1x

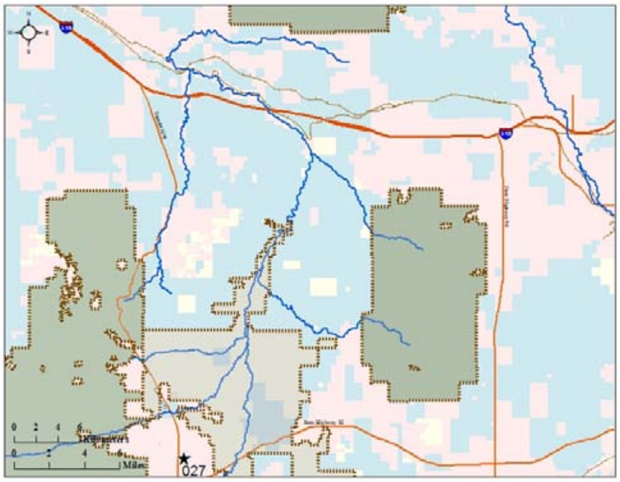
Name: DSCF0075.jpg

Azimuth: 90 **Zoom:** 1x

Appendix F: Database of Field Investigations

Linkage #:	94	**Waypoint #:**	027		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.69882072	**Longitude:**	-110.649767
Observers:	Paul Beier, Dan Majka	**UTM X:**	533189.1874	**UTM Y:**	3507106.336
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Linkage area to north and northeast - very little residential development.

Site Photographs

Name: DSCF0076.jpg

Azimuth: 0 **Zoom:** 1x

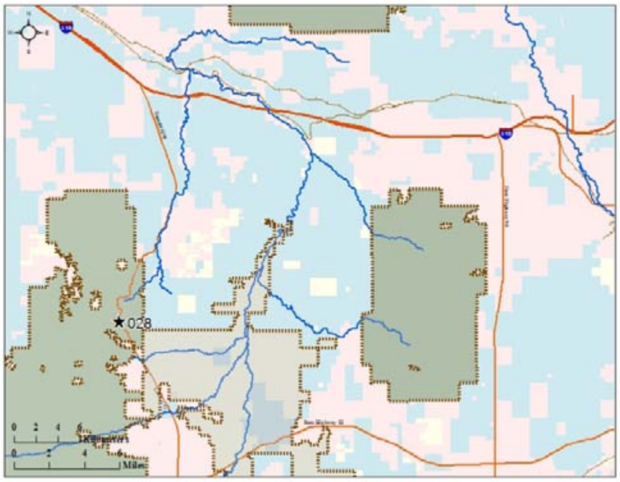
Notes: Taken from Curly Horse Rd, just east of AZ83

Name: DSCF0077.jpg

Azimuth: 58 **Zoom:** 1x

Linkage #:	94	**Waypoint #:**	028		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.81154491	**Longitude:**	-110.711394
Observers:	Paul Beier, Dan Majka	**UTM X:**	527315.9957	**UTM Y:**	3519583.444
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



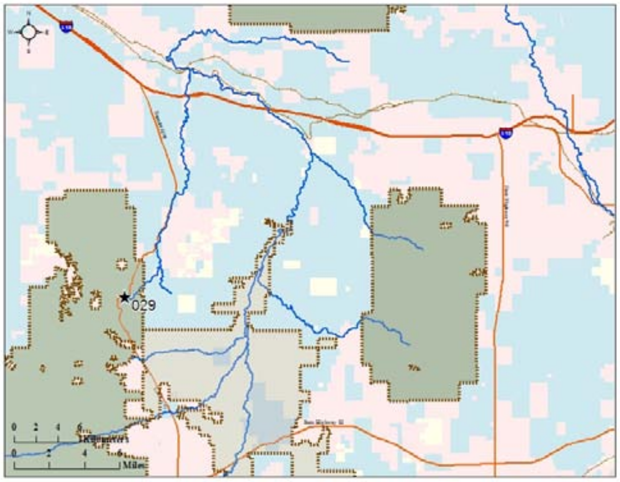
Waypoint Notes

Vast oak woodland west of waypoint.

Site Photographs

Linkage #:	94	**Waypoint #:**	029		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.83155159	**Longitude:**	-110.706446
Observers:	Paul Beier, Dan Majka	**UTM X:**	527778.3583	**UTM Y:**	3521802.238
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Oak woodlands - taken from along SR 83

Site Photographs

Name: DSCF0080.jpg

Azimuth: 10 **Zoom:** 1x

Name: DSCF0081.jpg

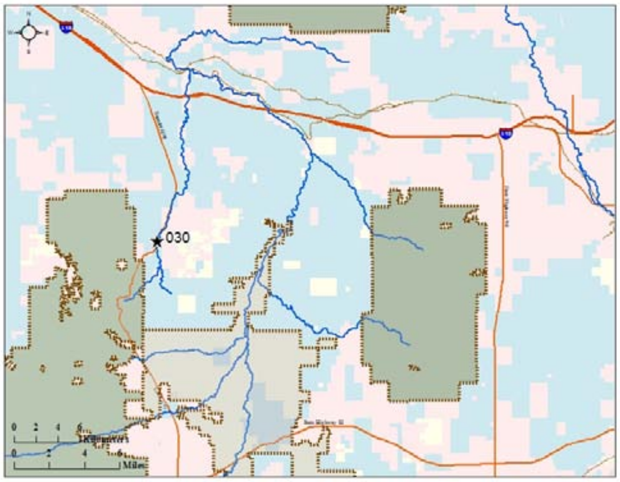
Azimuth: 64 **Zoom:** 1x

Name: DSCF0082.jpg

Azimuth: 100 **Zoom:** 3x

Linkage #:	94	**Waypoint #:**	030		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.87785993	**Longitude:**	-110.674552
Observers:	Paul Beier, Dan Majka	**UTM X:**	530781.0658	**UTM Y:**	3526943.686
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Ranchettes off Hilton Ranch Rd.

Site Photographs

Name: DSCF0083.jpg

Azimuth: 100 **Zoom:** 2x

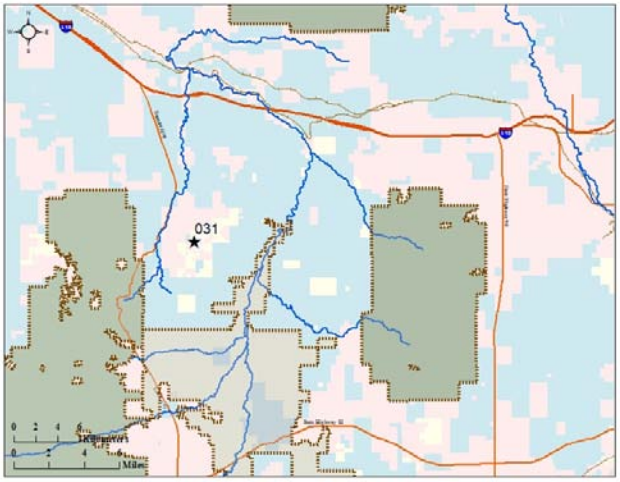
Notes: Taken from junction of Hilton Ranch Rd. and SR 83

Name: DSCF0084.jpg

Azimuth: 64 **Zoom:** 1x

Linkage #:	94	**Waypoint #:**	031		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.87661388	**Longitude:**	-110.638988
Observers:	Paul Beier, Dan Majka	**UTM X:**	534145.2313	**UTM Y:**	3526816.214
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Closest house is the easternmost house in this 'development' except for approx. 3 houses 1 mile east. Counted 37 homes visible as we drove through this development.

Site Photographs

Name: DSCF0085.jpg

Azimuth: 318 **Zoom:** 1x

Notes: Ranchettes off Hilton Ranch Rd.; SR 83 is in the distance.

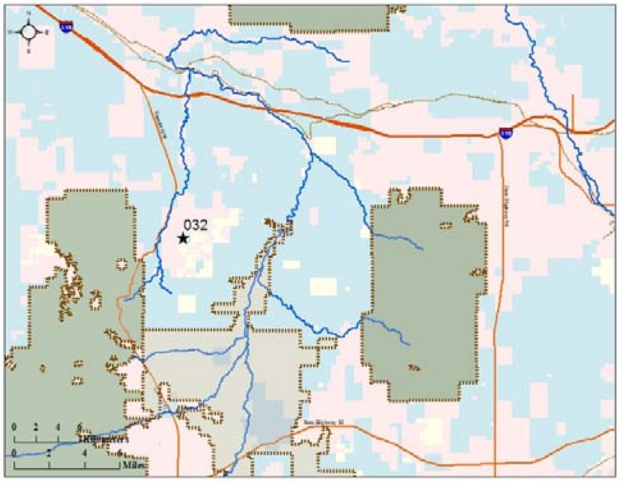
Name: DSCF0086.jpg

Azimuth: 294 **Zoom:** 2x

Notes: Photo taken from paved hillslope on Hilton Rd.

