Ecological impacts of new and upgraded dirt roads in Cabeza Prieta National Wildlife Refuge and avoidance, mitigation and compensation strategies

by

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Primitive roads in and around Cabeza Prieta National Wildlife Refuge (CPNWR), including sections of the historic “El Camino del Diablo”, were upgraded to provide access to the border with Mexico for the construction of the USA-Mexico border wall. This report contains an assessment of the ecological impacts of the improved dirt roads around Tule Well. It also details recommendations for what could be done to avoid, mitigate or compensate for the impacts. This information is likely useful to the stakeholders in the area (USFWS, Border Patrol, U.S. Army Corps of Engineers, public). This information could help with discussions among the stakeholders on the purpose and need for these roads, and how to manage the roads over the longer term as well as how to mitigate the impacts. In addition to the assessment of the roads around Tule Well, this report contains an assessment of the road up to Childs Mountain Overlook in the north east section of CPNWR. The viewpoint overlooks a portion of the refuge. The road to Childs Mountain Overlook is gated, but there are plans to increase public use of the viewpoint. The report details characteristics of the road to the overlook including hydrology and erosion processes that may affect the integrity of the road.</td></tr>
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1. INTRODUCTION

1.1. Background

Primitive roads in and around Cabeza Prieta National Wildlife Refuge (CPNWR), including sections of the historic “El Camino del Diablo” (Friends of the Sonoran Desert, 2016), were upgraded to provide access to the border with Mexico for the construction of the USA-Mexico border wall. Until recently, there were only a few primitive high clearance 4x4 roads that received very low visitor use (perhaps 500-1,000 vehicles per year (excluding USFWS and Border Patrol vehicles)), and that only allowed for low travel speed (Pers. Communication, Sid Slone, Refuge Manager CPNWR). While the future “purpose and need” of the upgraded roads within CPNWR may be unclear or uncertain, having more, wider, and smoother roads is likely to increase the impacts on the natural environment compared to the “before” situation.

On top of Childs Mountain, in the north east section of CPNWR, a viewpoint overlooks a portion of the refuge. The road to Childs Mountain Overlook is gated, but there are plans to increase public use of the viewpoint (Pers. Communication, Sid Slone, Refuge Manager CPNWR). The road up to Childs Mountain Overlook may have to be modified to allow for increased public use. These modifications may include guardrails in select places and paving of the last 1.5 miles to the overlook (Pers. Communication, Sid Slone, Refuge Manager CPNWR).

1.2. Objectives

The first objective is assessing the ecological impacts of the improved dirt roads around Tule Well, and to provide recommendations for what could be done to avoid, mitigate or compensate for the impacts. This information is likely useful to the stakeholders in the area (USFWS, Border Patrol, U.S. Army Corps of Engineers, public). This information could help with discussions among the stakeholders on the purpose and need for these roads, and how to manage the roads over the longer term as well as how to mitigate the impacts. The second objective is to have a first assessment of the road up to Childs Mountain Overlook, particularly regarding hydrology and erosion processes.

1.3. Road Sections of Interest

The project focuses on the roads and road sections indicated below. The road sections of interest are the roads near Tule Well and the road up to Childs Mountain Overlook (Figure 1). The roads near Tule Well were recently upgraded for the construction of the USA-Mexico border wall. The road up to Childs Mountain Overlook may be opened to day-use and needs to be evaluated for its potential impacts and measures to address these impacts. Within the Tule Well area, the roads are dirt road only. Within the Childs Mountain area there are gravel and paved roads present.

