

Silverbell Road (South) Wildlife Linkage Initial Assessment: El Camino del Cerro Road to Grant Road, Pima County, Arizona

Prepared for

Kittelson & Associates, Inc.

For Submittal to

City of Tucson Department of Transportation

Prepared by

SWCA Environmental Consultants

February 2010

**Silverbell Road (South) Wildlife Linkage Initial Assessment:
El Camino del Cerro Road to Grant Road, Pima County, Arizona**

Prepared for

**Kittelson & Associates, Inc.
33 North Stone Avenue, Suite 800
Tucson, Arizona 85701
Attn: Jim Schoen**

and

**City of Tucson Department of Transportation
P.O. Box 27210
Tucson, Arizona 85726-7210
Attn: Catesby Willis**

Prepared by

**SWCA Environmental Consultants
343 West Franklin Street
Tucson, Arizona 85701
(520) 325-9194
www.swca.com**

SWCA Project No. 15553

February 2010

TABLE OF CONTENTS

	<u>Page</u>
1.0 INTRODUCTION	1
2.0 FOCAL SPECIES	3
2.1 Focal Species A: Bobcat.....	4
2.2 Focal Species B: Herpetofauna and Small Mammal Species.....	4
3.0 OBJECTIVES	6
4.0 STUDY AREA AND ROAD EVALUATION METHODOLOGY	8
4.1 Study Area	8
4.2 Land Ownership and Use	12
4.3 Relationship between Silverbell Road and Wildlife Corridors/Movement Routes....	13
4.4 Linkage Assessment Methodology	14
4.4.1 Identifying and Assessing Existing Ungulate and Carnivore Crossing Locations along or across Roadways	15
4.4.2 Identifying and Assessing Potential Crossing Locations and Structures	15
4.4.3 Identifying and Assessing Multiple Landscape and Man-made Features that may Impede Wildlife Movement across Roadways	16
4.4.4 Evaluation Criteria.....	16
5.0 RESULTS	18
5.1 Existing Features	18
5.1.1 Structures	18
5.1.2 Fill Slopes	19
5.1.3 Road-Stream Crossings	19
5.1.4 At-Grade Crossings	19
5.1.5 Other Features that May Deter or Enhance Wildlife Movement across Silverbell Road.....	21
5.2 Priority Wildlife Movement Zones and Criteria for Designation	21
5.2.1 Priority Crossing Zone A: Tres Rios South Wildlife Crossing.....	21
5.2.2 Priority Crossing Zone B: Roger Road Wastewater Treatment Plant Fencing Area.....	22
6.0 RECOMMENDATIONS	24
6.1 Specific Recommendations/Mitigation Measures within Priority Crossing Zones ...	24
6.1.1 Tres Rios Wildlife Crossing	24
6.1.2 Roger Road Wastewater Treatment Plant Fencing Area	27
6.2 Additional Recommendations/Mitigation Measures Outside of Priority Crossing Zones	29
6.2.1 Drainage Structures	29
6.2.2 Vegetation Management.....	29
6.3 Recommended Monitoring.....	29
6.3.1 AVC Monitoring.....	30
6.3.2 Underpass Monitoring	30
6.3.3 Roadside Track Beds	31
6.3.4 Adaptive Management.....	32
7.0 REFERENCES.....	33

LIST OF TABLES

<u>Table</u>	<u>Page</u>
5-1. Dimensions of Existing Structures in Feet along Silverbell Road South.	19
6-1. Recommended Minimum Dimensions in Feet of Underpass Structures along Silverbell Road. Structures are presented in order of priority.	24
6-2. Recommended Minimum Dimensions in Feet of Underpass Structures along Silverbell Road. Structures are presented in order of priority.	27

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
4-1. Project location map.....	9
4-2. Overview of this portion of Silverbell Road.	10
5-1. Map of proposed drainage structures for this portion of Silverbell Road.....	20

LIST OF APPENDICES

Appendix

- A. Representative Photos of Structures and At-Grade Crossings along this Portion of
Silverbell Road

1.0 INTRODUCTION

Habitat fragmentation has been targeted as one of the most serious threats to biodiversity worldwide (Wilcox and Murphy 1985; Saunders et al. 1991). Fragmentation typically leads to the isolation of populations, thus creating local subpopulations scattered across a landscape (Dobson et al. 1999). Isolation of these subpopulations may lead to local extinctions in that, over time, populations restricted to isolated patches may experience a reduction in genetic diversity due to increased inbreeding, increased risk of local extinction due to population dynamics and catastrophic events, and decreased ability to recolonize (Yanes et al. 1995; Hanski and Simberloff 1997; Hanski 1999). Landscapes that become fragmented often lack heterogeneity as well as pose specific threats to population viability (Noss and Cooperrider 1994). Additional impacts that typically result from fragmentation include the direct loss of habitat, fragmentation effects, and edge effects (Murcia 1995). Fragmentation effects include changes in community structure, function, and composition. Edge effects include increased light, noise, and chemical pollution; microclimate alteration; non-native species invasion; and increased disturbance and increased mortality through direct interaction with humans. Studies in highly fragmented landscapes of southern California have documented the impacts on populations of birds (Bolger et al. 1997; Scott and Cooper 1999), herpetofauna (Boarman and Sazaki 1996; Fisher and Case 2000), and mammals (Beier 1993, 1995; Crooks and Soulé 1999; Haas 2000; Lyren 2001; Lyren et al. 2005).

One of the principal factors contributing to habitat fragmentation has been the construction of roadways (Meffe et al. 1997). Roadways may impact wildlife in a variety of ways (see review in Ouren and Haas, in press); they have been identified as threats to the long-term persistence of rare and threatened species, including grizzly bears (Gibeau and Herrero 1998; Servheen et al. 1998), black bears (Brody and Pelton 1989), gray wolves (Paquet and Callahan 1996), Florida panthers (Foster and Humphrey 1995; Land and Lotz 1996), mountain lions (Beier 1996), lynx (Ruediger 1998), ocelots (Tewes and Blanton 1998), snakes (Rudolph et al. 1998), and desert tortoises (Boarman and Sazaki 1996). Not only do these roadways separate previously connected areas of habitat; they also create a barrier effect for organisms attempting to move between patches (Yanes et al. 1995). In addition, increasing highway mortality also plays a role in decreasing population numbers (Harris and Gallagher 1989).

To counteract the negative impact of roadways on wildlife movement, different types of mitigation techniques have been identified to maintain connectivity while providing safety to the traveling public by reducing the threat of wildlife-vehicle collisions (Huijser et al. 2007). These techniques have ranged from methods used to influence driver behavior (e.g., road warning signs, animal detection systems), influence animal behavior (e.g., deer reflectors and mirrors, olfactory repellants), and physically separating wildlife from roadways. The latter provides the safest means (for both drivers and wildlife) of increasing driver safety while simultaneously maintaining the safe passage of wildlife across roadways. Specifically, the role of underpasses as an alternative route to surface crossings have received increasing attention (Mansergh and Scotts 1989; Foster and Humphrey 1995; Yanes et al. 1995; Rodriguez et al. 1996; Clevenger and Waltho 2000; Haas 2000), and in urbanizing areas there has been an increasing amount of research devoted to determining the usefulness of underpasses for large carnivores (Haas 2000; Lyren 2001; Ng et al. 2004; Lyren et al. 2005;

Haas and Crooks, in prep.). Furthermore, the positioning of these structures relative to developed areas within the surrounding landscape has been identified as factoring into the probability that various wildlife species will utilize such structures, thus maximizing their functionality for multiple wildlife species (Haas and Crooks, in prep.).

The proposed widening of Silverbell Road within the jurisdiction of the City of Tucson in Pima County, a Regional Transportation Authority (RTA)-funded roadway project, provides an excellent opportunity to identify, monitor, and plan wildlife linkages as they relate to transportation projects. Identifying critical locations that could provide for the successful movement of wildlife across roads presents a unique opportunity to incorporate mitigation opportunities that promote the safe passage of wildlife across roadways in this project's design/construction phase.

2.0 FOCAL SPECIES

For any linkage analysis, it is important to identify a suite of species on which recommendations will be focused, as the concept of focal species in reserve design and wildlife connectivity is a central theme in local and regional conservation planning (Miller et al. 1998; Soulé and Terborgh 1999). Focal species are typically identified to symbolize ecological conditions that are critical to healthy, functioning ecosystems (Lambeck 1997); however, species with special status designation have also been identified. Our initial group of focal species included federal- and state-listed species, as well as Priority Vulnerable Species (PVS) identified in Pima County's Sonoran Desert Conservation Plan (SDCP) (Pima County 2006), a Multi-Species Conservation Plan (MSCP). According to the SDCP (Pima County 2006) and Mapguide Geographic Information System (GIS) utility (Pima County 2009), the project area falls within or adjacent to a Priority Conservation Area (PCA) for the following ten PVS: lesser long-nosed bat (*Leptonycteris curasoae yerbabuenae*), Huachuca water umbel (*Lilaeopsis schaffneriana* ssp. *recurva*), listed as Endangered by the U.S. Fish and Wildlife Service (USFWS); northern Mexican gartersnake (*Thamnophis eques megalops*), listed as Candidate by the USFWS; cactus ferruginous pygmy-owl (*Glaucidium cactorum brasilianum*), lowland leopard frog (*Rana yavapaiensis*), California leaf-nosed bat (*Macrotus californicus*), and western burrowing owl (*Athene cunicularia hypugaea*), each listed as Wildlife of Special Concern by the State of Arizona (WSCA) and Species of Concern (SC) by the USFWS; giant spotted whiptail (*Aspidoscelis burti stictogrammus*), listed as SC by the USFWS; and Abert's towhee (*Pipilo aberti*) and desert box turtle (*Terrapene ornata luteola*), both listed as PVS within the MSCP.

For this assessment, SWCA Environmental Consultants (SWCA) determined whether any of the PVS may occur in the project area or whether they have the potential to use this area for daily or seasonal movements. Though many of the PCAs fell within the project area, it was determined that none of the species are expected to occur there. And due to the lack of agaves and few saguaros, it is expected that foraging habitat is not present for the lesser long-nosed bat. The Huachuca water umbel, lowland leopard frog, northern Mexican garter snake, and giant spotted whiptail are not expected to occur in the project area due to the ephemeral nature of the Santa Cruz River at the point in which it flows through the project area. However, it is possible that these three reptile species could temporarily move through this portion of the Santa Cruz River as individuals of the species disperse and travel between preferred habitats. Similarly, although it is not expected that the western burrowing owl or cactus ferruginous pygmy-owl would occur in the project area, it is possible that individuals of the two species could disperse across this portion of Silverbell Road in search of preferred habitats to the north and south. It is unknown whether the desert box turtle, Abert's towhee, and California leaf-nosed bat may occur in the project area.

Additional species identified as target species for the Saguaro-Tortolita Linkage include bobcat (*Lynx rufus*), cave myotis (*Myotis velifer*), javelina (*Tayassu tajacu*), mountain lion (*Puma concolor*), mule deer (*Odocoileus hemionus crooki*), pocketed free-tailed bat (*Nyctinomops femorosaccus*), and Sonoran desert tortoise (*Gopherus agassizii*). Black bear (*Ursus americanus*) may use this area very infrequently, and their movements would likely be attributed to dispersal events. The Santa Cruz River represents the most likely location along

this stretch of road where crossings could occur, since it is a large, natural feature that could provide for long, linear movements by these species. The bobcat, javelina, kit fox, mule deer, Sonoran desert tortoise, cave myotis, and pocketed free-tailed bat all have the potential to travel and forage throughout this area.