Linkage #:	94	**Waypoint #:**	032		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.8801725	**Longitude:**	-110.650044
Observers:	Paul Beier, Dan Majka	**UTM X:**	533098.1932	**UTM Y:**	3527207.23
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



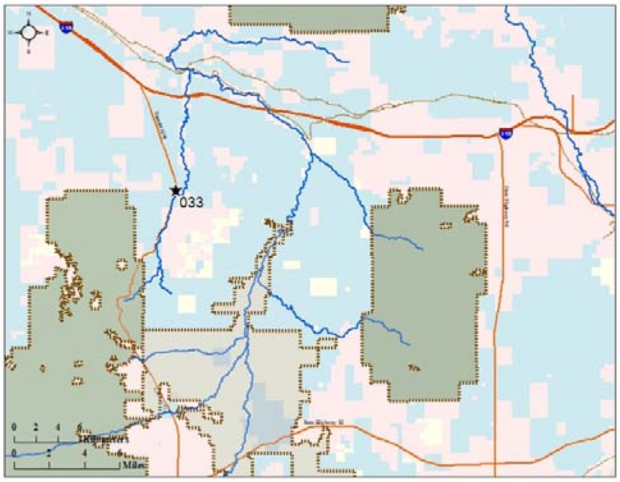
Waypoint Notes

This point marks the easternmost house within this Ranchette 'development.' Northbound on SR83, very few scattered homes until next waypoint & photo. NO PHOTO WITH THIS WAYPOINT.

Site Photographs

Linkage #:	94	**Waypoint #:**	033		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.91970105	**Longitude:**	-110.656414
Observers:	Paul Beier, Dan Majka	**UTM X:**	532481.8668	**UTM Y:**	3531586.711
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map

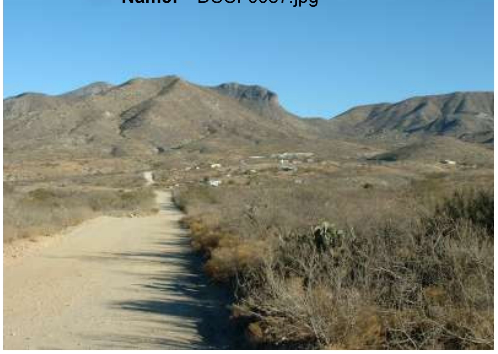


Waypoint Notes

Homes east of SR83 on dirt side road. 36 mailboxes at turnoff.

Site Photographs

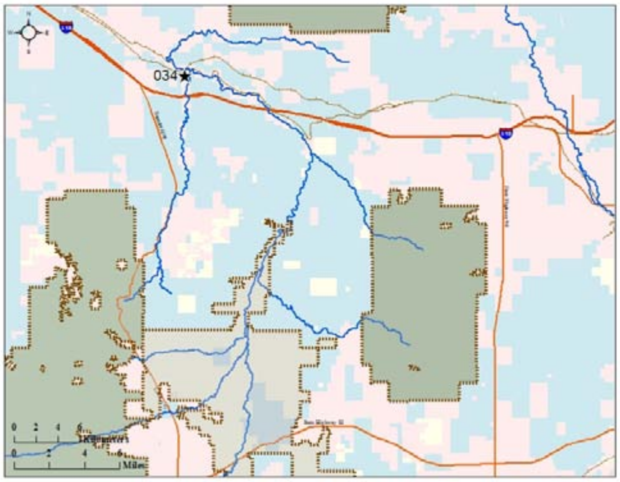
Name: DSCF0087.jpg



Azimuth: 106 **Zoom:** 2x

Linkage #:	94	**Waypoint #:**	034		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	32.01421414	**Longitude:**	-110.647319
Observers:	Paul Beier, Dan Majka	**UTM X:**	533307.5476	**UTM Y:**	3542065.57
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Took Marsh Station Rd./Frontage Rd. east from I-10/SR83 Jct. No homes except for approx. 1/4 mile west of Stigall up to Stigall Rd., then open again.

Site Photographs

Name: DSCF0088.jpg

Azimuth: 348 **Zoom:** 1x
Notes: Railroad bridge over Cienega Creek.

Name: DSCF0089.jpg

Azimuth: 66 **Zoom:** 1x
Notes: Riparian vegetation along Cienega Creek

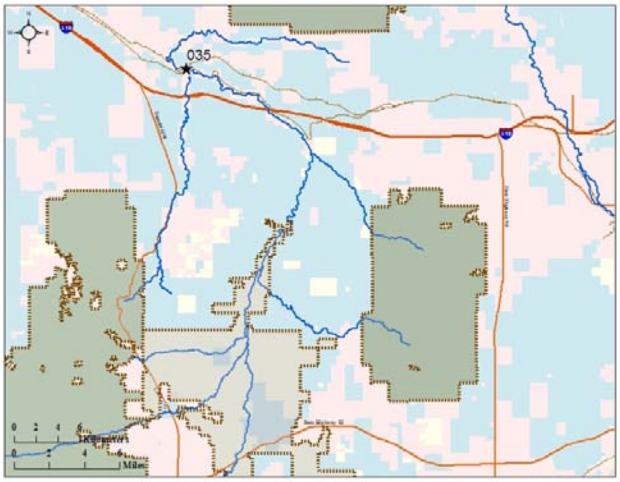
Name: DSCF0090.jpg

Azimuth: 80 **Zoom:** 2x
Notes: Riparian vegetation along

Appendix F: Database of Field Investigations

Linkage #:	94	**Waypoint #:**	035		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	32.01995624	**Longitude:**	-110.645956
Observers:	Paul Beier, Dan Majka	**UTM X:**	533434.2241	**UTM Y:**	3542702.466
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

To the East on Marsh Station Rd:

1) 1st development on north side of Agua Verde Rd. seems to have approx. 20-30 homes, including a true castle on a peak.

2) 2nd branch at Red Rock Ranch Rd. has approx. 40 mailboxes. No development to south of Marsh Station Rd.

Site Photographs

Name: DSCF0091.jpg

Azimuth: 210 **Zoom:** 1x

Notes: Cienega Creek Marsh Rd./Railroad bridge.

Name: DSCF0092.jpg

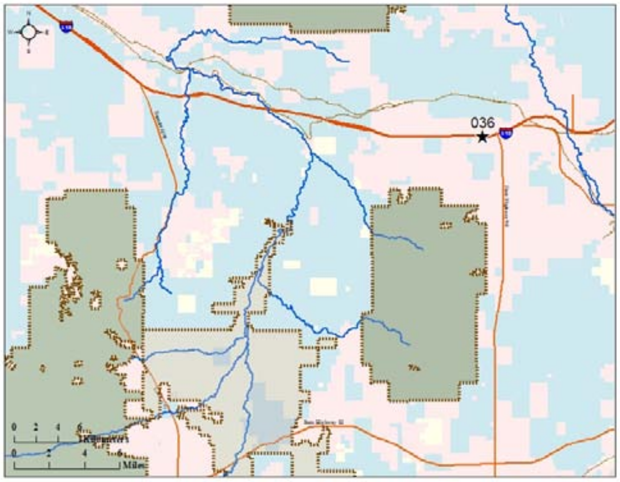
Azimuth: 134 **Zoom:** 1x

Name: DSCF0093.jpg

Azimuth: 260 **Zoom:** 1x

Linkage #:	94	**Waypoint #:**	036		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.9629075	**Longitude:**	-110.36061
Observers:	Paul Beier, Dan Majka	**UTM X:**	560418.6760	**UTM Y:**	3536502.747
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

No development from Exit 302 westward except 1 church on Blackstar Rd. The undeveloped area continues west from this culvert for almost 1/3 mile to next side road. Then land has homes on 4+ acre lots; vacant parcels for sale along Vidal Loop Rd. It might be possible to design a 1/2 mile wide corridor following this wash and uplands on the east side of the wash. On south side of I-10, maybe 8 homes on 4 acre lots off S. Frontage Rd., but again no homes for 1/2 mile east of this wash. Then, Desert Willow Rd. (posted, but apparently few if any homes on the street - 2 mail boxes). Total of 8 mail boxes on N. Frontage Rd. Posted state land to southwest of Stallion Ranch Rd.