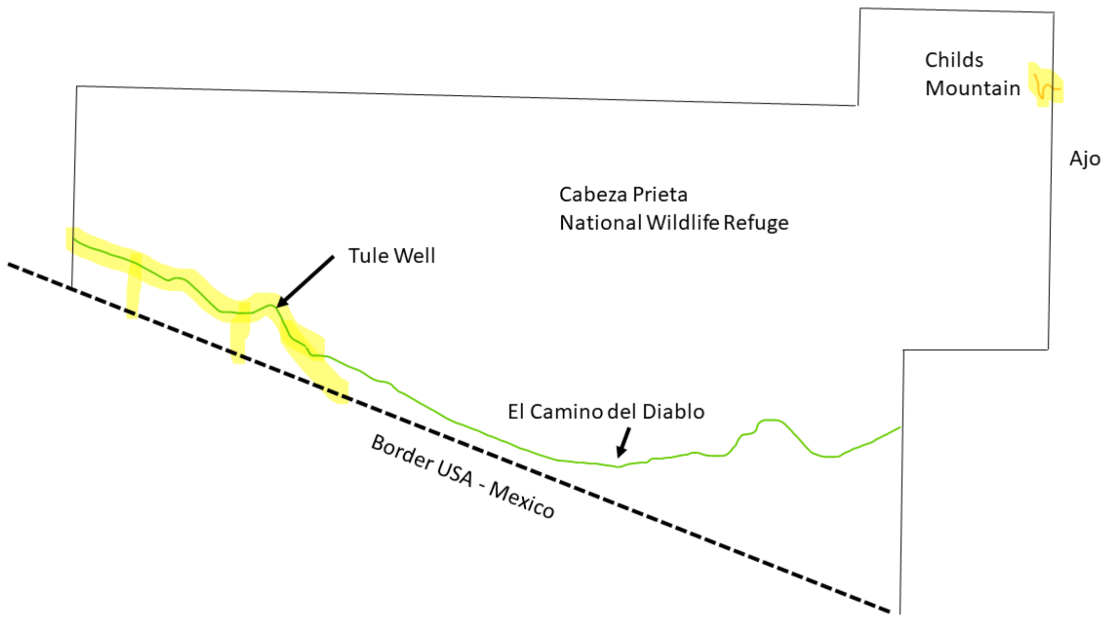

Figure 1: The road sections of interest (highlighted in yellow) on the Cabeza Prieta National Wildlife Refuge, Arizona, USA. There are three turn offs to the border wall that were part of the field review South Tordillo road (south of Jct 110, most western road on map), O-5 road (west of Tule Well, middle road on map), and Tule Extension road (east of Tule Well, most eastern road on map).

1.4. Tasks

Task 1: Field review

The researchers conducted a field review of roads in and around Cabeza Prieta National Wildlife Refuge. This included meeting representatives of USFWS to discuss the former, current and potential future condition and use of the dirt roads around Tule Well and Childs Mountain. The general ecological impacts of dirt roads were discussed, and what could be done to avoid, mitigate or compensate for these effects. The measures may range from road removal and habitat restoration to reducing the impacts of roads and traffic, and to the compensation of these impacts by implementing conservation measures elsewhere. The field review also included selected road sections in Organ Pipe Cactus National Monument (OPCNM). Selected roads in OPCNM may function as a reference for impacts as well as mitigation and restoration efforts in CPNWR.

Task 2: Report
The researchers documented the experiences of the field review in a report (this report). The report includes a first assessment of the current roads around Tule Well Refuge, a description of the likely abiotic and biotic impacts associated with these roads, and how these effects may be avoided, mitigated, or compensated. Finally, the report includes a first assessment of the road up Childs Mountain Overlook, particularly regarding hydrology and erosion processes.

2. GENERAL ECOLOGICAL IMPACTS OF ROADS AND DIRT ROADS IN SPECIFIC

2.1. General Ecological Impacts of All Roads

Roads and traffic have a range of abiotic impacts. These abiotic impacts include (e.g. Forman et al., 2003; van der Ree et al., 2015):