For this linkage analysis, the bobcat was selected as the target species. Mammalian carnivores can be effective focal species to evaluate the degree of landscape-level connectivity or fragmentation in a region. Large carnivores are particularly vulnerable to extinction in fragmented habitats because of wide ranges and resource requirements, low densities, slow population growth rates, long range dispersal, and direct persecution by humans (Noss et al. 1996; Woodroffe and Ginsberg 1998; Crooks 2000), and their disappearance may generate cascades that ripple down the food web (Crooks and Soulé 1999; Henke and Bryant 1999; Estes et al. 2001; Ripple et al. 2001). In fragmented habitats in San Diego, Crooks and Soulé (1999) suggest that extirpation of dominant predators (e.g., coyotes [*Canis latrans*]) can contribute to ecological release of smaller predators and increased extinction rates of their avian prey. Large carnivores (e.g., bobcat) therefore are ecologically pivotal organisms whose status can indicate functional connectivity of ecosystems, and using mammalian carnivores in conservation planning adds a critical layer of conservation strategy that may provide a robust method for protecting other species that have less demanding needs (Lambeck 1997; Miller et al. 1998; Carroll et al. 1999).

Smaller-bodied herpetofauna and small mammal species were also identified as a focal species group, primarily due to the need to appropriately space underpasses to ensure that populations have the ability to successfully navigate across a landscape bisected by large impediments to species movement such as Silverbell Road.

2.1 FOCAL SPECIES A: BOBCAT

Bobcats are less sensitive to fragmentation and have smaller dispersal distances and home ranges (see Lyren 2001:Table 1.11; Riley et al. 2003) than mountain lions. Bobcats therefore can persist in smaller habitat fragments, but, like mountain lions, only those that have adequate connections to larger natural areas. Consequently, bobcats are valuable indicators of connectivity at smaller, more local, spatial scales in developing landscapes, which is typical of the landscape surrounding this stretch of Silverbell Road. Alternatively, bobcats are more sensitive to fragmentation than coyotes (Crooks and Soule 1999; Haas 2000; Ng et al. 2004), so designing and placing crossing structures directed at facilitating bobcat movement will also accommodate the safe passage of coyotes, another top predator common throughout this linkage area. Bobcats will thus serve as a surrogate species to successfully provide corridors for movement for other species (e.g., javelina).

2.2 FOCAL SPECIES B: HERPETOFAUNA AND SMALL MAMMAL SPECIES

Few studies have looked at the requirements needed to mitigate the negative effects of roadways for lizards and snakes within the Sonoran desert (Arizona Game and Fish Department [AGFD] 2006a). This group represents a specific challenge in the Sonoran Desert Arizona Upland landscape because lizards and snakes are slow moving and physiologically

attracted to road surfaces for thermoregulation and foraging (AGFD 2006a). Two studies in southern Arizona (Rosen and Lowe 1994; Kline and Swann 1999) have documented many reptile and amphibian vehicle-collision mortalities on repeated transects and have extrapolated estimates to surrounding areas. Rosen and Lowe (1994) conducted roadkill surveys throughout Organ Pipe Cactus National Monument and comparison sites away from the highway. The authors concluded that Highway 85, which bisects the National Monument, substantially effected the regional snake population with vehicle collisions accounting for 2,000 to 4,000 estimated mortalities over four years. Kline and Swann (1998) conducted multi-species roadkill surveys in Saguaro National Park (East and West units) and similarly estimated several thousand vertebrates killed annually as a result of traffic. The impacts of these mortalities vary between species and undoubtedly have a more dramatic effect on the long-lived and slowly reproducing individuals (e.g., desert tortoise, Gila monster). Species such as the spadefoot toads have abbreviated, yet explosive reproductive episodes (strongly associated with monsoons) and populations may withstand high mortality episodes during such events (Kline and Swann 1998).

3.0 OBJECTIVES

The objective of this analysis is to utilize wildlife distribution and movement data, evaluate adjacent land uses and proposed development zones, and document existing and potential crossing locations for wildlife connectivity-associated mitigation measures, in order to maintain and enhance the movement of wildlife across Silverbell Road. Regional transportation planning efforts seek to develop infrastructure that meets the expected increase in travel capacity while maintaining the safe passage of wildlife across roadways. Therefore, recognizing opportunities to maintain or increase the rate of wildlife movement across roads while increasing driver safety, as well as identifying those locations where such measures can be addressed, is paramount in achieving a regional transportation system that seeks to reduce the impacts of roadways on wildlife.

This study would serve as the first step in a series of proposed analyses that seek to address minimizing the impacts of transportation systems on wildlife connectivity from several perspectives: 1) identifying short-term strategies and techniques to minimize road impacts on wildlife; 2) incorporating site assessment recommendations into the early design phases of the project; 3) collecting animal-vehicle collision (AVC) data along various roadways to identify stretches of road that pose significant threats to wildlife and driver safety; 4) monitoring successful crossing attempts for multiple species through various methods to refine mitigation locations and recommendations, and prioritizing road segments that may be subjected to future wildlife connectivity-related mitigation measures; 5) developing significance thresholds and post-construction monitoring to ensure that recommended mitigation measures are maintaining successful passage of wildlife across roads over time; and 6) coordinating with town and county departments and other municipalities to incorporate mitigation measures into local planning efforts to ensure the long-term functionality of wildlife connectivity mitigation investments.

These objectives complement each other in a variety of ways. First, by conducting roadway assessments along stretches of road slated for improvements, we can identify existing and potential locations that, from an engineering perspective, represent optimal locations to construct appropriate crossing structures for various wildlife species. This report summarizes the methods and results from this step of the larger study design presented above. Secondly, by collecting several types of data (including AVC, underpass use, and activity along roadways), we can refine recommendations and test how various stretches of road compare to each other with regard to their ecological significance (as determined by what species may be impacted by future transportation projects), their current rate of wildlife crossing activity (as determined by monitoring existing rates of crossing activity), and their risk to drivers and wildlife (as determined by the rate of AVCs along that stretch of road). In addition, ensuring that recommended mitigation measures are adequate in maintaining the successful passage of wildlife across roads is a critical step in the long-term functionality of wildlife movement across the region. By determining various significance criteria before project construction begins, a benchmark by which to gauge the success of mitigation measures can be established, thus creating an adaptive management process that will not only ensure the long-term success of that particular mitigation measure, but serve as a reference from which future mitigation strategies can be based.

This report summarizes initial efforts to develop a list of species that have the potential to be impacted by this roadway widening project, characterize existing crossing locations, and identify potential mitigation opportunities. To meet these goals, the following steps were taken: 1) conducting an investigation of previous studies and databases that could provide information regarding the species that are either present within these linkages or that have the potential to use these linkages; 2) determining the locations of potential crossing zones; 3) conducting a thorough field analysis of existing and potential wildlife crossing zones for the aforementioned stretch of Silverbell Road; and 4) prioritizing crossing locations and developing potential mitigation measures.

4.0 STUDY AREA AND ROAD EVALUATION METHODOLOGY

4.1 STUDY AREA

The section of roadway being evaluated as a Wildlife Linkage for this report is the segment of Silverbell Road from El Camino del Cerro Road at the northern end to Grant Road/Ironwood Hills Road at the southern end (project area), within the city of Tucson and Pima County, Arizona (Figure 4-1). The roadway at the southern end of the project area changes name as it crosses over Silverbell Road: Grant Road from the east and Ironwood Hills Road to the west. This segment of Silverbell Road runs parallel to Interstate 10 (I-10) and the Union Pacific Railroad, which are both approximately 1 mile to the east, and adjacent to the Santa Cruz River and various residential and commercial areas starting north at El Camino del Cerro Road and running south to Grant Road (Figure 4-2).

This portion of Silverbell Road lies between the Tucson Mountains and Saguaro National Park West to the west, the Tortolita Mountains to the north, and the Santa Cruz River to the east (and farther to the east lies the Santa Catalina Mountains). Therefore, this linkage may act as both a critical east-west and north-south connection for wide-ranging animals moving between these areas and mountain ranges, particularly because this portion of Silverbell Road includes the Santa Cruz River (including being just south of the point at which the Rillito River empties into the Santa Cruz), known to be a major movement corridor for numerous species. The primary goal for this linkage is to maintain this connection for the various wildlife species that are known or thought to move through this area, including bobcat, coyote, mule deer, raccoon (*Procyon lotor*), javelina, and Sonoran desert tortoise; as well as smaller-bodied mammalian (including bats), herpetofauna, and avifauna species (Arizona Wildlife Linkages Workgroup 2006). Other large-ranging species, such as mountain lion, may occasionally use this area during long-distance movements from surrounding mountain ranges.

The portion of the Santa Cruz River that passes adjacent to and through the project area may provide a significant movement corridor for large and medium-sized species such as mountain lion, bobcat, coyote, mule deer, and javelina. These species may either travel large distances between the surrounding areas and mountain ranges or may simply travel shorter distances between various areas surrounding the city of Tucson and Pima County as part of their daily movement patterns. Some of the smaller drainages that pass through the project area may also provide movement corridors for various animals, including numerous species of lizards, snakes, and rodents; coyotes, javelina, and bobcats; and bird species that typically walk rather than fly, such as roadrunners (*Geococcyx californianus*) and Gambel's quail (*Callipepla gambelii*).



Figure 4-1. Project location map.

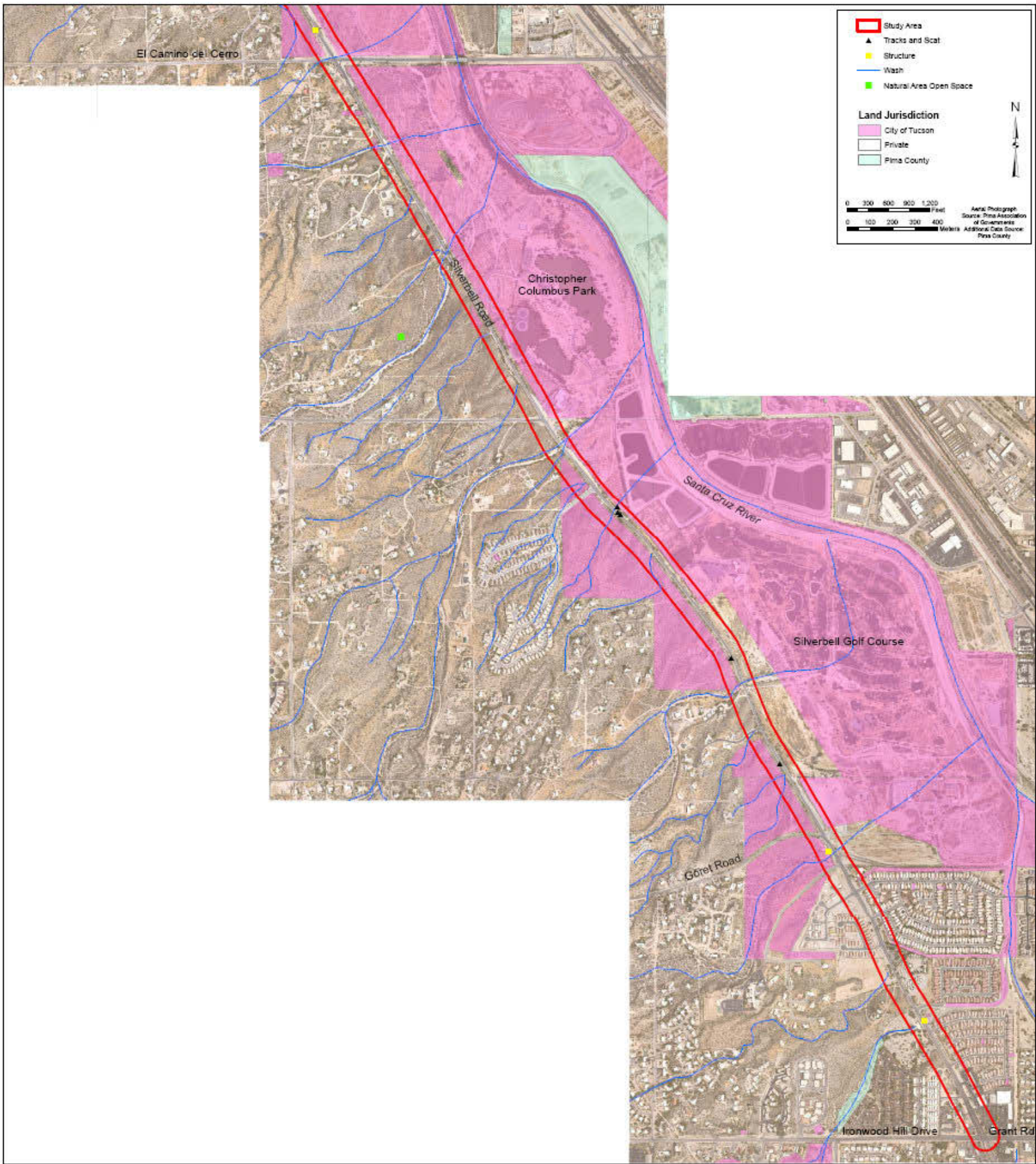


Figure 4-2. Overview of this portion of Silverbell Road.