Site Photographs

Name: DSCF0095.jpg

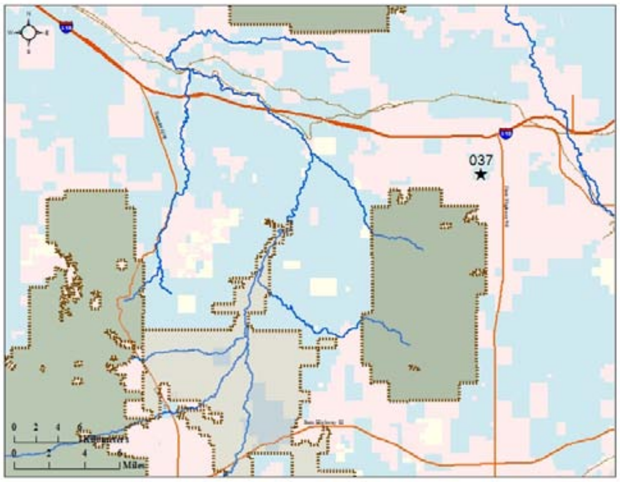
Azimuth: 184 **Zoom:** 1x

Notes: Taken from Black Star Rd. (N. Frontage Rd.). 3 5x10 box culverts under I-10, with gap between lanes.

Appendix F: Database of Field Investigations

Linkage #:	94	**Waypoint #:**	037		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.93210208	**Longitude:**	-110.361903
Observers:	Paul Beier, Dan Majka	**UTM X:**	560316.632	**UTM Y:**	3533087.412
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

The Hackberry/Patricia/Choate/Canary Springs Rds neighborhood seems to have a total of about 4 or 5 homes. Seems permeable. Met owners who say there are approx. 10 parcels here. Smith Ranch owns 700+ acres and is probably planning development. The major NW-SE road on map is a gas pipe line road.

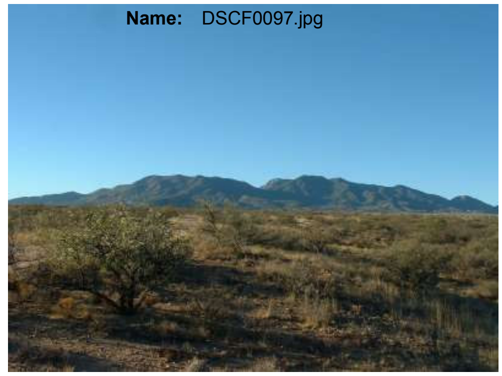
Site Photographs

Name: DSCF0096.jpg

Azimuth: 230 **Zoom:** 1z

Notes: Images taken from edge of driveway.

Name: DSCF0097.jpg



Azimuth: 200 **Zoom:** 1x

Name: DSCF0098.jpg

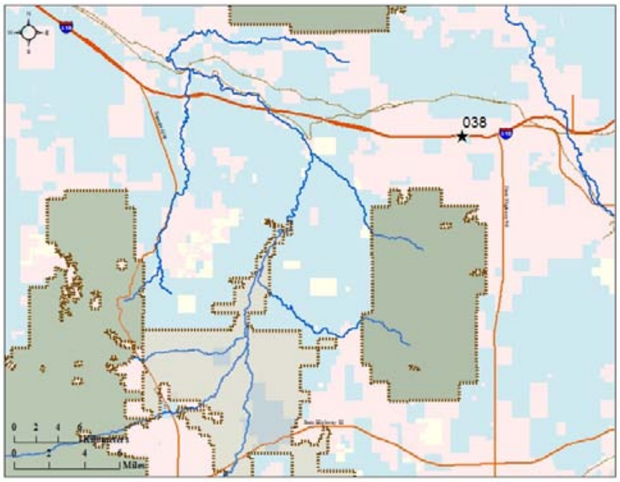
Azimuth: 0 **Zoom:** 1x

Name: DSCF0099.jpg

Azimuth: 56 **Zoom:** 3x

Linkage #:	94	**Waypoint #:**	038		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.96352642	**Longitude:**	-110.379777
Observers:	Paul Beier, Dan Majka	**UTM X:**	558607.0737	**UTM Y:**	3536560.812
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Some homes are being built to the norther here, on large lots. There is also a crossing structure for Cadillac Wash east of here.

Site Photographs

Name: DSCF0100.jpg

Azimuth: 170 **Zoom:** 1x

Notes: Photo taken from mp300 wash under I-10, at N. Frontage Rd.

Name: DSCF0101.jpg

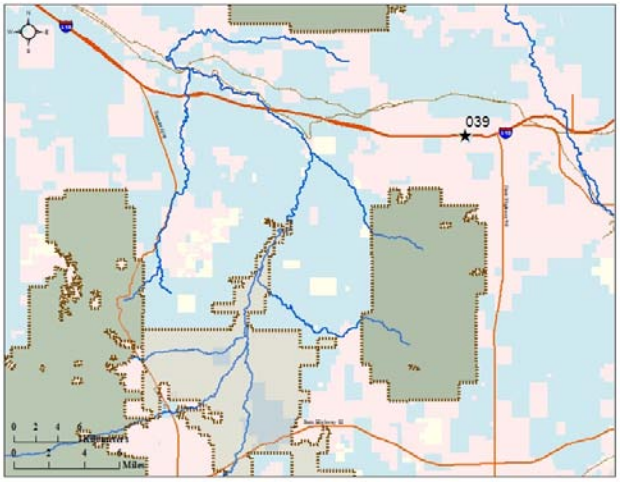
Azimuth: 0 **Zoom:** 1x

Name: DSCF0102.jpg

Azimuth: 30 **Zoom:** 1x

Linkage #:	94	**Waypoint #:**	039		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.96356389	**Longitude:**	-110.376752
Observers:	Paul Beier, Dan Majka	**UTM X:**	558892.9006	**UTM Y:**	3536566.607
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Photos taken north of I-10 at Cadillac Wash. New home towards west, but there is probably a viable narrow corridor centered on Cadillac Wash. North of I-10: Smith Ranch Rd. is locked - no development yet, but apparently large plans for this area.

Site Photographs

Name: DSCF0103.jpg

Azimuth: 182 **Zoom:** 1x

Notes: Culvert under Cadillac Wash

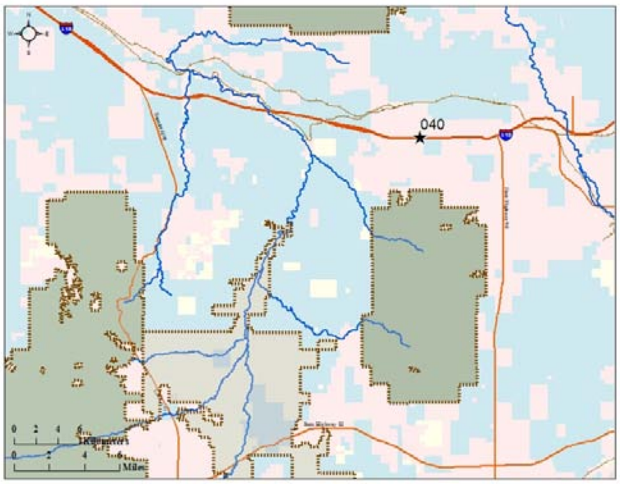
Name: DSCF0104.jpg

Azimuth: 48 **Zoom:** 1x

Notes: View north down wash.

Linkage #:	94	**Waypoint #:**	040		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.96331394	**Longitude:**	-110.420913
Observers:	Paul Beier, Dan Majka	**UTM X:**	554720.0738	**UTM Y:**	3536515.722
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Two 8x10 ft. box culverts.