- Soil removal for road in preparation of building up the roadbed.
- Introducing non-native substrate for roadbed.
- Disruption of local hydrology under the roadbed.
- Disruption of hydrological processes on the adjacent lands. Roads act as linear barriers in fluid systems, disrupting surface and subsurface water flow, bringing subsurface water to the surface, concentrating water in non-natural ways leading to increased water availability in some areas and decreased water availability in others. Concentrated water also transports pollutants and sediment from the road into the adjacent landscape and into adjacent water bodies. Concentrated water can also cause physical damage to the road infrastructure, increasing maintenance needs and costs. In addition, roads and the associated culverts and bridges usually confine streams and rivers to widths that are narrower than the “full bank width”.
- In association with hydrology, roads affect erosion and sedimentation processes on the adjacent lands.
- Chemical pollutants in the soil, water, and air (from pavement wear, tires, exhaust, vehicle fluids (e.g. coolant, wiper fluid, oil, fuel, grease, hydraulic fluids, brake fluid), road salt or road sand, or deicing chemicals, garbage from littering, herbicides from controlling non-native species in the roadsides, heavy metals from culverts and bridges, pollutants from cargo spills, etc.)
- Dust (especially on unpaved (gravel, dirt) roads).
- Noise associated with traffic.

The impacts on the biotic environment are diverse and may include (e.g. Forman et al., 2003; van der Ree et al., 2015) (Figure 2):

- Habitat loss. The road surface and roadbed destroy or affect natural vegetation, soil and hydrology. Along high-speed paved roads, the clear zone immediately adjacent to the pavement allows drivers an opportunity to regain control of their vehicle after having left the road surface. The vegetation in the clear zone is mowed and cut frequently as larger trees and shrubs form obstacles that may result in a more serious crash. The road, shoulder and right-of-way management practices lead to habitat loss for most species.
- Direct wildlife road mortality. Collisions with large mammals are not only a threat to human safety. The animals involved typically die as the result of a crash. Small species such as invertebrates, amphibians, reptiles and small mammals are also killed by vehicles, though collisions with small species rarely result in vehicle damage and are generally not a threat to human safety. Moreover, carcasses of small animal species are rarely detected and recorded.

- Barrier to wildlife movements. Most animal species do not cross roads as often as they cross natural terrain, and only a portion of their crossing attempts are successful. This leads to smaller and more isolated habitat patches that can affect the population survival probability of a species in an area. Small species that need cover (e.g. invertebrates, amphibians, reptiles, small mammals) and species that are sensitive to human presence and disturbance (regardless of their size) are particularly affected.
- Decrease in habitat quality in a zone adjacent to the road. Noise, light, air and water pollution, erosion, and increased access for humans into areas adjacent to roads can affect the habitat quality in a zone adjacent to transportation infrastructure. Depending on the parameter and species concerned, the road effect zone may vary between a few feet up to several miles.
- Right-of-way habitat and corridor. The vegetation in the right-of-way, between the edge of the pavement or travel lanes and the right-of way boundary, is subject to severe disturbance (soil, hydrology, pollution, mowing or cutting, grading, seeding of non-native species etc.). Non-native and invasive plant and animal species can spread alongside the infrastructure and can also spread into the surrounding areas. If the transportation corridor is surrounded by natural vegetation with little disturbance, the habitat and the species in the right-of-way can be a problem for native species. On the other hand, if the surrounding landscape is heavily impacted by humans already (e.g. (sub)urban and agricultural areas), then the narrow strip alongside roads and railroads can be a refugium for native species, and, because of the linear nature of transportation infrastructure right-of-ways, may form corridors connecting the remaining habitat patches in the fragmented landscape. This corridor effect, however, can also be a population sink for some species because of the hazards associated with roads and traffic.