I-10 and the Union Pacific Railroad each span in a mostly northwest-southeast direction along the Santa Cruz River valley adjacent to this portion of Silverbell Road. This portion of the valley consists of mining, and commercial and residential development, although portions of the lands along this highway corridor remain undeveloped. Various east-west roadways connect Silverbell Road to I-10 to the east within the project area, including El Camino del Cerro Road and Grant Road/Ironwood Hills Road. Silverbell Road is the primary north-south travel route for various communities northwest of Tucson and within Marana, including Continental Ranch, connecting these areas to Tucson.

The main goal for this linkage is to maintain and improve connectivity for wildlife species traveling on both a landscape-level scale (inter-mountain range movements) and local scale (within and adjacent to the Tucson city limits), given the proposed widening of Silverbell Road and other roads within the town and county limits. Furthermore, ongoing and future residential and commercial development combined with greater predicted traffic volumes pose a threat to wildlife movement throughout the area. Therefore, the permeability of the project area to pass large-ranging wildlife species and smaller-bodied species that are sensitive to habitat fragmentation has been identified as an important factor in maintaining the long-term persistence of these species while simultaneously increasing driver safety by minimizing AVCs.

The segment of Silverbell Road from El Camino del Cerro Road to Grant Road ranges in elevation from approximately 2,240 to 2,320 feet above mean sea level (msl). Most of the project area is disturbed as a result of commercial and residential development and mining activities (gravel pits); however, some of the area is undisturbed. The entire reach of the Santa Cruz River between Grant Road and El Camino del Cerro Road contains concrete-lined bank protection features.

This segment of Silverbell Road is located within the Arizona Upland subdivision of the Sonoran Desertscrub biotic community. One vegetation association was identified in this road segment: upland desertscrub. Dominant vegetation in the project area includes velvet mesquite (*Prosopis velutina*), foothill paloverde (*Parkinsonia microphylla*), blue paloverde (*P. florida*), whitethorn acacia (*Acacia constricta*), catclaw acacia (*A. greggii*), creosote bush (*Larrea tridentata*), triangle-leaf bursage (*Ambrosia deltoidea*), and burroweed (*Isocoma tenuisecta*). Other species observed include barrel cactus (*Ferocactus wislizeni*), prickly pear cactus (*Opuntia* sp.), chainfruit cholla (*Cylindropuntia fulgida*), staghorn cholla (*C. versicolor*), walkingstick cactus (*C. spinosior*), Mexican paloverde (*P. aculeata*), brittlebush (*Encelia farinosa*), ocotillo (*Fouquieria splendens*), saguaro (*Carnegiea gigantea*), globe cactus (*Mammillaria* sp.), threeawn (*Aristida* sp.), spidergrass (*A. ternipes*), and fluffgrass (*Dasyochloa pulchella*). Non-native species include salt cedar, Lehman lovegrass (*Eragrostis lehmanniana*), stinkgrass (*E. cilianensis*), prickly Russian thistle (*Salsola tragus*), bermudagrass (*Cynodon dactylon*), buffelgrass (*Pennisetum ciliare*), and a variety of ornamental plant species associated with residential and commercial landscaping.

Xeroriparian mixed scrub vegetation is associated with ephemeral washes intersecting the road segment. This vegetation type is associated with an ephemeral or intermittent water supply and typically contains plant species that also occur within neighboring upland habitats,

although riparian plants are typically larger and often occur at higher densities than those in adjacent uplands. The dominant plant species observed along washes include desert broom (*Baccharis sarothroides*), velvet mesquite, wolfberry (*Lycium* sp.), spiny or desert hackberry (*Celtis ehrenbergiana*), graythorn (*Ziziphus obtusifolia*), whitethorn acacia, singlewhorl burrobrush (*Hymenoclea monogyra*), and cane bluestem (*Bothriochloa barbinodis*).

4.2 LAND OWNERSHIP AND USE

The majority of the project area is under the jurisdiction of the City of Tucson, although Pima County also manages some of the land in the project area. However, there are numerous portions of private land in the areas that will be widened along this portion of Silverbell Road. Massapequa Associates LLC owns the commercial land on the northeast corner of the intersection of Grant and Silverbell roads. First American Title, Title Security Agency of Arizona, Silverbell Properties LLC, and Desert Heritate Ltd. Partnership each also own significant parcels of land towards the southern end of the project area.

There are numerous residential dwellings in the project area. Low-density residential housing occurs mostly on the west side of Silverbell Road, although there are some pre-fabricated houses present on the east side of the road. Commercial development occurs at the south end of the project area, on all four corners of the Grant and Silverbell intersection, containing numerous commercial buildings including shopping plazas, a car wash, a convenience store, and a bank. There is a mobile home park on the east side of Silverbell Road between Grant and Goret roads. The Silverbell Municipal Golf Course is located on the east side of Silverbell Road between Sweetwater Drive and Goret Road. The Pima County Animal Care Center is located on the northeast corner of the intersection of Silverbell Road with Sweetwater Drive. Christopher Columbus Regional Park is also located on the east side of Silverbell Road between Sweetwater Drive and El Camino del Cerro Road. The Roger Road Wastewater and Sewage Treatment Plant is adjacent to (east of) the Santa Cruz River at approximately the Sweetwater Drive alignment, just outside of the project area.

According to Pima County mapguide (2009), the entire east side of Silverbell Road is not currently zoned by Pima County. The west side of Silverbell Road is split fairly evenly between SR (medium-intensity rural) and unzoned lands (Pima County 2007).

As the population of the town of Marana is projected to increase significantly by 2040, there are expected to be some major changes to this stretch of Silverbell Road which will provide one of the main access routes for travel between Tucson and a large portion of Marana for numerous residents. Pima Association of Governments (PAG) has projected that some of the intersections in the project area will carry three or even four times the current volume of traffic. Early design plans for this segment of Silverbell Road include widening the whole stretch to a three- or four-lane divided desert parkway with a median, bike lanes, and pedestrian facilities.

In order to create a functional wildlife crossing, it is important to recognize adjacent land uses that could influence species use over time. This information can be useful in determining which locations along Silverbell Road will be the most likely to maintain continued species

use given adjacent land use in the future. Alternatively, given changes in adjacent land use, provisions that incorporate wildlife corridors or movement paths can be included into those development plans so as to maintain the functionality of wildlife crossing structures or other mitigation measures over time.

Portions of the Santa Cruz River channel and areas adjacent to and within Christopher Columbus Regional Park and Silverbell Municipal Golf Course are identified as open space areas; however, various development projects are expected within this portion of Silverbell Road, especially near the current commercial development centered on the Silverbell Road-Grant Road intersection.

4.3 RELATIONSHIP BETWEEN SILVERBELL ROAD AND WILDLIFE CORRIDORS/MOVEMENT ROUTES

This segment of Silverbell Road falls directly between two linkages identified by the Arizona Wildlife Linkages Assessment workgroup: Linkage 80 (Saguaro-Tortolita) and Linkage 87 (Tucson Mountains-San Xavier, San Robles Pass). This statewide effort, the purpose of which was “to identify and promote wildlife habitat connectivity using a collaborative, science-based effort to provide safe passage for people and wildlife,” identified 152 linkages across Arizona (Arizona Wildlife Linkages Assessment Workgroup 2006). The Saguaro-Tortolita linkage consists primarily of private land (68 percent) and State Land Trust (31 percent). Target species associated with this linkage include bobcat, cactus ferruginous pygmy-owl, cave myotis, javelina, kit fox, mountain lion, mule deer, pocketed free-tailed bat, and Sonoran desert tortoise. Threats to this linkage include agriculture, the Central Arizona Project (CAP), I-10, the railroad, and urbanization. The Tucson Mountains-San Xavier linkage consists primarily of private land (88 percent). Target species associated with this linkage include bobcat, California leaf-nosed bat, cave myotis, giant spotted whiptail, greater western mastiff bat (*Eumops perotis californicus*), mountain lion, pocketed free-tailed bat, Sonoran desert tortoise, and western burrowing owl. Threats to this linkage include border security, State Route 86, and urbanization.

Pima County is in the process of developing a Multi-Species Conservation Plan (MSCP) that includes the project area. As part of the MSCP, Pima County has identified Priority Conservation Areas (PCAs) for various species covered within the plan. As part of this wildlife linkage effort, the Town of Marana intends to support all identified PCAs during the design of all wildlife crossings and abatement measures. Additionally, the Town of Marana intends to coordinate with Pima County to uphold and support any wildlife linkages that are identified during the potential Pima County Wildlife Linkage Assessment that is expected to be undertaken soon.

The City of Tucson and Town of Marana are also currently developing separate Habitat Conservation Plans (HCPs) that will outline conservation programs, including areas to be set aside, species-specific management areas, etc. As part of this wildlife linkage project, this project will support both HCP conservation program efforts when applicable during the design of all wildlife crossings and abatement measures.

Additionally, this area lies between the Tucson Mountains (and Saguaro National Park West) and the Santa Cruz River, thus the area could be expected to provide for important movement routes for numerous species as described earlier in this report. And there are some local areas of interest in and adjacent to the project area as well. North of Sweetwater Drive and west of Silverbell Road there is an area of open space referred to as the “Tres Rios Wildlife Crossing.” SWCA believes that it is important to ensure that wildlife is able to move between this area of open space and Christopher Columbus Regional Park (including access to the lakes within the park), thus being designated as Priority Crossing Zone A for the project area (refer to Section 5.1). Additionally, the area near the Roger Road Wastewater Treatment Plant retention basins is rich in small mammal use (cottontails and round-tailed ground squirrels), thus being designated as Priority Crossing Zone B for the project area (refer to Section 5.2).

4.4 LINKAGE ASSESSMENT METHODOLOGY

Data used to determine any previously identified wildlife crossing zones included critical habitat area maps for selected species from AGFD databases; Natural Community Conservation Planning (NCCP) planning maps and conservation areas; existing data/studies that have investigated focal species movement patterns relative to highways, habitat, and other landscape features; and AVC data from state, regional, and/or local accident reports, records, and databases.