Site Photographs

Name: DSCF0105.jpg

Azimuth: 176 **Zoom:** 1x

Notes: Photo taken from I-10 culvert

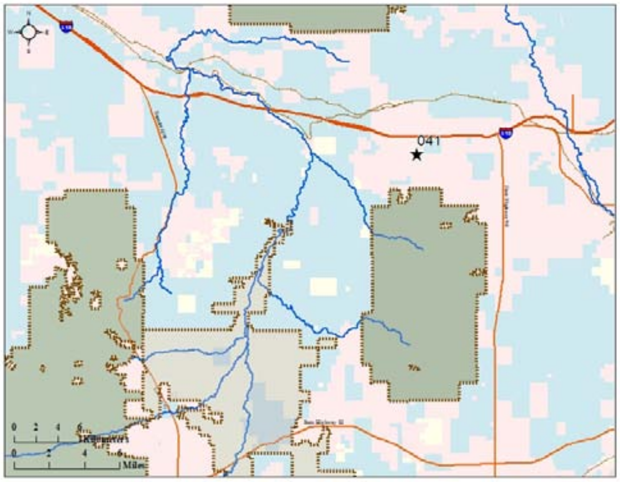
Name: DSCF0106.jpg

Azimuth: 0 **Zoom:** 1x

Notes: Photo taken from south side of culvert, facing north.

Linkage #:	94	**Waypoint #:**	041		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.94855307	**Longitude:**	-110.423419
Observers:	Paul Beier, Dan Majka	**UTM X:**	554491.9659	**UTM Y:**	3534878.301
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Photos taken from 3060 Joseph St. J-6 Ranch Rd. developed - seems to be mostly 4-12 acre lots.

Site Photographs

Name: DSCF0107.jpg

Azimuth: 302 **Zoom:** 2x
Notes: Ranchettes to northwest.

Name: DSCF0108.jpg

Azimuth: 54 **Zoom:** 1x
Notes: Ranchettes to northeast.

Name: DSCF0109.jpg

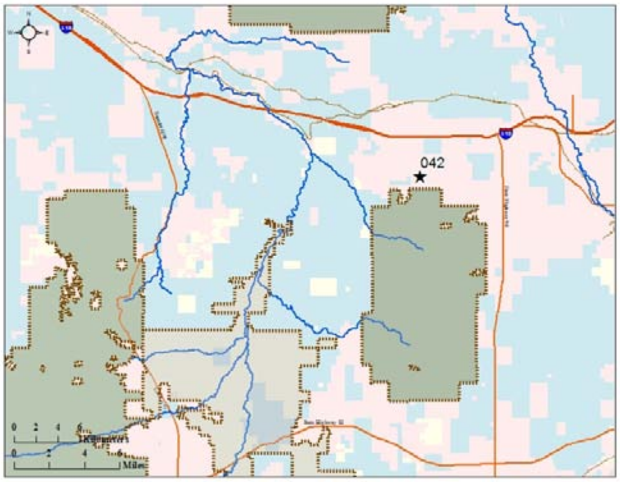
Azimuth: 152 **Zoom:** 1x
Notes: No development to southeast.

Name: DSCF0110.jpg

Azimuth: 172 **Zoom:** 1x
Notes: No development to south.

Linkage #:	94	**Waypoint #:**	042		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.93033073	**Longitude:**	-110.420805
Observers:	Paul Beier, Dan Majka	**UTM X:**	554749.8318	**UTM Y:**	3532859.785
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

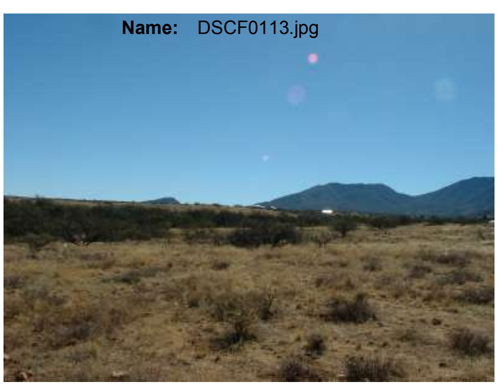
All of the upper J-6 Ranch Rd. area has powerlines, and there are several new roads present. Seems to have 10+ acre lots, with some possibly much larger. There are about 5 older homes - some up near boundary of Coronado Forest.

Site Photographs

Azimuth: 0 **Zoom:** 2x

Notes: Photo taken within potential linkage area; Ranchettes off J-6 Ranch Rd. visible.

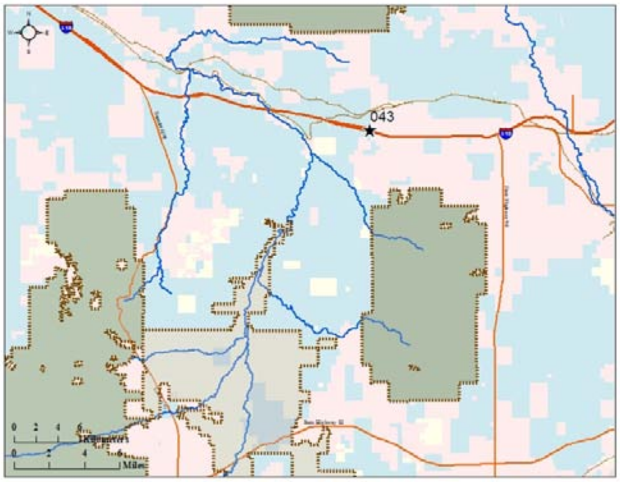
Azimuth: 80 **Zoom:** 1x



Azimuth: 152 **Zoom:** 1x

Linkage #:	94	**Waypoint #:**	043		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.96860803	**Longitude:**	-110.469419
Observers:	Paul Beier, Dan Majka	**UTM X:**	550133.5564	**UTM Y:**	3537079.042
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



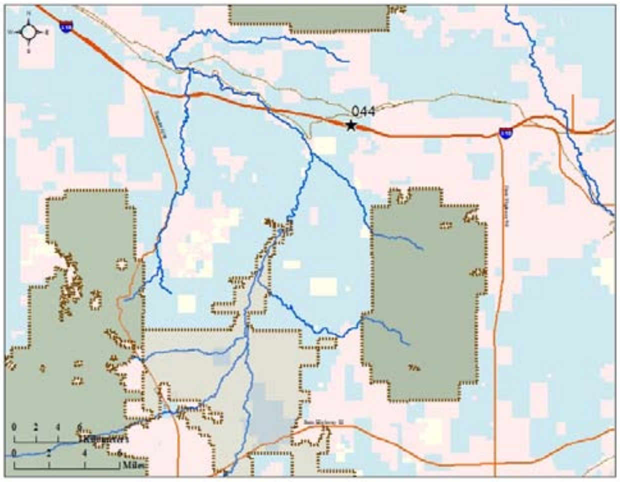
Waypoint Notes

approx. 8x10 box culvert under I-10. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	94	**Waypoint #:**	044		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.97279722	**Longitude:**	-110.486794
Observers:	Paul Beier, Dan Majka	**UTM X:**	548489.6497	**UTM Y:**	3537535.471
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



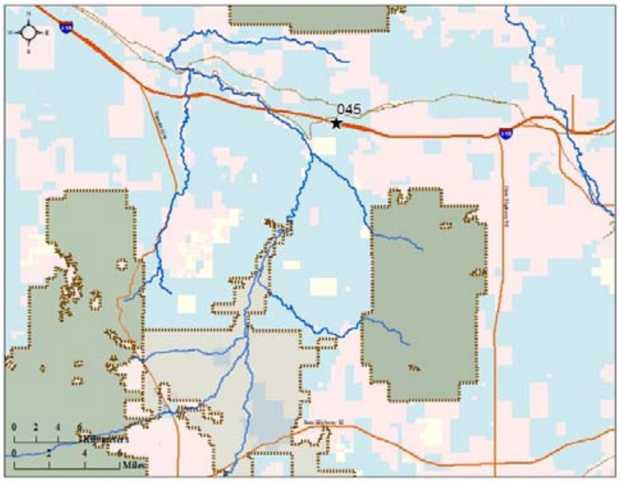
Waypoint Notes

Wash under I-10, with 2 small (8x10 ft?) culverts. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	94	**Waypoint #:**	045		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.97490645	**Longitude:**	-110.501517
Observers:	Paul Beier, Dan Majka	**UTM X:**	547097.4504	**UTM Y:**	3537762.762
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