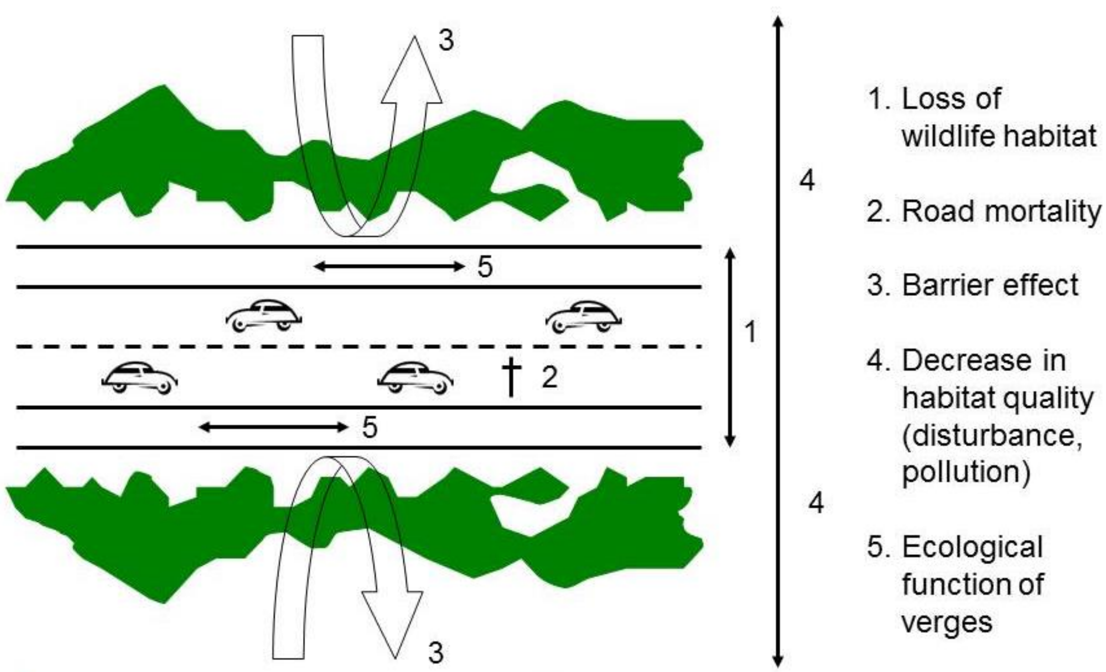

Figure 2: The effects of roads and traffic on wildlife.

2.2. Ecological Impacts of Dirt Roads in Arid Ecosystems

Specific impacts or dirt roads and traffic in arid ecosystems include:

Habitat loss beyond the original track: dirt roads in arid environments may not be well defined and road users may find different routes to avoid obstacles, including loose sand, heavily eroded road sections or muddy and inundated tracks. This can result in a very wide braided system of tracks that can be hundreds of yards or miles wide rather than the width of the "original" dirt road (e.g. Keshkamat et al., 2013). Flat areas are more vulnerable to this phenomenon than areas with steep slopes where the topography may not allow road users to deviate much from the original route.

Easily damaged soil and vegetation: Cryptobiotic soil crust consist of living organisms such as algae, cyanobacteria, and fungi. Once disturbed, e.g. through driving on them, they may take many decades up to several hundreds of years to recover (Belnap et al., 1994; Belnap, 1995; Belnap & Warren, 2002). This means that even rare or occasional driving can lead to a permanently disturbed soil and associated desertification. However, it is technically possible to restore native biocrust within a few years through inoculation with salvaged biocrust (Chiquoine et al., 2016). But large-scale restoration would likely be very costly. Creating new tracks or general off-road driving can also damage and kill larger plants.

Cryptobiotic soil or biological soil crust, Barry M. Goldwater Air Force Range or Barry M. Goldwater Range (BMGR), North of Tinajas Altas, Arizona.

Ocotillo (*Fouquieria splendens*) damaged by vehicles, South Tordillo road looking south from El Camino del Diablo, about 4.6 miles east of the western boundary, Cabeza Prieta National Wildlife Refuge, Arizona (32°15'22.764" N 113°53'22.001" W).

Dust: Dust from vehicles driving by, or from the wind picking up soil from dirt roads can affect air quality, visibility, and deposits on the adjacent vegetation can reduce photosynthesis by plants (Goossens & Buck, 2011; Kavouras et al., 2016). Dust on the vegetation can even affect where herbivores graze up to hundreds of yards from dirt roads (Ndibalem et al., 2008).

Erosion and sediments: Dirt roads and the use of dirt roads by vehicles can cause erosion and disruption of hydrological processes in the adjacent areas (e.g. Gesford & Anderson, 2006; Ouren et al. 2007; Villlareal et al., 2016). The impacts include loss of soil, desertification, and sediment deposition in streams and other water bodies.