The following maps and data sources were referenced:

- Critical Habitat area maps from the U.S. Fish and Wildlife Service (USFWS) database
- Pima Association of Governments planning maps
- Pima County’s Sonoran Desert Conservation Plan and Associated GIS “Mapguide”
- Town of Marana Habitat Conservation Plan (HCP)
- Arizona Game and Fish Department (AGFD) animal-vehicle collision database

This segment of Silverbell Road is currently two lanes with dirt shoulders, no center median, and a speed limit of 45 miles per hour (mph). Speed limits vary for the main arteries connecting to this portion of Silverbell Road: Grant Road (from the east) is 40 mph, while Ironwood Hills Road (to the west) is 40 mph in the daytime and 35 mph at night; Goret Road is 35 mph west of Silverbell, and 25 mph east of Silverbell; Sweetwater Road is 45 mph west of Silverbell, and leads directly to a dead end east of Silverbell Road; and El Camino del Cerro Road is 45 mph west of Silverbell, and 45 mph in the daytime and 40 mph nighttime east of Silverbell Road. Twelve commercial driveways, 18 residential driveways, and 17 residential streets intersect the project area.

There are limited AVC records available for the project area; however, there are AVC incidents recorded for mule deer, javelina, coyotes, great horned owl (*Bubo virginianus*), skunk, raccoon (*Procyon lotor*), a hawk, and a Great blue heron (*Ardea herodias*) from in or adjacent to the stretch of Silverbell Road between Camino del Cerro and Grant roads (AGFD

2009). Most of these incidents appeared to be of animals attempting to cross Silverbell Road; however, some incidents were recorded from surrounding roadways.

SWCA biologists conducted a field reconnaissance of the project area on June 9 and 10, 2009. One U.S. Geological Survey (USGS) 7.5-minute topographic map (Jaynes, Arizona) was used for general orientation and to locate the project boundaries. The field reconnaissance consisted of a pedestrian survey of the project area to evaluate anecdotal evidence of wildlife activity (e.g., tracks, scat, visual surveys); vegetation and landscape features considered important to the potential occurrence of animal species that may cross this segment of Silverbell Road; various roadway characteristics (e.g., number of lanes, speed limit); and existing roadway infrastructure. Vegetation was classified to the community level according to the map “Biotic Communities of the Southwest” in Brown (1994). The purpose of these field visits was to collect on-the-ground information to refine and build upon the understanding of existing and potential locations to facilitate the safe passage of wildlife across Silverbell Road. The site assessment consisted of the steps summarized in the following subsections.

4.4.1 Identifying and Assessing Existing Ungulate and Carnivore Crossing Locations along or across Roadways

SWCA biologists recorded all sign of species activity along the entire stretch of roadway, including tracks, scat, game trails, carcasses, and visual sightings. Such information provided baseline documentation as to where animals have been active along the roadway shoulder, and served as preliminary locations for which to evaluate the potential for future modifications that could promote the safe passage of wildlife across the roadway.

4.4.2 Identifying and Assessing Potential Crossing Locations and Structures

Three types of unique situations that could potentially serve as a wildlife crossing locales were identified in this analysis: 1) structures, 2) fill slopes, and 3) at-grade areas. At each of these locations a predetermined suite of variables were measured.

Structures include any bridge or culvert that could provide for the safe passage of target species underneath the roadway. Structural dimensions (length, width, and height) were recorded and vegetation was measured within a 100-meter (m) radius around each entrance to the structure. Vegetation was averaged to yield a percentage category of cover for vegetation less than and greater than 1 m in height, thereby differentiating between low grass or shrub cover and higher shrub and tree cover. At each of these locations SWCA highlighted opportunities, where appropriate, to provide additional measures that could be initiated to further promote the movement of focal species and other wildlife species through the structures.

Fill slopes include any location where the roadway is elevated relative to the surrounding topography; they typically occur where the roadway bisects drainages. For all fill slopes, SWCA measured the fill height and fill width. Fill height is the height of fill between the roadway and the natural, non-fill slope on either side of the roadbed; fill imprint is the distance along the roadway occupied by the fill (i.e., the width of the filled drainage that the

road bisects). In situations where there was an existing structure greater than 1 m in height (located at the base of a larger fill slope), the fill height above the structure was documented, because these locations may offer an opportunity to enlarge an existing structure without changing the alignment of the roadway.

At-grade areas include other roadway segments that are not point locations. Rather, they incorporate longer stretches of the roadway (typically 0.25 mile to several miles in length). These locations frequently include stretches of road that parallel one side of a drainage or riparian area, places where a particular vegetation type approaches or abuts the road shoulders, or locations where wildlife are funneled to a particular point by other natural or man-made constrictive features in the landscape (i.e., choke point).

4.4.3 Identifying and Assessing Multiple Landscape and Human-made Features that May Impede Wildlife Movement across Roadways

Roadway barriers to wildlife movement were characterized according to the number of lanes and presence of shoulder barriers, median barriers, and other features. Additional miscellaneous features along the roadway that could hinder wildlife movement across the road or serve as potential soft barriers to species movement were also recorded.

We emphasize that our aforementioned efforts to determine wildlife crossing areas and locations that offer the best sites for which to direct future mitigation strategies were not comprehensive, as these methods only elucidate conditions existing within a small window of time. AVC data only indicate those locations along Silverbell Road where crossing attempts by wildlife were unsuccessful. Successful crossings of roadways can only be directly measured by monitoring existing structures that provide for the safe movement of wildlife underneath the roadway or through behavioral studies monitoring fine-scale movement patterns relative to the roadway (i.e., telemetry studies). Additional methods that would largely identify additional or potential crossing locations, or aid in refining particular zones that may be experiencing a greater frequency of crossing activity, should be considered (although they were not part of this investigation). Such methods may include focused AVC surveys, remotely-triggered camera surveys, and track surveys; strategies to incorporate these methods are identified in Section 7.3 below.

4.4.4 Evaluation Criteria

SWCA used three criteria to select locations where results suggested that improvements would enhance wildlife connectivity.

Criteria 1: Underpass spacing

Bissonette and Adair (2008) used the scaling properties of species movement as an ecological bases for effective spacing of wildlife crossing structures and determined that underpass spacing should occur at the square root of the species home range size (HR0.5) to provide population-level connectivity. They estimated this spacing from the square root of the animal's home range, which is a squared linear measure related to dispersal distance, thus resulting in a linear measurement. Based on information about species' home range sizes

within the project area, the surrounding region, or in similar habitats and urbanized environments, we estimated the following minimum spacing requirements for wildlife-friendly underpass placement:

- Bobcat: average home range along wildland/urban interfaces of 5.1 km² (Lyren et al. 2006; Lyren et al. 2008; Lyren et al. 2009), 2.25 km underpass spacing
- Herpetofauna and small mammals: AGFD (2006b) recommends that small mammal and herpetological crossings should be between 150 to 300 feet apart from another crossing. Similarly, Bissonette and Adair (2008) recommend underpass spacing distances of 264 feet. Therefore, a spacing pattern of 250 feet was used as the scaling property for these groups of species.

Criteria 2: High fill slopes

Fill slopes were assessed to determine whether their height could accommodate a structure sufficient in height and width to facilitate passage of bobcats (structures may include span bridges, arch culverts, or large box culverts). This was to identify candidate locations for either enlarging existing structures or constructing new structures in fill slopes where no structure large enough to permit such passage existed. Consideration was also given to mule deer, which frequent the surrounding landscapes to the east and west of Silverbell Road, although distribution is more likely along the northern portion of Silverbell Road due to less developed areas.

Criteria 3: Proximity to open space lands

SWCA overlaid lands identified as having conservation value or significance with this portion of Silverbell Road to identify which portions of the road were bisected by lands presumably identified for long-term conservation. These lands included Proposed 2010 Conservation Bond Program Highest Priority Private lands, 2004 Conservation Bond Program Highest Priority Private lands, Special Species Management Areas, and MSCP Committed Lands.

5.0 RESULTS

5.1 EXISTING FEATURES

To maintain and enhance the movement of wildlife across the section of Silverbell Road from El Camino del Cerro Road to Grant Road, it is necessary to first document existing and potential crossing locations for wildlife connectivity-associated mitigation measures. It is a challenge to develop infrastructure that meets the expected increase in travel capacity while maintaining the safe passage of wildlife across roadways. Therefore, SWCA documented opportunities to maintain or increase the rate of safe wildlife movement across Silverbell Road, and identified locations where such measures can potentially be addressed in order to help reduce the impacts of Silverbell Road on local wildlife.

SWCA identified existing and potential locations that, from an engineering perspective, represent optimal locations to construct appropriate crossing structures for various wildlife species. By collecting and analyzing several types of data (including AVC, underpass use, and activity along roadways), SWCA was able to recommend various mitigation measures adequate in maintaining the successful passage of wildlife across roads, a critical step in the long-term functionality of wildlife movement across the region. These recommendations are based on the evaluation criteria presented in Section 4.4.4 and thus provide locations for future structures that optimize the functionality of regional connectivity for wildlife throughout the area.

Following is a description of the inventoried locations along Silverbell Road South.

5.1.1 Structures

Two structures were inventoried within this Silverbell Road South Linkage (Table 5-1). Both of these structures are box culverts associated with the Speedway and Painted Hills washes, channeling ephemeral stormwater flows east-northeast under Silverbell Road. All channels in the project area drain into the Santa Cruz River. Both of these box culverts currently provide terrestrial crossings; however, each presents potential barriers to certain wildlife species. The largest of these structures is a 14.5-foot-wide six-chamber box culvert. Dimensions and the degree of vegetative cover surrounding the underpasses are presented in Table 5-1. Representative photographs are provided in Appendix A.

Table 5-1. Dimensions of Existing Structures in Feet along Silverbell Road South.

Structure Number	Length ¹	Width ²	Height	% Cover ³	Comments
1. Six-chamber box culvert	50.0	14.5	6.0	3	Just south of point in which Goret Road crosses Silverbell Road.
2. Five-chamber box culvert	50.0	12.0	6.0	3	Sign at wash states Greasewood Wash, Pima County Mapguide refers to it as Painted Hills Wash.

¹ Distance between each entrance to the structure

² Width of each chamber

³ Percent category of vegetation within a 100-m radius of structure entrances; first value is percent category for vegetative cover <1 m and second value is for vegetative cover >1 m; values are averaged for each underpass entrance; percent categories include 0, 0%; 1, <10%; 2, 11–25%; 3, 26–50%; 4, 51–75%; 5, >75%

5.1.2 Fill Slopes

No fill slopes were identified along the Silverbell Road Linkage.

5.1.3 Road-Stream Crossings

There are no perennial aquatic crossings along the Silverbell Road Linkage; however, there are numerous ephemeral drainages that have seasonal peaks of water flow and are discussed in Section 6.5.1. These ephemeral drainages may be important for movement of herpetofauna and small mammal species, but would not provide movement for aquatic species.

5.1.4 At-Grade Crossings

Numerous at-grade crossings were identified within the Silverbell Road project area. A few of the at-grade crossings involve the points where a dirt road or driveway accesses Silverbell Road. Roads typically serve as carnivore travel routes, particularly those that are located in proximity to water sources. As such, these locations represent potential movement routes for large-ranging wildlife species, particularly bobcats and coyotes. However, the majority of the at-grade crossings are points where washes flow over Silverbell Road, identified as Points of Concentration (POCs) in Figure 5-1. It has been determined that all of the stormwater flow needs to be diverted under Silverbell Road for purposes of driver safety; thus most, if not all, of these at-grade crossings are proposed to be replaced with some type of drainage structure during the Silverbell Road Widening Construction project. Equestrian, pedestrian, and off-highway vehicle (OHV) use was also noted at many of these at-grade crossings.



Figure 5-1. Map of proposed drainage structures for this portion of Silverbell Road.

5.1.5 Other Features that May Deter or Enhance Wildlife Movement across Silverbell Road

Periodic water flow across Silverbell Road at-grade has resulted in undercutting and erosion, which in turn has created a potential barrier to wildlife movement in numerous portions of the project area. This may be a barrier to certain species, particularly certain species of small mammals and herpetofauna, physically unable to climb up the ledge and travel through the structure. As the current proposal for the Silverbell Road Widening project involves removing all at-grade water crossings, this is not expected to be an issue in the future (see Section 6.0).