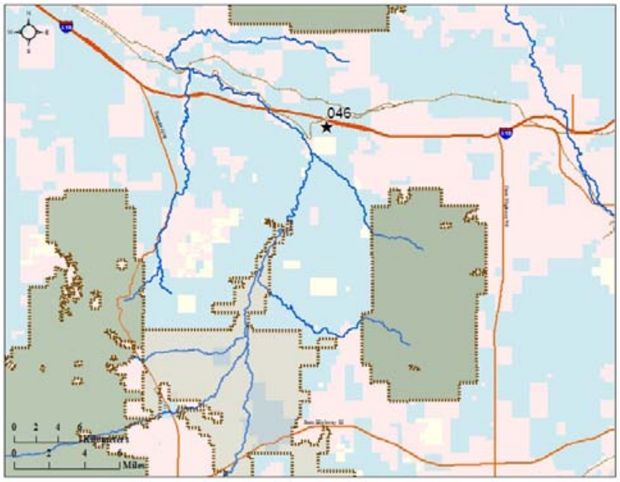
Waypoint Notes

Wash under I-10, with small culvert. NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	94	**Waypoint #:**	046		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.97159241	**Longitude:**	-110.510663
Observers:	Paul Beier, Dan Majka	**UTM X:**	546234.9425	**UTM Y:**	3537391.477
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



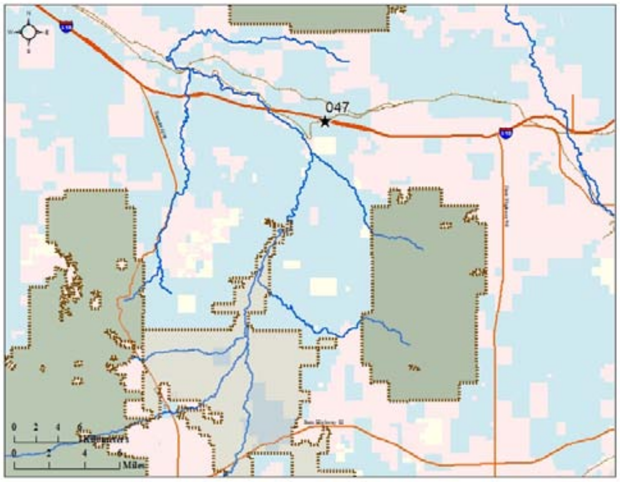
Waypoint Notes

This waypoint is surrounded by creosotebush & mesquite associations.

Site Photographs

Linkage #:	94	**Waypoint #:**	047		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.97635526	**Longitude:**	-110.512321
Observers:	Paul Beier, Dan Majka	**UTM X:**	546075.9506	**UTM Y:**	3537918.702
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

This vehicle underpass could be converted for use as a wildlife linkages underpass. Railroad underpass is 200m west. There is no development on this road except a gravel storage area on the north side of I-10. To the south, the road accesses Cienega Creek and a major power line.

Site Photographs

Name: DSCF0114.jpg

Azimuth: 50 **Zoom:** 1x

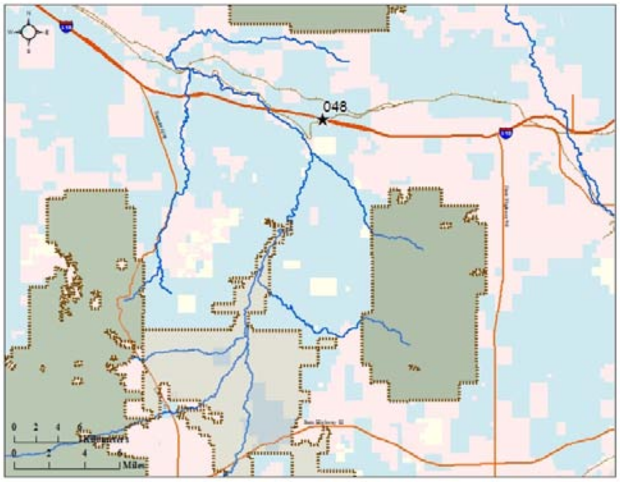
Notes: Photos taken from Emprita Rd. off I-10.

Name: DSCF0115.jpg

Azimuth: 22 **Zoom:** 2x

Linkage #:	94	**Waypoint #:**	048		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.97709446	**Longitude:**	-110.514722
Observers:	Paul Beier, Dan Majka	**UTM X:**	545848.7812	**UTM Y:**	3537999.618
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Site Photographs

Name: DSCF0116.jpg

Azimuth: 50 **Zoom:** 1x

Notes: Photos taken from junction or railroad and I-10, west of Empirita Rd.

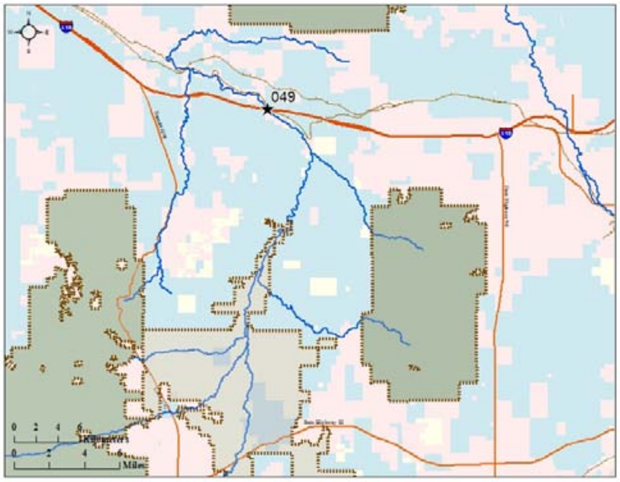
Name: DSCF0117.jpg

Azimuth: 240 **Zoom:** 2x

Notes: Photo faces Santa Ritas.

Linkage #:	94	**Waypoint #:**	049		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.98600291	**Longitude:**	-110.567501
Observers:	Paul Beier, Dan Majka	**UTM X:**	540858.2251	**UTM Y:**	3538965.911
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Photos taken from Cienega Creek, north side of I-10. 4 major sections. Great bridge. No vegetation in bottom of bridge (probably too shaded), but approx. 25 ft. high in center.

Site Photographs

Name: DSCF0118.jpg

Azimuth: 158 **Zoom:** 1x
Notes: I-10 bridge for Cienega Creek.

Name: DSCF0119.jpg

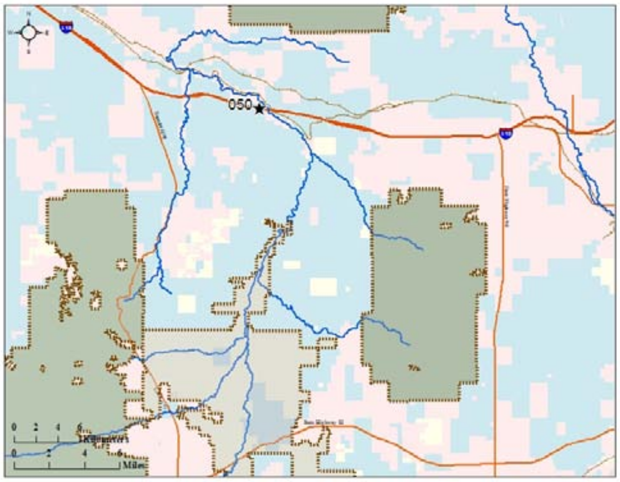
Azimuth: 132 **Zoom:** 1x
Notes: I-10 bridge for Cienega Creek.

Name: DSCF0120.jpg

Azimuth: 352 **Zoom:** 1x
Notes: Downstream view of Cienega Creek.