Non-native species and predation pressure: Seeds from non-native species can be spread by vehicles (e.g. Taylor et al. 2012; Rew et al 2018). In addition, dirt roads increases mesocarnivore presence and predation pressure, including on desert tortoises (Agha et al. 2017).

3. AVOIDANCE, MITIGATION AND COMPENSATION STRATEGIES

While mitigation (reducing the severity of an impact) is common, avoidance is better and should generally be considered first. For example, the negative effects of roads and traffic may be avoided if a road is not constructed, or the most severe negative effects may be avoided by re-routing away from the most sensitive areas (Figure 3). If the effects cannot be avoided, mitigation is a logical second step. Mitigation is done in the road-effect zone (Figure 3) and may include measures aimed at reducing direct wildlife mortality as a result of collisions, at reducing the barrier effect (e.g., through providing for safe wildlife crossing opportunities), and at reducing hydrologic impacts through improved design and engineering to minimize how the road impacts the hydrological system. However, mitigation may not always be possible, or mitigation may not be sufficient. Then a third approach may be considered: compensation or off-site mitigation. Compensation may include increasing the size and quality of existing habitat patches, creating new habitat patches or improving the connectivity between the habitat patches that would allow for larger, more connected, and more viable network populations. Finally, it is also possible to have a combination of avoidance, mitigation, and compensation measures.

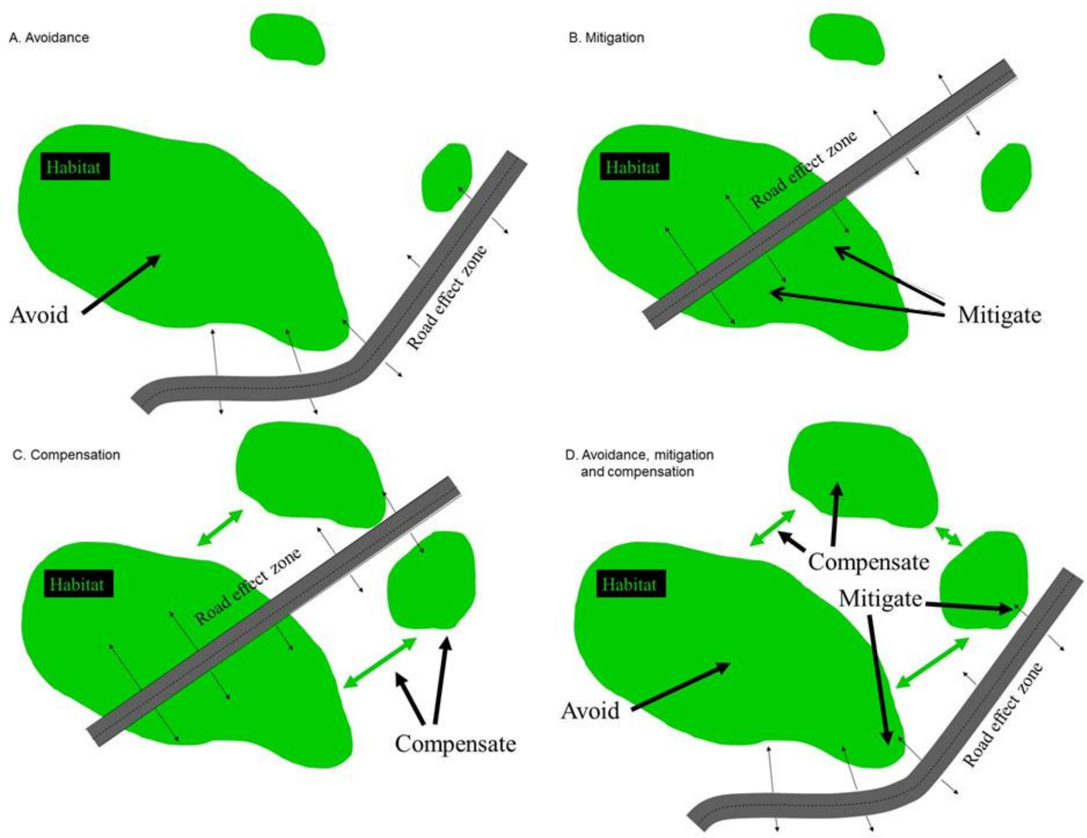

Figure 3: A three step approach: A. Avoidance, B. Mitigation, C. Compensation, D. Combination of avoidance, mitigation and compensation.