Several additional linear features bisect Silverbell Road and could provide additional movement routes for wildlife, including various dirt roads that parallel the east side of Silverbell Road between El Camino del Cerro and Goret roads. There is no significant fencing along this stretch of Silverbell Road. Several stretches of chain link fence (most falling down) border the right-of-way and residential dwellings. The chain link fencing could pose a barrier to wildlife that are too large to pass through the baffle on the fencing; smaller rodent and herpetofauna species could easily pass through this fencing.

5.2 PRIORITY WILDLIFE MOVEMENT ZONES AND CRITERIA FOR DESIGNATION

5.2.1 Priority Crossing Zone A: Tres Rios South Wildlife Crossing

This crossing zone is located less than 1 mile north of Sweetwater Road and includes the area where various drainages empty into the human-made water ponds of Christopher Columbus Regional Park. It is identified as the portion of Silverbell Road between POC-117 and POC-119 (see Figure 5-1). This zone includes one of the three areas that Pima County has designated as Natural Open Space collectively referred to as the Tres Rios Wildlife Crossing feature. Included in this zone are numerous important wildlife features: 1) Important Riparian Area (IRA), these drainages flow into a portion of the Santa Cruz River that is designated as an IRA within the SDCP; 2) area of Natural Open Space, one of three areas delineated as part of the Tres Rios Wildlife Crossing; and 3) an area of MSCP-committed land located west and upstream of Silverbell Road, part of the Tucson Mountain Regional Park (see Figure 4-2).

Within this portion of the Silverbell Road Widening project, efforts to maintain and enhance the value of the Santa Cruz River corridor, floodplain, and its washes and secondary water courses include bank treatments, restoration of native vegetation, and protection of wildlife habitat. Active and passive recreational opportunities are also identified along this corridor, including paved multi-use pathways, soft surface trails for hiking and equestrian usage, formal park or recreational uses, and equestrian-related facilities.

Several factors contribute to this location representing a Priority Crossing Zone:

- The Santa Cruz River provides a major north-south travel corridor for animals. Large topographic features such as river corridors (e.g., the Santa Cruz River channel) represent potential movement routes for large-ranging species and also provide certain habitat and cover for other, less wide-ranging species.

- This stretch of Silverbell Road interfaces with Christopher Columbus Regional Park, a resource conservation/open space area, and includes one of the three Tres Rios Wildlife Crossing areas. By maintaining or enhancing opportunities for wildlife to safely cross this portion of Silverbell Road, combined with the identification of this area as a resource conservation/open space area, the long-term functionality of this linkage can be maintained. By investing in transportation infrastructure that improves wildlife connectivity in areas that have been set aside as open space, such designations can be justified due to the inability of conflicting land uses to diminish the functionality of wildlife crossing structures and other forms of connectivity-related mitigation.

In addition, several challenges to maintaining and increasing the functionality of this crossing zone have been identified:

- This area exhibits a high amount of recreational pressure due to the adjacent location of Christopher Columbus Regional Park. Proposed recreation trails and other recreational uses (including fishing, toy motorized boat use, picnicking, hiking, dog walking, etc.) could impact this area as a priority crossing zone by decreasing wildlife use of the area. Wildlife species have been documented to avoid (Clevenger and Waltho 2000) or temporally shift their movement patterns (Haas and Turschak 2002) at underpasses exhibiting high rates of human activity.
- The river bed and associated flood plain exhibit signs of OHV and equestrian use. OHV sites have been extensively monitored to determine both the direct effects on reptile mortality and changes in species abundance relative to undisturbed portions of the desert (Bury et al. 1977; Berry 1980; Bury 1980; Luckenbach and Bury 1983; Brooks 1999). Off-road vehicle activity has been linked with population declines of the desert tortoise (*Gopherus agassizii*) (Bury 1980) and Couch's spadefoot (*Scaphiopus couchi*) (Berry 1980). Aside from reptiles, desert bird and small mammal density and diversity has been reported to decline in areas where OHV use was extensive (Buscak and Bury 1974, Bury et al. 1977, Luckenbach 1978; Luckenbach and Bury 1983; Brooks 1999).
- Vegetation is dense along the drainages leading directly into the ponds. Vegetative cover can play an important role in determining road crossings and underpass use for many species, including bobcats (Haas 2000). However, certain species that may have the potential to use this crossing zone infrequently may avoid areas of dense vegetation. In the case of the Santa Cruz River and adjacent pond areas, maintaining a mosaic of vegetation patches and areas devoid of vegetation is likely the best approach at maintaining multi-species movements along this corridor.

5.2.2 Priority Crossing Zone B: Roger Road Wastewater Treatment Plant Fencing Area

This crossing zone is located south of Sweetwater Road and includes the area where various drainages empty onto lands occupied by the human-made Tucson Water detention basins, recharge ponds, and wastewater treatment ponds located north of Silverbell Municipal Golf

Course. It is identified as the portion of Silverbell Road between POC-114 and POC-116 (see Figure 5-1). Included in this zone are two important wildlife features: 1) Important Riparian Area (IRA), the flow of these drainages is interrupted from connecting to a portion of the Santa Cruz River that is designated as an IRA within the SDCP; and 2) a Biological Core Management Area that covers most of the Santa Cruz River floodplain directly downstream from this zone.

Several factors contribute to this location representing a Priority Crossing Zone:

- Multiple drainages provide potential travel corridors connecting relatively undeveloped areas (golf course, water treatment facilities). The presence of multiple drainages within a short stretch of road provides multiple opportunities for wildlife to utilize drainage structures. Providing multiple crossing structures along roadways has been identified as an excellent measure to maintain the successful passage of wildlife across roads for both large-bodied and small-bodied organisms (Clevenger and Waltho 2000; Haas 2000; Mata et al. 2005). This may be especially important in this zone as the man-made impact of the golf course and water treatment facilities has severely impacted the flow of drainages leading into this area. Thus, it is possible that recommendations within this zone may include structures solely intended for wildlife movement, not intended to facilitate any hydrological purpose.
- Drainages will require the construction of culverts (structures) through which wildlife can travel. Structures, if designed correctly, can serve a dual function in maintaining surfacewater flow and providing opportunities for wildlife to pass through the structures.

In addition, several challenges to maintaining and increasing the functionality of this crossing zone have been identified:

- Drainages run through or adjacent to residential areas. The proximity of residential areas to these drainages presents potential impacts from non-native predators (dogs and cats), increased noise and light pollution, and human activity. Dogs have been identified disrupting wildlife movement patterns (Harrison 1997; Haas and Turschak 2002; George and Crooks 2006), and cats are efficient predators on smaller-bodied mammal and herpetofauna species (Coleman and Temple 1993; Crooks and Soule 1999).
- Localized flooding during monsoons (and to a lesser extent, during periods of heavy winter rains) may create barriers to certain species movement through the structures. These drainages may experience seasonal peaks in water flow, which may cause erosion of the structures or create a buildup of material (e.g., vegetation, logs) at the entrance to the structure. Because of the potential for erosion and undercutting of the structure due to seasonal peaks in water flow, it is important to maintain movement for certain species for which an undercut outlet or inlet represents a barrier. Furthermore, routine maintenance to remove debris and other objects that might be carried by water during high rainfall events is important so that the underpass allows for the passage of wildlife throughout the entire year.

6.0 RECOMMENDATIONS

6.1 SPECIFIC RECOMMENDATIONS/MITIGATION MEASURES WITHIN PRIORITY CROSSING ZONES

6.1.1 Tres Rios Wildlife Crossing

Based on the favorable environmental conditions identified in Section 5.2.1 above, it is recommended that several crossing structures be developed within the washes that cross this section. The widening of Silverbell Road will inherently increase the distance at which animals will need to traverse this roadway. As such, it is important to consider associated appropriate widths and heights of the structures to negate the appearance of long, narrow structures, which certain species may be less reluctant to use. Table 6-1 provides recommended dimensions for structures based on a projected underpass length of 130 feet (which would be the new road width and associated right-of-way [future underpass length]). We note, however, that situating underpass entrances as close as possible to the road edge to reduce structure length and promote use by smaller-bodied species that typically use the road edge (e.g., reptiles, small mammals) has often been recommended (Ascensão and Mira 2007), and is particularly a preferred design feature for multi-lane roadways.

Table 6-1. Recommended Minimum Dimensions in Feet of Underpass Structures along Silverbell Road. Structures are presented in order of priority.

Crossing ID ¹	Recommended Minimum Dimensions Based on 130-foot Roadway and Right-of-Way Footprint			
	Type ²	Length	Width	Height
POC-119 (Roger Wash)	CBC	130	12	8
POC-118	CBC	130	10	5
POC-117	CP	130	3	3

¹ – POC numbers, as identified in Table 8 in Kittelson 2010

² – CBC = concrete box culvert; CP = concrete pipe culvert

The proposed widening would result in an increase in crossing distance (the distance that animals must travel to cross the roadway), and new structures should weigh the avoidance of culvert use by wildlife due to a low structure openness (a value defined as the width x height divided by the length of the structure). Bobcats have been documented utilizing many structures within the proposed dimensions of the new structures (Haas 2000; Lyren et al. 2005). Minimum dimensions, as proposed above, would result in an openness value that would range from 0.020 to 0.222 m for the three structures; bobcats have been documented using structures less than 5 feet high and with openness values ranging from 0.015 to 0.247 m (Haas 2000). The recommended heights are suggested because potentially sensitive wildlife species like bobcats may not be accustomed to traveling through longer structures; thus having an increase in clearance (height) would optimize the probability that this species

would travel through the structure. Following is a description of justifications for the recommendations provided in Table 6-1.

POC-119: Roger Wash

This location is between Christopher Columbus Regional Park and County-identified natural open space and the drainage located here (Roger Wash) provides a suitable travel route for a variety of wildlife species based on the vegetation characteristics and relative isolation from surrounding development. The size of this drainage combined with the low-density development upstream of this location provide opportunities for wildlife traveling along this drainage to easily reach the Santa Cruz River to the east and less developed lands to the west. The resulting openness index of the new structure (12 feet wide by 8 feet high) would be 0.222 m, the largest openness of structures within this Priority Crossing Zone.

POC-118

This location is crossed by a smaller drainage located south of POC-119/Roger Wash. Although the drainage is much smaller in size compared to Roger Wash, it is located adjacent to Open Space lands, and thus serves as another potential movement route for wildlife species. Because this location is also located Christopher Columbus Regional Park and County-identified natural open space, it has been identified as a site where a suitable crossing structure could be placed. However, because of the nature of the drainage (not as much opportunity to create a larger structure due to topography), opportunities to install a structure similar to that proposed for POC-119 are limited. Therefore, this location has been identified as having a smaller structure that, although not as large as the POC-119/Roger Wash structure, can provide an additional safe crossing opportunity for bobcats and other medium-bodied wildlife species. The resulting openness index of the new structure (10 feet wide by 5 feet high) would be 0.113 m, which is well above openness values utilized by bobcats at similar structures.

POC-117

This location lies immediately south of POC-118 and is much smaller than both drainages identified at POC-119 and POC-118, yet it represents another potential movement route between the Christopher Columbus Regional Park and open space lands. Because of the small nature of the drainage, opportunities to install a structure similar to that proposed for POC-118 are limited, however a smaller structure that can provide safe crossing opportunities for smaller-bodied herpetofauna and small mammal species could be placed here. As such, a 3-foot-diameter pipe culvert is proposed for this section. The resulting openness index of the new structure would be 0.020 m, which is slightly above the minimum openness value utilized by bobcats at similar structures; site-specific modifications to this location (e.g., limiting the adjacent landscaping along the roadside; constricting recreation trails and/or sidewalks to be located closer to the roadway) could occur to reduce the length of this structure.