Linkage #:	94	**Waypoint #:**	050		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.98678687	**Longitude:**	-110.575484
Observers:	Paul Beier, Dan Majka	**UTM X:**	540103.6835	**UTM Y:**	3539049.82
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

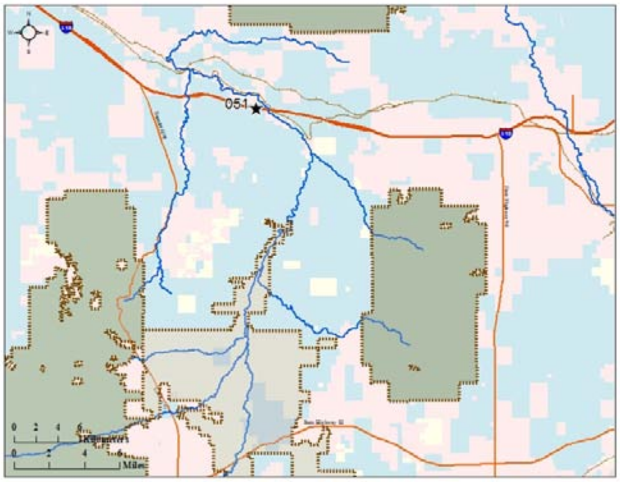
Culvert on wash along I-10. No safe way of accessing culvert along I-10 - NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Appendix F: Database of Field Investigations

Linkage #:	94	**Waypoint #:**	051		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.98717479	**Longitude:**	-110.578562
Observers:	Paul Beier, Dan Majka	**UTM X:**	539812.7684	**UTM Y:**	3539091.681
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



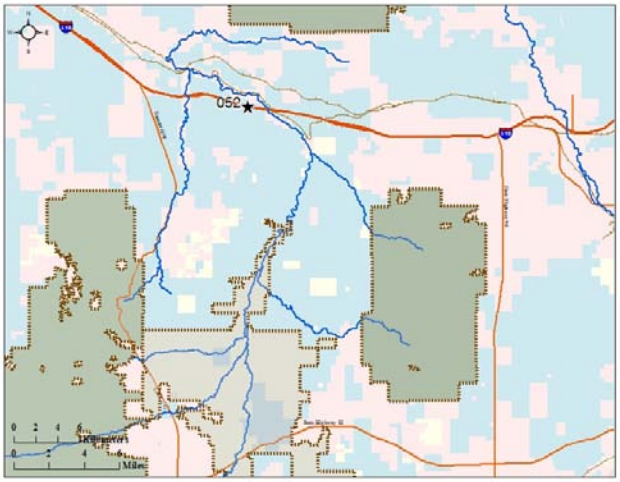
Waypoint Notes

Culvert on wash along I-10. No safe way of accessing culvert along I-10 - NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	94	**Waypoint #:**	052		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.98816201	**Longitude:**	-110.586297
Observers:	Paul Beier, Dan Majka	**UTM X:**	539081.5888	**UTM Y:**	3539198.287
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



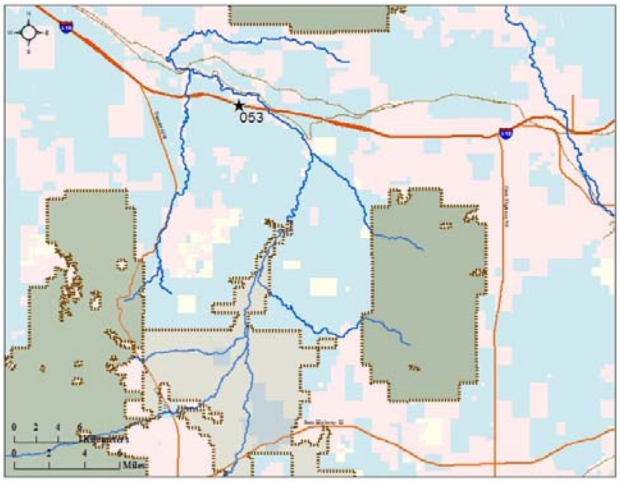
Waypoint Notes

Culvert on wash along I-10. No safe way of accessing culvert along I-10 - NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	94	**Waypoint #:**	053		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.99000686	**Longitude:**	-110.595468
Observers:	Paul Beier, Dan Majka	**UTM X:**	538214.5190	**UTM Y:**	3539399.5
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

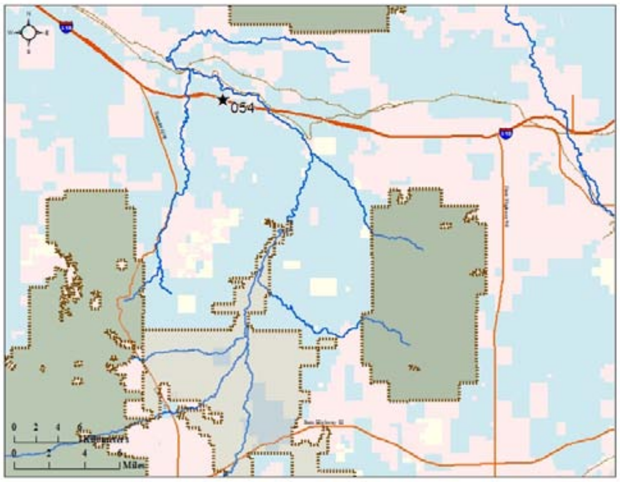
Culvert on wash along I-10. No safe way of accessing culvert along I-10 - NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Appendix F: Database of Field Investigations

Linkage #:	94	**Waypoint #:**	054		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.99436721	**Longitude:**	-110.610763
Observers:	Paul Beier, Dan Majka	**UTM X:**	536767.8846	**UTM Y:**	3539877.513
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



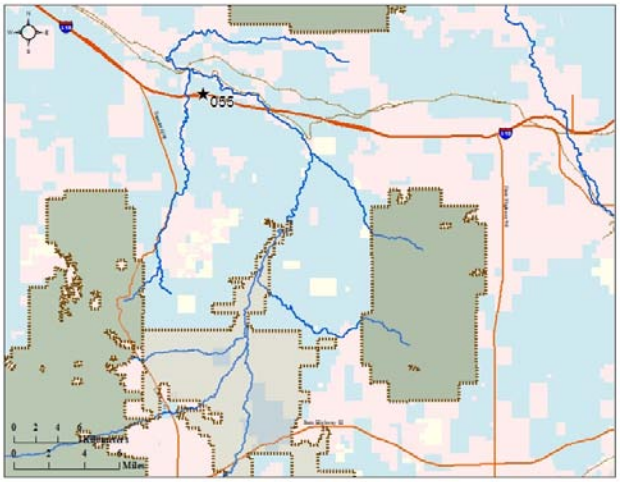
Waypoint Notes

Culvert on wash along I-10. No safe way of accessing culvert along I-10 - NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	94	**Waypoint #:**	055		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.99897986	**Longitude:**	-110.629703
Observers:	Paul Beier, Dan Majka	**UTM X:**	534977.07	**UTM Y:**	3540382.512
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



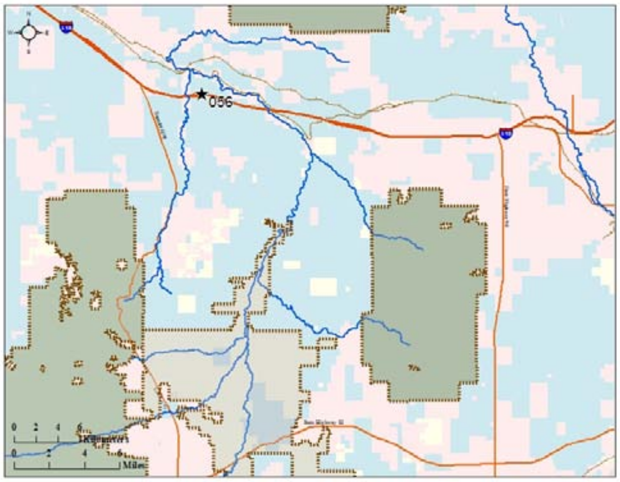
Waypoint Notes

Culvert on wash along I-10. No safe way of accessing culvert along I-10 - NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	94	**Waypoint #:**	056		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.99901557	**Longitude:**	-110.631617
Observers:	Paul Beier, Dan Majka	**UTM X:**	534796.2492	**UTM Y:**	3540385.853
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



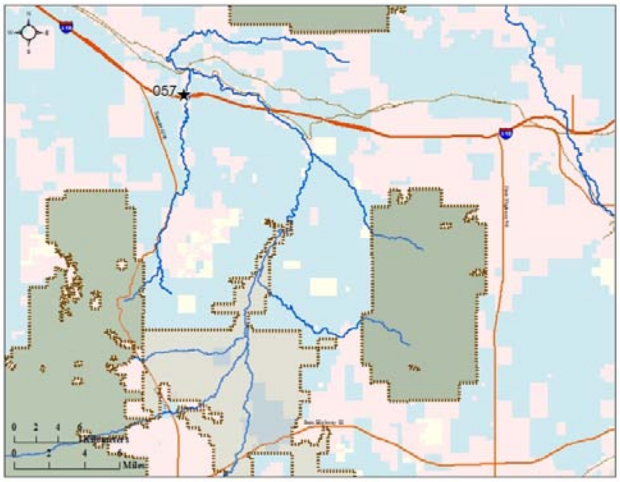
Waypoint Notes

Culvert on wash along I-10. No safe way of accessing culvert along I-10 - NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #:	94	**Waypoint #:**	057		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	31.99853369	**Longitude:**	-110.648173
Observers:	Paul Beier, Dan Majka	**UTM X:**	533232.5484	**UTM Y:**	3540327.231
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Photos taken north of I-10 at Davidson Canyon.