4. FIELD REVIEW ROADS AROUND TULE WELL

4.1. Introduction

The ecological effects of the roads around Tule Well described in this chapter are based on a one-day field visit in conjunction with discussions with refuge personnel. This chapter is not based on in-depth field studies in this area.

4.2. Ecological Effects

4.2.1. Habitat Loss

The section of El Camino del Diablo around Tule Well was widened from 12-14 ft to ≥22 ft and the road surface was smoothened (Pers. Communication, Sid Slone, Refuge Manager CPNWR). The roads in Cabeza Prieta NWR do not have a formal right-of-way; there is usually undisturbed soil and vegetation immediately adjacent to the road prism. The length of El Camino del Diablo from the western boundary (CPNWR boundary with Barry M. Goldwater Range West or Marine Corps Air Station Yuma (BMGR-W)) to the Tule Extension road to the border wall (just east of Tule Well, see Figure 1)) is approximately 16.0 mi. If we assume that the "old" road was on average 13 ft wide, and that the widened road is on average 22 ft wide, the habitat lost because of the widening is 9 ft (2.74 m) over a length of 16.0 mi (25.74 km), which is 17.4 acres (70,539 m^2 or 7.05 ha). The 17.4 acres does not include pull-outs, equipment staging areas or "man camps" that were created by construction traffic, equipment, or areas cleared to house workers. The 17.4 acres also does not include the habitat loss associated with the widening of the O-5 road (west of Tule Well, about 3 miles (not measured)) and the Tule Extension road to the border wall (most eastern, east of Tule Well, about 3 miles (not measured)). The South Tordillo road (about 3.0 mi in length, measured) was not formally widened, but is was driven on by construction traffic, despite the road being closed to construction traffic.

"Old" section of dirt road just west of the actual El Camino del Diablo, about 1.1 mile south-east of Tinajas Altas, Barry M. Goldwater Range (BMGR), Arizona (32°18'22.812" N 114°1'53.916" W). This is the closest remaining “reference” for the “old” El Camino del Diablo west of Cabeza Prieta National Wildlife Refuge (CPNWR).

"Old" section of El Camino del Diablo just east of the junction with Tule Extension road, east of Tule Well, Cabeza Prieta National Wildlife Refuge (CPNWR), Arizona (32°11'55.584" N 113°43'36.863" W). This is the closest remaining “reference” for the “old” El Camino del Diablo east of the widened road section.

A widened section of El Camino del Diablo, about 5.5 miles east of the western boundary, Cabeza Prieta National Wildlife Refuge, Arizona (32°15'5.039" N 113°52'30.413" W).

South Tordillo road looking south from El Camino del Diablo, about 4.6 miles east of the western boundary, Cabeza Prieta National Wildlife Refuge, Arizona (32°15'22.775" N 113°53'21.888" W). This road section was driven on by construction traffic despite being closed to construction traffic. Also note the damage to the Ocotillo (*Fouquieria splendens*) on the right.

O-5 road looking south from El Camino del Diablo west of Tule Well, about 11.8 miles east of the western boundary, Cabeza Prieta National Wildlife Refuge, Arizona (32°13'9.041" N 113°46'50.712" W). Similar to sections of El Camino del Diablo, this road section was also widened.

Tule Extension road looking south from El Camino del Diablo east of Tule Well, about 16.0 miles east of the western boundary, Cabeza Prieta National Wildlife Refuge, Arizona (32°11'57.876" N 113°43'41.136" W). Similar to sections of El Camino del Diablo, this road section was also widened.