Other measures to enhance connectivity in this Priority Crossing Zones

There are a variety of other measures that could be implemented for the three locations identified above, including vegetation treatments, artificial light management, wildlife fencing, and additional crossing structures.

Vegetation

An important factor that would increase the probability of species use of underpasses within this Priority Crossing Zone is the maintenance of vegetation along the roadside (i.e., limiting vegetation along the Silverbell Road right-of-way) and between the underpass entrances and roadside edge. In addition, native vegetation, including velvet mesquite and blue palo verde, should be planted in front of and adjacent to the underpass entrances to reduce the potential visual threat that traffic traveling along Silverbell Road may pose to wildlife species using these structures. This is particularly important for larger-bodied wildlife species; if monitoring determines that additional measures (i.e., drift fencing) are necessary to direct wildlife to crossing structures, vegetation plantings may be placed in association with these additional mitigation measures (see Section 6.3).

For larger structures, such as POC-119, the placement of woody debris (e.g., stumps, branches) and boulders along the length of the structure would aid in maximizing the probability that smaller-bodied species would use the structure (Linden 1997). For smaller structures, such as POC-118, although several studies have documented amphibian and reptile use of passages under two-lane roads (Langton 1989; Boarman and Sazaki 1996; Jackson 1996) and simulated structures of 40 feet (Painter and Ingraldi 2005), little is known regarding the effectiveness of these structures under roadways that are four or more lanes.

Roadside Lighting

The amount of artificial lighting along the stretch of roadway that crosses through this Priority Crossing Zone can also affect wildlife movements. Efforts should be made to keep street-side lighting at least 200 feet away from each of the identified structure locations above, particularly POC-119. If lighting is required for traffic safety, it should be directed away from the structure (e.g., reconfigure lighting at the entrance of Christopher Columbus Regional Park to not shine directly over POC-117 and POC-118).

Roadside Fencing

No fencing is proposed for this zone due to the number of access points along this stretch of roadway.

Additional Structures

To further accommodate herpetofauna and small mammal species, it is recommended that three additional crossing structures (i.e., pipe culvert) at least 1.5 feet in diameter be placed between POC-119 and POC-118.

6.1.2 Roger Road Wastewater Treatment Plant Fencing Area

Based on the favorable environmental conditions identified in Section 5.2.2 above, it is recommended that several crossing structures be developed within the washes that cross this section. Table 6-2 provides recommended dimensions for structures based on a projected underpass length of 130 feet (which would be the new road width and associated right-of-way [future underpass length]).

Table 6-2. Recommended Minimum Dimensions in Feet of Underpass Structures along Silverbell Road. Structures are presented in order of priority.

Crossing ID ¹	Recommended Minimum Dimensions Based on 130-foot Roadway and Right-of-Way Footprint			
	Type ²	Length	Width	Height
POC-116 (Trails End Wash)	CBC	130	12	8
POC-114	CP	130	8	5

¹ – POC numbers, as identified in Table 8 in Kittelson 2010

² – CBC = concrete box culvert; CP = concrete pipe culvert

Minimum dimensions, as proposed above, would result in an openness value that would range from 0.090 to 0.222 m for the two structures; bobcats have been documented using structures less than 5 feet high and with openness values ranging from 0.015 to 0.247 m (Haas 2000). The recommended heights are suggested because potentially sensitive wildlife species like bobcats may not be accustomed to traveling through longer structures; thus having an increase in clearance (height) would optimize the probability that this species would travel through the structure. Following is a description of justifications for the recommendations provided in Table 6-2.

POC-116: Trails End Wash

Similar to POC-119, the location of this proposed structure along another sizeable drainage that extends west through low-density development. The vegetation characteristics and relative isolation from surrounding development are likely to provide opportunities for wildlife traveling along this drainage, as opposed to the majority of other drainages within this Priority Crossing Zone. Furthermore, this drainage empties into the Santa Cruz River immediately north of several human-made ponds/retention basins and immediately south of a larger pond located within Christopher Columbus Regional Park. The resulting openness index of the new structure (12 feet wide by 8 feet high) would be 0.222 m, the largest openness of structures within this Priority Crossing Zone.

POC-114

This location is located immediately west of several man-made water ponds located within Christopher Columbus Regional Park. The proximity to water sources (the ponds and the Santa Cruz River) and the Silverbell Golf Course provide unique habitat characteristics (water

sources as a breeding and foraging area for wildlife species) and foraging opportunities (golf course as a source of prey items for carnivores (e.g., bobcats and coyotes). Providing a safe passage opportunity across this stretch of Silverbell Road will allow for wildlife species to navigate safely between these habitat features and upland habitats to the west of Silverbell Road. Field visits documented multiple wildlife sign (roadkill round-tailed ground squirrels and coyote scat) at this location. Although there is limited opportunity for a structure with the height dimensions similar to that proposed for POC-116, a structure 5 feet in height and 8 feet in width is proposed. The resulting openness index of the new structure would be 0.090 m, which falls within the range of structural openness values used by bobcats.

Other measures to enhance connectivity in this Priority Crossing Zones

There are a variety of other measures that could be implemented for the two locations identified above, including vegetation treatments, artificial light management, wildlife fencing, and additional crossing structures.

Vegetation

As suggested in Section 6.1.1, maintenance of vegetation along the roadside and between the underpass entrances and roadside edge is important in reducing the potential for wildlife to access the roadside shoulder to utilize habitat or forage. Keeping the shoulder devoid of vegetation that could attract wildlife while targeting native plantings in front of and adjacent to the underpass entrances will both reduce the chance of wildlife accessing the roadside and reduce the potential visual threat to traffic traveling along Silverbell Road.

For larger structures, such as POC-116, woody debris (e.g., stumps, branches) and boulders situated the length of the structure would aid in maximizing the probability that smaller-bodied species would use the structure (Linden 1997). For smaller structures, such as POC-114, placement of such materials may be difficult but should be considered.

Roadside Lighting

As stated in Section 6.1.1, efforts should be made to keep street-side lighting at least 200 feet away from each of the identified structure locations above, particularly POC-116. If lighting is required for traffic safety, it should be directed away from the structure (e.g., reconfigure lighting at the intersection of Silverbell Road and Sweetwater Drive to not shine directly over POC-116; similar recommendations for the Silverbell Road and Avenida Albor intersection north of POC-114).

Roadside Fencing

Roadside fencing is recommended for this entire Priority Crossing Zone. This is based on field observations of wildlife activity in the area, proximity of habitat features and other potential attractants for wildlife species (e.g., ponds, Santa Cruz River, golf course), and opportunity to create an effective fencing network to reduce potential wildlife mortality along this stretch of Silverbell Road. Fencing along the east side of this Priority Crossing Zone could extend from the Silverbell Road/Sweetwater Drive intersection south to the north side

of the Silverbell Golf Course driving range (an access road borders the northern edge of the driving range). Along the west side of Silverbell Road, fencing could extend from the southwest corner of the Silverbell Road/Sweetwater Drive intersection south to Avenida Albor. To prevent a gap in fencing at this intersection, fencing could be directed west along Avenida Albor to its intersection with Boyer Lane. Across from this point, fencing could begin again along the southern side of Avenida Albor and extend east to Silverbell Road, where it would continue south along the west side of Silverbell Road, terminating across from the access road that heads east from Silverbell Road (terminus of east side fencing). Fencing should be at least 8 feet high to prevent animals from jumping over and accessing the road.

Additional Structures

Two additional structures have been identified within this Priority Crossing Zone and would be placed in smaller drainages to accommodate water flow during periods of high rainfall. These include POC-113 and POC-115. In addition to these two structures and to further accommodate herpetofauna and small mammal species, it is recommended that three additional crossing structures (i.e., pipe culvert) at least 1.5 feet in diameter be placed between POC-115 and POC-116.

6.2 ADDITIONAL RECOMMENDATIONS/MITIGATION MEASURES OUTSIDE OF PRIORITY CROSSING ZONES

6.2.1 Drainage Structures

Roadway widening may also necessitate additional drainage structures along Silverbell Road. For those stretches of road not within the identified linkage priority area, it is important to recognize what function these additional structures provide to wildlife movement. Additional structures should be sized at least 1 foot in diameter to provide passage for small mammal and herpetofauna species. Additional monitoring would be useful in determining which locations best serve to place structures for smaller-bodied species.

6.2.2 Vegetation Management

The presence of vegetation along road shoulders may often serve as an attractant to wildlife species, thus luring them to the side of the road and increasing of being struck by oncoming vehicles (Case 1978; Cain et al. 2003). A potential strategy to minimize AVCs would be to manage the vegetative ROW along stretches of road where wildlife crossing structures are absent (either by planting species that would be unpalatable or provide little cover) and improve the roadside habitat (through the planting of palatable or nutritious plant species) in areas immediately adjacent to smaller crossing structures, in order to direct wildlife to these crossing locations (see Groot and Hazebrook 1996; Putman 1997; Varland and Schaefer 1998; Brown et al. 1999; Hyman and Vary 1999).

6.3 RECOMMENDED MONITORING

There is very little information as to the distribution, abundance, and movement routes of various wildlife species across Silverbell Road. Therefore, a coordinated effort to collect

wildlife crossing-related datasets that will contribute to local and regional knowledge of wildlife movement across Silverbell Road, in addition to prioritizing recommended mitigation locations so that transportation enhancement monies can be best appropriated to those projects, is an important step in developing a monitoring framework that seeks to address the long-term functionality of recommended mitigation measures. Such an effort should include AVC data collection, roadside track bed surveys, and underpass monitoring. The combination of these multiple survey techniques will not only provide information on the value of existing crossing locations along Silverbell Road, but will serve to refine knowledge of where species are crossing roadways (non-structural locations), where appropriate mitigation strategies can be directed to provide or enhance movement, and how such measure could be designed; such information could be incorporated into the final design phases of this particular roadway project. Finally, this data will serve as baseline data by which to gauge future wildlife crossing activity in response to mitigation measures (e.g., crossing structures, wildlife fencing, vegetation treatments, methods to influence driver behavior) associated with transportation improvement projects, and may contribute to regional datasets that could collectively analyze regional patterns of wildlife movement in response to various transportation-related infrastructure.

Following is a suite of monitoring techniques that should be utilized to identify additional mitigation measures, determine baseline rates of crossing activity (or lack thereof), and develop an adaptive management strategy to ensure mitigation success:

6.3.1 AVC Monitoring

AVC surveys are recommended for the portion of Silverbell Road between the Silverbell Golf Course and El Camino del Cerro. This covers both Priority Crossing Zones. Surveys should consist of two phases: an initial 30-day intensive sampling schedule (with surveys conducted every day) and a second sampling schedule that will be determined by the results of the intensive sampling. The purpose of the intensive sampling schedule is to determine the maximum number of days needed to detect various wildlife species, or groups of species. For example, the results of intensive surveys may indicate that a sampling schedule of three days is needed to record 90 percent of herpetofauna road kills, but a schedule of seven days is needed to record 90 percent of large mammal kills. Such information would be useful in determining appropriate sampling strategies to effectively record and monitor AVC patterns along road segments. The road shoulder would be walked during the morning and individuals would be identified to species, aged, and sexed, and their position recorded with a global positioning system (GPS) unit.

6.3.2 Underpass Monitoring

Underpass usage rates can be monitored using two methods. First, track beds can be established at each structure, with a bed occurring at the midpoint of each structure; alternatively, track beds can be established at the entrances to these structures. Track beds would consist of gypsum powder, which is a finely-grated powder that allows for easy identification of imprints left by wildlife. Tracks left by individuals passing through the underpass would be identified to species. Direction of travel would also be documented, and

species usage would be recorded as the number of times a given species used the underpass divided by the number of days the underpass was sampled.