Site Photographs

Name: DSCF0121.jpg

Azimuth: 116 **Zoom:** 2x

Notes: Large bridge over Davidson Canyon at I-10.

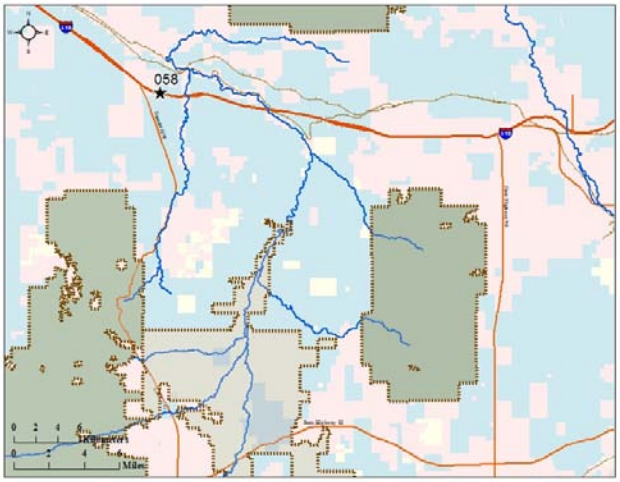
Name: DSCF0122.jpg

Azimuth: 32 **Zoom:** 1x

Notes: View northward up Davidson Canyon, towards Rincon Mtns.

Linkage #:	94	**Waypoint #:**	058		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	32.00006087	**Longitude:**	-110.671380
Observers:	Paul Beier, Dan Majka	**UTM X:**	531039.9587	**UTM Y:**	3540489.611
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



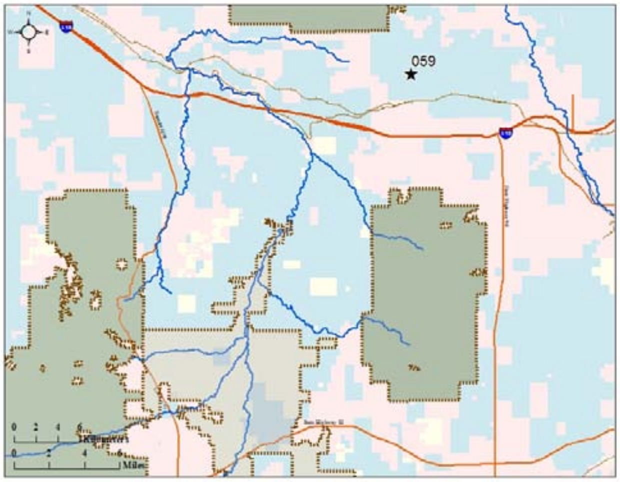
Waypoint Notes

Culvert on wash along I-10. No safe way of accessing culvert along I-10 - NO PHOTOS FOR THIS WAYPOINT.

Site Photographs

Linkage #: 94
Waypoint #: 059
Linkage Zone: Rincons - Santa Ritas - Whetstones
Latitude: 32.01425278
Longitude: -110.428632
Observers: Paul Beier, Dan Majka
UTM X: 553960.7832
UTM Y: 3542158.145
Field Study Date: 1/6/2006
Last Printed: 9/21/2006

Waypoint Map



Waypoint Notes

Photos taken from tiny hill top, west off N. Mescal Rd. From Mescal, there are ranchettes all along Mescal Rd. as far north as railroad tracks. North of the tracks, there are no homes at all to the east and no homes for at least 1 mile to the west. There is a move set village (ope 3 days per week) > 1 mile from all buildings, but it does not seem to be a barrier. Bell Road was a faint 2-track that seemed to be hardly used. True Bell Rd Jct is 1 mile north of mapped one.

Site Photographs

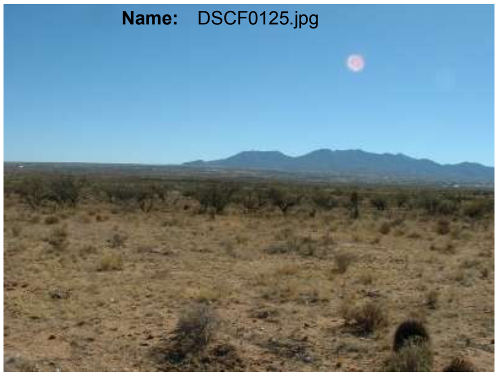
Name: DSCF0123.jpg

Azimuth: 320 **Zoom:** 1x
Notes: Rincon Mtns

Name: DSCF0124.jpg

Azimuth: 62 **Zoom:** 1x
Notes: View towards northeast

Name: DSCF0125.jpg



Azimuth: 168 **Zoom:** 1x
Notes: View towards Whetstone Mtns.

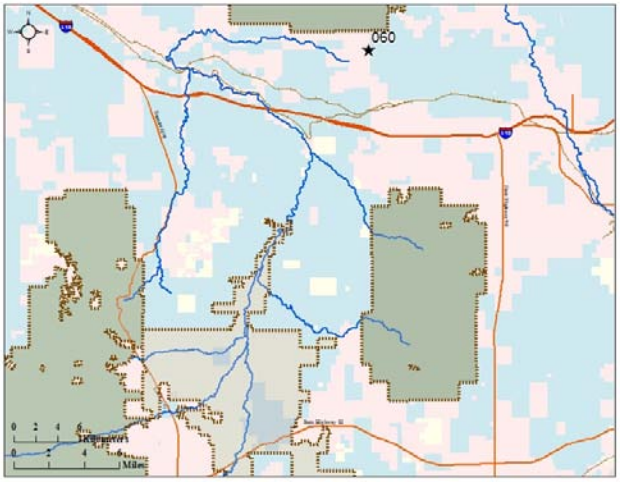
Name: DSCF0126.jpg

Azimuth: 188 **Zoom:** 4x
Notes: Village of Mescal

Appendix F: Database of Field Investigations

Linkage #:	94	**Waypoint #:**	060		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	32.03413784	**Longitude:**	-110.469803
Observers:	Paul Beier, Dan Majka	**UTM X:**	550061.6939	**UTM Y:**	3544342.489
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Head of turnoff to "World University", LPR (dog) Ranch". Just SW of here, road hits a locked gate. No development at all on this road, but road is a well-maintained gravel road.

Site Photographs

Name: DSCF0128.jpg

Name: DSCF0129.jpg

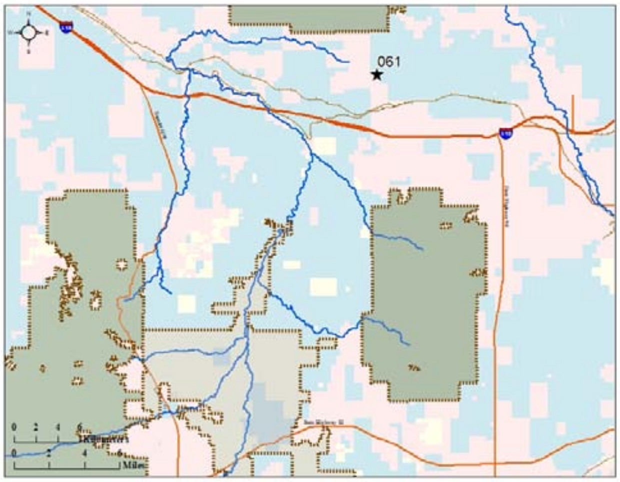
Notes: World University

Name: DSCF0130.jpg

Name: DSCF0131.jpg

Linkage #:	94	**Waypoint #:**	061		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	32.01440063	**Longitude:**	-110.461672
Observers:	Paul Beier, Dan Majka	**UTM X:**	550840.3436	**UTM Y:**	3542158.514
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Photos taken from 13459 Bell Rd.