A second method that alleviates potential monitoring limitations of the track beds incorporates the use of remotely triggered digital cameras stationed at each underpass. These cameras are secured to the structure or to a post (preferably telspar) driven into the ground to prevent theft. The post and attached camera are placed either along the headwall of the structures or, for span bridges, at the midpoint of each bridge. Cameras would be checked at least every four weeks, with more frequent camera maintenance occurring at underpasses with higher wildlife activity. Cameras record the species' direction of travel and time of pass. Of particular interest is the potential to identify individual bobcats (by observing marking patterns on pelage) as they pass by the camera (Lyren et al. in prep.). This would be very useful since bobcats are a focal species for this linkage, and understanding bobcat usage rates of different structures along this stretch of road would further serve to gain knowledge on population responses to future increases in traffic patterns and roadway configurations.

Optimal structures to monitor include all of those identified in the Priority Crossing Zones, including POC-119, POC-118, POC-117, POC-116, and POC-114, and any other smaller structures designed for water conveyance within these two zones. We note that underpass monitoring by cameras focuses largely on the passage of large- and medium-bodied mammals; smaller mammal species and herpetofauna are rarely detected at these stations, so track beds are a more appropriate technique. However, track beds rarely allow the observer to detect which species is traveling over the substrate. Therefore, to obtain species-specific rates of underpass use for small mammal and herpetofauna species, mark-recapture methods could provide the best means to detect species passage through the structure.

6.3.3 Roadside Track Beds

The rationale behind conducting roadside track bed surveys along the road shoulder is to determine the existing rate of at-grade crossing activity by wildlife, particularly in areas where a sufficient crossing structure exists. Perhaps the biggest issue in establishing a sampling design that can adequately determine whether at-grade crossing rates change after installation of wildlife connectivity mitigation measures is to sample a large enough stretch of roadway. Prior to any sampling, a power analysis should be conducted to determine which sampling effort would be needed in order to detect such changes.

Track beds consist of a 2-m-wide swath of finely sifted sandy material and occur at the immediate edge of the pavement. Track beds would be walked weekly on consecutive days to determine species crossing rates. For each visit to the track bed, the following data would be recorded: previous precipitation levels, ambient air temperature, track bed condition, species leaving a track, certainty of track, crossing behavior, direction of track relative to the roadway, location of track(s) relative to the end of the track bed, and whether the track was recorded in the respective track bed across the roadway.

Track bed locations would occur within each Priority Crossing Zone and extend between POC-120 to POC-111. Within this zone, multiple track beds would be placed in order to

assess the at-grade (surface level) crossing rate prior to construction and compared to at-grade and underpass crossing rates after construction.

6.3.4 Adaptive Management

This data would not only serve to refine the initial site assessments, but would also serve as baseline data to address effectiveness monitoring and adaptive management, both which would occur after completion of roadway widening. Although prior studies have evaluated underpass use in relation to landscape features, structural dimensions, and other variables after construction at several sites, less common are rigorous efforts to conduct pre-construction and post-construction monitoring of roadway corridors and underpasses to determine the following: 1) where structural wildlife crossings might be most effectively used on existing roadway corridors; 2) how installing structural wildlife crossings influence crossing locations, crossing frequencies, and AVCs along roadway corridors where they are installed; and 3) how adaptive management strategies can provide measures to maintain and increase the safe passage of wildlife across roads (as determined by the establishment of mitigation success measures and significance criteria.

This initial baseline data collection, followed by effectiveness monitoring, would serve to ensure that mitigation measures are adequate in providing the safe passage of wildlife across roads that are subjected to improvement projects. Based on preconstruction monitoring efforts, significance thresholds could be developed that would trigger additional mitigation measures to be put in place if the proposed mitigation measures are not adequate at reducing AVCs and at-grade crossings while simultaneously promoting the safe passage of wildlife across roadways. By determining various significance criteria before project construction begins, a benchmark by which to gauge the success of mitigation measures was established, thus creating an adaptive management process that will not only ensure the long-term success of that particular mitigation measure, but will serve as a reference from which future mitigation strategies can be based.

7.0 REFERENCES

- Arizona Game and Fish Department. 2006a. Evaluation of Wildlife Crossings along the Proposed Expansion and Realignment of Camino de Manana. Arizona Game and Fish Department, Research Branch.
- . 2006b. Guidelines for bridge construction or maintenance to accommodate fish and wildlife movement and passage. Arizona Game and Fish Department, Habitat Branch.
- . 2009. Roadkill Data for Region 5 as of 8-13-09. Unpublished data from the Arizona Game and Fish Department Roadkill Database.
- Arizona Wildlife Linkages Assessment Workgroup. 2006. Arizona's wildlife linkages assessment.
- Ascensão, F., and A. Mira. 2007. Factors affecting culvert use by vertebrates along two stretches of road in southern Portugal. *Ecological Research* 22:57–66.
- Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars. *Conservation Biology* 7:94–108.
- . 1995. Dispersal of juvenile cougars in fragmented habitat. *Journal of Wildlife Management* 59:228–237.
- . 1996. Metapopulation models, tenacious tracking, and cougar conservation. Pages 293–323, *In* Metapopulations and wildlife conservation. D.R. McCullough, ed. Island Press. Washington, D.C.
- Berry, K.H. 1980. A review of the effects of off-road vehicles on birds and other vertebrates. Pages 451–467, *In* Management of western forests and grasslands for nongame birds—workshop proceedings. R.M. DeGraaf and N.G. Tilghman, eds. U.S. Forest Service, Intermountain Forest and Range Experiment Station. General Technical Report INT-86. February 11–14, 1980.
- Bissonette, J. A. and W. Adair. 2008. Restoring habitat permeability to roaded landscapes with isometrically-scaled wildlife crossings. *Biological Conservation* 141:482–488.
- Boarman, W.I. and M. Sazaki. 1996. Highway mortality in desert tortoises and small vertebrates: success of barrier fences and culverts. *In* Trends in addressing transportation related wildlife mortality: Proceedings of the Transportation Related Wildlife Mortality Seminar. G.L. Evink, P. Garrett, D. Zeigler, and J. Berry, eds. State of Florida, Department of Transportation, Environmental Management Office. Tallahassee, FL. FL-ER-58-96.
- Bolger, D.T., T.A. Scott, and J.T. Rotenberry. 1997. Breeding bird abundance in an urbanizing landscape in coastal southern California. *Conservation Biology* 11:406–421.

- Brody, A.J. and M.R. Pelton. 1989. Effects of roads on black bear movements in western North Carolina. *Wildlife Society Bulletin* 17:5–10.
- Brooks, M.L. 1999. Effects of protective fencing on birds, lizards, and black-tailed hares in the western Mojave Desert. *Environmental Management* 23:387–400.
- Brown, D.E. 1994. *Biotic communities: southwestern United States and northwestern Mexico*. University of Utah Press. Salt Lake City, UT.
- Brown, D.L., J. Laird, W.D. Summers, and A. Hamilton. 1999. Methods used by the Arizona Department of Transportation to reduce wildlife mortality and improve highway safety. Pages 175–178, *In Proceedings of the third international conference on wildlife ecology and transportation*. G.L Evink, P. Garret, and D. Zeigler, eds.
- Bury, R.B. 1980. What we know and do not know about off-road vehicle impacts on wildlife. Pages 110–122 *In Off-road vehicle use—a management challenge*. R.N.L. Andrews and P. Nowak, eds. U.S. Office of Environmental Quality. Washington, D.C. p. 110–122.
- Bury, R.B., R.A. Luckenbach, and S.D. Busack. 1977. Effects of off-road vehicles on vertebrates in the California desert USA. U.S. Fish and Wildlife Service, Wildlife Research Reports no. 8. Washington, D.C. p. 1–23.
- Cain, A.T., V.R. Tuovila, D.G. Hewitt and M.E. Tewes. 2003. Effects of a highway and mitigation projects on bobcats in Southern Texas. *Biological Conservation* 114:189–197.
- Carroll, C., W.J. Zielinski, and R.F. Noss. 1999. Using presence-absence data to build and test spatial habitat models for the fisher in the Klamath Region, U.S.A. *Conservation Biology* 13:1344–1359.
- Case, R.M. 1978. Interstate highway road-killed animals: a data source for biologists. *Wildlife Society Bulletin* 6: 8–13.
- Clevenger, A.P. and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. *Conservation Biology* 14:47–56.
- Coleman, J.S. and S.A. Temple. 1993. Rural residents' free-ranging domestic cats: a survey. *Wildlife Society Bulletin* 21:381–390.
- Crooks, K.R. 2000. Mammalian carnivores as target species for conservation in southern California. Pages 105–112, *In Second interface between ecology and land development in California*. J. Keeley, M. Baer-Keeley, and C. Fotheringham, eds. U.S. Geological Survey. Open-File Report 00-62.
- Crooks, K.R. and M.E. Soulé. 1999. Mesopredator release and avifaunal collapse in urban habitat fragments. *Nature* 400:563–566.

- Dobson, A., K. Ralls, M. Foster, M.E. Soulé, D. Simberloff, D. Doak, J.A. Estes, L.S. Mills, D. Mattson, R. Dizro, H. Arita, S. Ryan, E.A. Norse, R.F. Noss, and D. Johns. 1999. Connectivity: maintaining flows in fragmented landscapes. Pages 129–170, *In* Continental Conservation: scientific foundations of regional reserve networks. M.E. Soulé and J. Terborgh, eds. Island Press. Washington, D.C.
- Estes, J., K. Crooks, and R. Holt. 2001. Ecological role of predators. Pages 857–878, *In* Encyclopedia of Biodiversity. S. Levin, ed. Academic Press. San Diego, CA.
- Fisher, R.N. and T.J. Case. 2000. Southern California herpetofauna research and monitoring: 1995–1999 data summation report. U.S. Geological Survey Technical Report. Submitted to U.S. Fish and Wildlife Service and California Department of Fish and Game. 200pp.
- Foster, M.L. and S.R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. *Wildlife Society Bulletin* 23:1–5.
- George, S.L. and K.R. Crooks. 2006. Recreation and large mammal activity in an urban nature reserve. *Biological Conservation* 133:107–117.
- Gibeau, M. L. and S. Herrero. 1998. Roads, rails, and grizzly bears in the Bow River Valley, Alberta. Pages 104–108, *In* Proceedings of the International Conference on Wildlife Ecology and Transportation. G.L. Evink, P. Garrett, D. Zeigler, and J. Berry, eds.
- Groot Bruinderink, G.W.T.A and E. Hazebroek. 1996. Ungulate traffic collisions in Europe. *Conservation Biology* 10:1059–1067.
- Haas, C.D. 2000. Distribution, relative abundance, and roadway underpass responses of carnivores throughout the Puente-Chino Hills. Master Thesis. California State Polytechnic University, Pomona, CA. 122 pp.
- Haas, C.D. and K.R. Crooks. *In prep.* Factors influencing carnivore and ungulate underpass activity across an urban wildlife corridor.
- Haas, C.D. and G. Turschak. 2002. Responses of large and medium-bodied mammals to recreation activities: the Colima Road underpass. U. S. Geological Survey Technical Report. Prepared for Puente Hills Landfill Native Habitat Preservation Authority. 26 pp.
- Hanski, I. 1999. Metapopulation ecology. Oxford University Press. New York.
- Hanski, I. and D. Simberloff. 1997. The metapopulation approach, its history, conceptual domain, and application to conservation. Pages 5–26, *In* Metapopulation biology: ecology, genetics, and evolution. Academic Press. San Diego, CA.
- Harris, L.D. and P.B. Gallagher. 1989. New initiatives for wildlife conservation: the need for movement corridors. Pages 11–34, *In* Preserving communities and corridors. G. Mackintosh, ed. Defenders of Wildlife. Washington, D.C.

- Harrison, R.L. 1997. A comparison of gray fox ecology between residential and undeveloped rural landscapes. *Journal of Wildlife Management* 61:112–122.
- Henke, S. E. and F.C. Bryant. 1999. Effects of coyote removal on the faunal community in western Texas. *Journal of Wildlife Management* 63:1066–1081.
- Huijser, M.P., P. McGowen, J. Fuller, A. Hardy, A. Kociolek, A.P. Clevenger, D. Smith, and R. Ament. 2007. Wildlife-vehicle collision reduction study. Report to Congress. U.S. Department of Transportation, Federal Highway Administration. Washington D.C.
- Hyman, W.A. and D. Vary. 1999. NCHRP Synthesis 272: best management practices for environmental issues related to highway and street maintenance. Transportation Research Board, National Research Council. Washington, DC.
- Jackson, S.D. 1996. Underpass systems for amphibians. *In* Trends in addressing transportation related wildlife mortality: Proceedings of the Transportation Related Wildlife Mortality Seminar. G.L. Evink, P. Garrett, D. Zeigler, and J. Berry, eds. State of Florida, Department of Transportation, Environmental Management Office. Tallahassee, FL. FL-ER-58-96.
- Kittelson and Associates, Inc. 2010. Silverbell Road Design Concept Report. Unpublished, internal draft for review purposes only.
- Kline, N.C., and Swann, D.E., 1998. Quantifying wildlife road mortality in Saguaro National Park. *In*: Evink, G., Garrett, P., Zeigler, D., Berry, J. (Eds.), Proceedings of the International Conference on Wildlife Ecology and Transportation, FL-ER-69-98. Florida Department of Transportation, Tallahassee, Florida, pp. 23–31.
- Lambeck, R.J. 1997. Focal species: a multi-species umbrella for nature conservation. *Conservation Biology* 11:849–856.
- Land, D. and M. Lotz. 1996. Wildlife crossing designs and use by Florida panthers and other wildlife in southwest Florida. *In* Trends in addressing transportation related wildlife mortality: Proceedings of the Transportation Related Wildlife Mortality Seminar. G.L. Evink, P. Garrett, D. Zeigler, and J. Berry, eds. State of Florida, Department of Transportation, Environmental Management Office. Tallahassee, FL. FL-ER-58-96.
- Langton, T.E.S. 1989. Amphibians and roads: proceedings of the toad tunnel conference. ACO Polymer Products. Shefford, England. 202 pp.
- Linden, P.J.H. van der, 1997. A wall of tree-stumps as a fauna-corridor. pp. 409–417, *In* Habitat fragmentation and infrastructure, proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering. K. Canters, ed. Ministry of Transport, Public Works and Water Management. Delft, The Netherlands.

- Luckenbach, R.A. 1978. An analysis of off- road vehicle use on desert avifaunas. Transactions of the North American Wildlife and Natural Resources Conference 43:157–162.
- Luckenbach, R.A. and R.B. Bury. 1983. Effects of off-road vehicles on the biota of the Algodones Dunes, Imperial County, California, USA. Journal of Applied Ecology 20:265–286.
- Lyren, L.M. 2001. Movement patterns of coyotes and bobcats relative to road underpasses in the Chino Hills are of Southern California. Master Thesis. California State Polytechnic University, Pomona, CA. 119pp.
- Lyren, L.M., R.S. Alonso, K.R. Crooks, and E.E. Boydston. 2009. Evaluation of Functional Connectivity for Bobcats and Coyotes across the Former El Toro Marine Base, Orange County, California. Administrative Report, 179 pp.
- Lyren, L.M., R.S. Alonso, K.R. Crooks, and E.E. Boydston. 2008. GPS telemetry, camera trap, and mortality surveys of bobcats in the San Joaquin Hills, Orange County, California. Administrative Report, 134 pp.
- Lyren, L.M., G.M. Turschak, E.S. Ambat, C.D. Haas, J.A. Tracey, E.E. Boydston, S.A. Hathaway, R.N. Fisher, and K.R. Crooks. 2006. Carnivore Activity and Movement in a Southern California Protected Area, the North/Central Irvine Ranch. U.S. Geological Survey Technical Report. 115 pp.
- Lyren L.M., G.M. Turschak, E.S. Ambat, C.D. Haas, J.A. Tracey, E.E. Boydston, S.A. Hathaway, R.N. Fisher, and K.R. Crooks. 2005. Final Report for the North Irvine Ranch Carnivore Movement Study. U.S. Geological Survey Technical Report. 115 pp.
- Lyren, L.M. Unpublished data. Preliminary results of CA-71/CA-91 carnivore movement study.
- Mansergh, I.M and D.J. Scotts. 1989. Habitat continuity and social organization of the mountain pygmy-possum restored by tunnel. Journal of Wildlife Management 53:701–707.
- Mata, C., I. Hervás, J. Herranz, F. Suárez and J.E. Malo. 2005. Complementary use by vertebrates of crossing structures along a fenced Spanish motorway. Biological Conservation 124:397–405.
- Meffe, G.K., R.C. Carroll, and contributors. 1997. Principles of conservation biology. Sinauer Associates, Inc. Sunderland, MA.
- Miller, B., R. Reading, J. Strittholt, C. Carroll, R. Noss, M. Soulé, O. Sanchez, J. Terborgh, D. Brightsmith, T. Cheeseman, and D. Foreman. 1998. Using focal species in the design of nature reserve networks. Wild Earth 8:81–92.

- Murcia, C. 1995. Edge effects in fragmented forests: implications for conservation. *Tree* 10:58–62.
- Ng, S.J., J.W. Dole, R.M. Sauvajot, S.P.D. Riley, and T.J. Valone. 2004. Use of highway undercrossings by wildlife in southern California. *Biological Conservation* 115:499–507.
- Noss, R.F. and A.Y. Cooperrider. 1994. *Saving nature's legacy: protecting and restoring biodiversity*. Defenders of Wildlife and Island Press. Washington, D.C.
- Noss, R. F., H.B. Quigley, M.G. Hornocker, T. Merrill, and P.C. Paquet. 1996. Conservation biology and carnivore conservation in the Rocky Mountains. *Conservation Biology* 10:949–963.
- Ouren, D. and C. Haas. *In press*. Ecological effects of roads and their use: a bibliographic review. U.S. Geological Survey Open File Report.
- Painter, M.L., and M.F. Ingraldi. 2005. Use of simulated highway underpass crossing structures by flat-tailed horned lizards (*Phrynosoma mcallii*). Final Report 594. Research Branch, Arizona Game and Fish Department. Flagstaff, Arizona. 40 pp.
- Paquet, P. and C. Callahan. 1996. Effects of linear developments on winter movements of gray wolves in the Bow River Valley of Banff National Park, Alberta. *In Trends in addressing transportation related wildlife mortality: Proceedings of the Transportation Related Wildlife Mortality Seminar*. G.L. Evink, P. Garrett, D. Zeigler, and J. Berry, eds. State of Florida, Department of Transportation, Environmental Management Office. Tallahassee, FL. FL-ER-58-96.
- Pima County. 2006. Pima County, Sonoran Desert Conservation Plan: Priority Vulnerable Species in Pima County. Accessed June 16, 2008. Available at: <http://www.pima.gov/cmo/sdcp/species/fsheets/vuln/vuln.html>.
- . 2007. Pima County Development Services website: Land Use Legend Summary, Urban Intensity Categories. Accessed June 26, 2009. Available at: http://www.pimaxpress.com/Planning/ComprehensivePlan/LUI_legend_summary2003.htm.
- . 2009. Pima County Mapguide website. Accessed June 26, 2009. Available at: <http://www.dot.co.pima.az.us/gis/maps/mapguide/mgmap.cfm?path=/cmo/sdcpmaps/sdcp.mwf&scriptpath=mgmapinitnullAPI.inc>.
- Putman, R.J. 1997. Deer and road traffic accidents: options for management. *Journal of Environmental Management* 51:43–57.
- Riley, S.P.D., R.M. Sauvajot, T.K. Fuller, E.C. York, D.A. Kamradt, C. Bromley, and R.K. Wayne. 2003. Effects of urbanization and habitat fragmentation on bobcats and coyotes in southern California. *Conservation Biology* 17:566–576.

- Ripple, W.J., E.J. Larsen, R.A. Renkin, and D.W. Smith. 2001. Trophic cascades among wolves, elk and aspen on Yellowstone National Park's northern range. *Biological Conservation* 102:227–234.
- Rodriguez, A., G. Crema, and M Delibes. 1996. Use of non-wildlife passages across a high speed railway by terrestrial vertebrates. *Journal of Applied Ecology* 33:1527–1540.
- Rosen, P.C., and Lowe, C.H., 1994. Highway mortality of snakes in the Sonoran desert of southern Arizona. *Biological Conservation* 68, 143–148.
- Rudolph, D.C., S.J. Burgdorf, R.N. Conner, and J.G. Dickson. 1998. Pages 236–240, *In* The impact of roads on the Timber Rattlesnake, (*Crotalus horridus*), in eastern Texas. *Proceedings of the International Conference on Wildlife Ecology and Transportation*. G.L. Evink, P. Garrett, D. Zeigler, and J. Berry, eds.
- Ruediger, B. 1998. Rare carnivores and highways-moving into the 21st century. Pages 10–16, *In* *Proceedings of the International Conference on Wildlife Ecology and Transportation*. G.L. Evink, P. Garrett, D. Zeigler, and J. Berry, eds.
- Saunders, D.A., R.J. Hobbs, and C.R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. *Conservation Biology* 5: 18–32.
- Scott, T.A. and D.S. Cooper. 1999. Summary of avian resources of the Puente-Chino Hills corridor. Annual Report. Prepared for the Mountains, Recreation, and Conservation Authority. 25 pp.
- Servheen, C., J. Walker, and W. Kasworm. 1998. Fragmentation effects of high-speed highways on grizzly bear populations shared between the United States and Canada. Pages 97–103, *In* *Proceedings of the International Conference on Wildlife Ecology and Transportation*. G.L. Evink, P. Garrett, D. Zeigler, and J. Berry, eds.
- Soulé, M.E. and J. Terborgh. 1999. *Continental Conservation: scientific foundations of regional reserve networks*. Island Press. Washington, D.C.
- Tewes, M.E. and D.R. Blanton. 1998. Potential impacts of international bridges on ocelots and jaguarundis along the Rio Grande wildlife corridor. Pages 135–139, *In* *Proceedings of the International Conference on Wildlife Ecology and Transportation*. G.L. Evink, P. Garrett, D. Zeigler, and J. Berry, eds.
- Varland, K.L. and P.J. Schaefer. 1998. Roadside management trends in Minnesota. Pages 214–228, *In* *Proceedings of the International Conference on Wildlife Ecology and Transportation*. G.L. Evink, P. Garrett, D. Zeigler, and J. Berry, eds.
- Wilcox, B., and D. Murphy. 1985. Conservation strategy: the effects of fragmentation on extinction. *The American Naturalist* 125:879–997.
- Woodroffe, R. and J.R. Ginsberg. 1998. Edge effects and the extinction of populations inside protected areas. *Science* 280:2126–2128.

Yanes, M., J.M. Velasco, and F. Suárez. 1995. Permeability of roads and railways to vertebrates: the importance of culverts. *Biological Conservation* 71:217–222.

APPENDIX A
**Representative Photos of Structures and At-Grade Crossings along this
Portion of Silverbell Road**



Photo A-1. Five-chamber box culvert at Greasewood Wash.



Photo A-2. Typical existing at-grade wash crossing.



Photo A-3. Example of existing non-functioning rip-rap and concrete apron at numerous locations



Photo A-4. Example of a densely vegetated flood-prone area in the project area.