Site Photographs

Name: DSCF0132.jpg

Azimuth: 160 **Zoom:** 1x

Notes: Whetstone Mtns,

Name: DSCF0133.jpg

Azimuth: 244 **Zoom:** 1x

Notes: Ranchettes (a 'bubble' excluded from linkage),

Name: DSCF0134.jpg

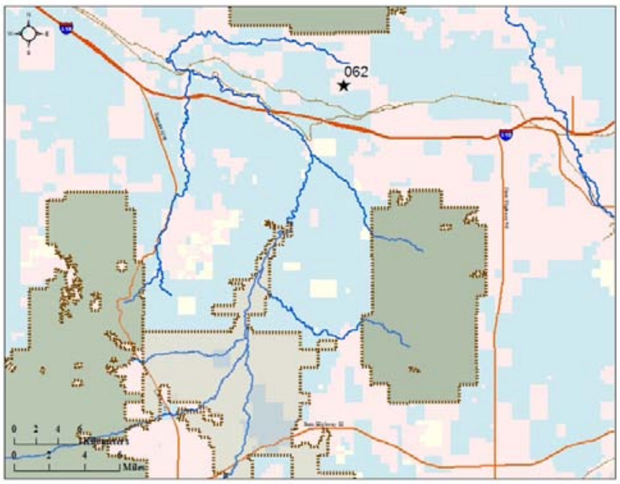
Azimuth: 300 **Zoom:** 1x

Notes: Southern top of Rincon foothillls.

Appendix F: Database of Field Investigations

Linkage #:	94	**Waypoint #:**	062		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	32.00673295	**Longitude:**	-110.494314
Observers:	Paul Beier, Dan Majka	**UTM X:**	547761.5039	**UTM Y:**	3541293.704
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



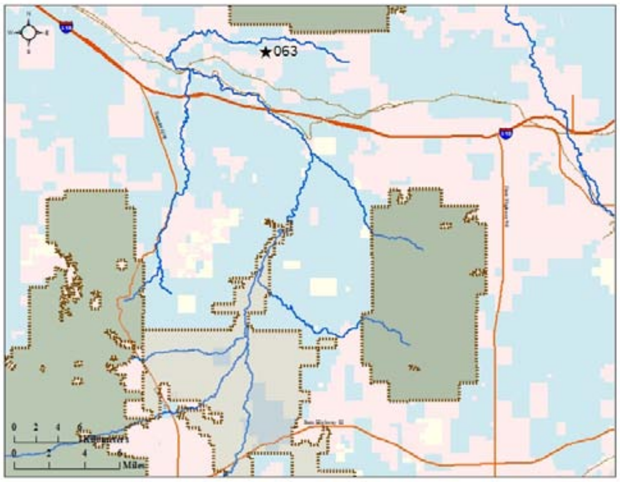
Waypoint Notes

This waypoint marks the westernmost house of the 'Bell Road' neighborhood. Everything is clear to the west from here. NO PHOTOS WITH THIS WAYPOINT.

Site Photographs

Linkage #:	94	**Waypoint #:**	063		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	32.0334967	**Longitude:**	-110.569407
Observers:	Paul Beier, Dan Majka	**UTM X:**	540657.1563	**UTM Y:**	3544229.594
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

From Marsh Station Rd., exit I-10, traveled west. Took 1st major right turn, became the road labeled Red Hill Ranch, but no road signs. Only a few scattered homes, mostly along the N-S powerline. Several signs were present advertising 4.13 acre parcels. Photos taken from hilltop on good powerline rd.

Site Photographs

Name: DSCF0135.jpg

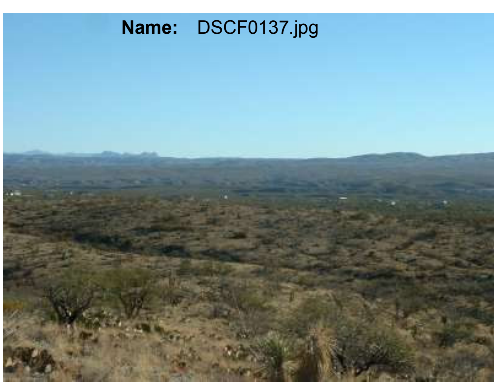
Azimuth: 135 **Zoom:** 1x

Notes: Looking towards linkage area and Whetstone Mtns.

Name: DSCF0136.jpg

Azimuth: 220 **Zoom:** 1x

Notes: Looking towards Santa Rita Mtns.



Name: DSCF0137.jpg

Azimuth: 174 **Zoom:** 3x

Notes: The 'worst' housing density along Marsh Station Rd.

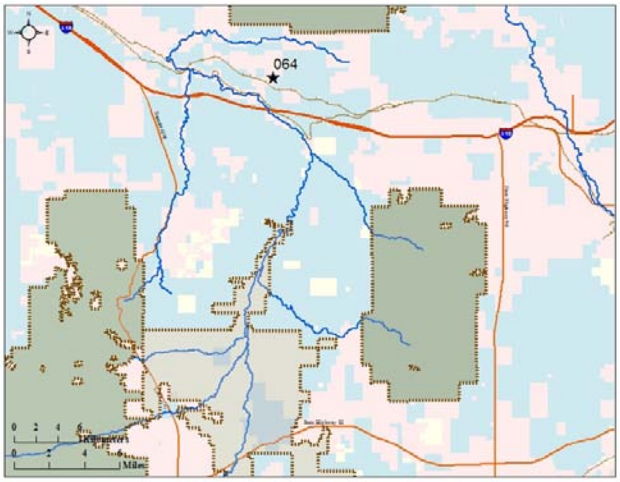
Name: DSCF0138.jpg

Azimuth: 10 **Zoom:** 1x

Notes: Looking towards Rincon Mtns.

Linkage #:	94	**Waypoint #:**	064		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	32.01256701	**Longitude:**	-110.561954
Observers:	Paul Beier, Dan Majka	**UTM X:**	541370.3552	**UTM Y:**	3541912.488
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

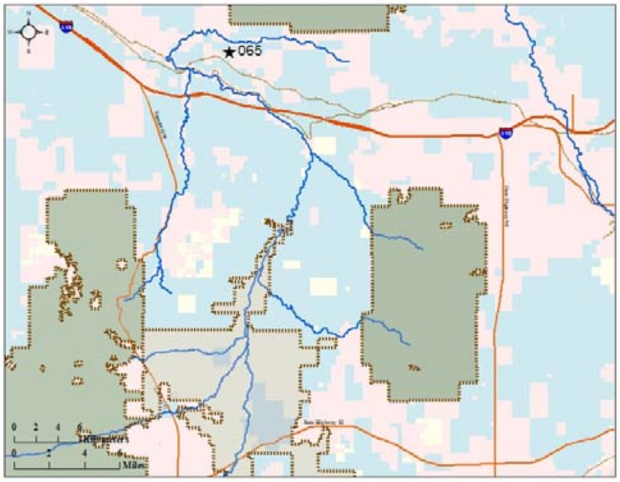
East of Orions Gateway. No more houses to East. Mostly vacant lots for sale on E-W paved road. Neighborhood of approx. 2 acre parcels, only a few built or under construction. Some open space to remain? Development size appears to be about 6 blocks N-S and 4 blocks E-W. NO PHOTOS WITH THIS WAYPOINT.

Site Photographs

Appendix F: Database of Field Investigations

Linkage #:	94	**Waypoint #:**	065		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**	32.03283763	**Longitude:**	-110.604452
Observers:	Paul Beier, Dan Majka	**UTM X:**	537348.4429	**UTM Y:**	3544143.887
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map



Waypoint Notes

Densest housing on western Marsh Station Rd. No houses east of Agua Verde Rd., and very few to the west.

Site Photographs

Azimuth: 158 **Zoom:** 2x

Notes: Photos taken from Agua Verde Rd.

Azimuth: 208 **Zoom:** 3x

Azimuth: 296 **Zoom:** 6x

Notes: Castle on peak.

Linkage #:	94	**Waypoint #:**	NONE1		
Linkage Zone:	Rincons - Santa Ritas - Whetstones	**Latitude:**		**Longitude:**	
Observers:	Paul Beier, Dan Majka	**UTM X:**		**UTM Y:**	
Field Study Date:	1/6/2006	**Last Printed:**	9/21/2006		

Waypoint Map

Waypoint Notes

Coppercut Rd. South from Sahuarita Rd. - 48 mailboxes at junction. South Rd., no homes for 1st mile. Side roads branch to right (West) of Copper Cut with low density housing. Probably 2-5 acre parcels.

Site Photographs