A pull-out associated with the widened El Camino del Diablo, at the junction with the South Tordillo road, about 4.6 miles east of the western boundary, Cabeza Prieta National Wildlife Refuge, Arizona (32°15'23.37" N 113°53'22.338" W). Note: when in use, the tires are dragged behind a border patrol vehicle to be able to track people who may have crossed the border.

Example of a staging area for materials and equipment along a widened section of El Camino del Diablo, about 1.8 miles south-east of Tinajas Altas, Barry M. Goldwater Range West (BMGR-W), Arizona (32°18'8.519" N 114°1'11.91" W).

A trailer camp (or "man camp") at the border wall, at the southern end of the Tule Extension road, Cabeza Prieta National Wildlife Refuge, Arizona (32°8'43.644" N 113°40'24.174" W).

Border wall and road, south of Tule Well, at the southern end of the O-5 road, adjacent to Cabeza Prieta National Wildlife Refuge, Arizona. The Roosevelt Reservation is a 60 ft wide strip of federal land along the border that is not part of the refuge (32°10'46.925" N 113°46'58.985" W), but the activities and infrastructure along the border do impact the ecology of the adjacent refuge.

While habitat was lost as a result of widening the road, columnar cacti species, e.g. Saguaros, were rescued and transplanted a little off the widened road sections.

A transplanted saguaro (*Carnegiea gigantea*) that was in the path of a widened section of El Camino del Diablo east of Tinajas Altas, Cabeza Prieta National Wildlife Refuge, Arizona.

4.2.2. Direct Road Mortality

The old historic road of El Camino del Diablo allowed for an average travel speed of 15-25 MPH (posted at 25 MPH) whereas the widened road sections allow for a travel speed of 35 MPH or greater (posted at 35 MPH). In addition, traffic volume has increased dramatically during construction, mostly from contractors building the border wall from early 2020 until the recent temporary shutdown of wall construction by Presidential Executive Order (Pers. Communication, Sid Slone, Refuge Manager CPNWR, February 2021). However, vehicle speed by road users is often considerably higher than 35 MPH (Pers. Communication, Sid Slone, Refuge Manager CPNWR). During construction of the border wall, vehicles associated with the wall construction have had two roll overs. On one occasion a vehicle hit and killed a desert bighorn sheep ram (*Ovis canadensis nelsoni*) (Pers. Communication, Sid Slone, Refuge Manager CPNWR). Sonoran pronghorn (*Antilocapra americana sonoriensis*), an endangered subspecies of the pronghorn, mostly occur in the eastern and northeastern portions of the refuge, and do not typically occur in the area with the widened roads. While any unnatural mortality of desert bighorn sheep is a conservation concern, the overall road mortality of large mammals along the widened road sections is probably low in absolute terms. In general, most collisions with large wild mammals occur on paved two-lane roads, with a posted speed limit of 55 MPH or higher, and between dusk and dawn (Huijser et al., 2008).

Relatively small animal species may also be a conservation concern on the CPNWR. For example, the road mortality of the desert tortoise, especially the Mojave desert tortoise or Agassiz's desert tortoise (*Gopherus agassizii*), is a concern elsewhere. However, direct road mortality of Mojave desert tortoises on dirt roads is generally thought to be low compared to that on high volume and high-speed paved roads (e.g. Pers. Communication, Michael Vamstad, Joshua Tree National Park, 11 February 2021; Pers. Communication, William Boarman, 12 February 2021). Nonetheless, juvenile tortoises can be mistaken for rocks or clumps of sand and may be killed when vehicles drive over them (Pers. Communication, Michael Vamstad, Joshua Tree National Park, 11 February 2021). Loss of juvenile tortoises is not as well documented and may be higher than loss of adult tortoises. During and after rain events, water may concentrate on the road, including in puddles that may take some time to dry out. In general, Mojave desert tortoises are known to be attracted to such water sources, including on dirt roads, probably making them more vulnerable to direct road mortality after rain events (Pers. Communication, Sid Slone, Refuge Manager CPNWR, February 2021). This may also hold for the Sonoran desert tortoise or Morafka's desert tortoise (*Gopherus morafkai*) in CPNWR. While dirt roads are not considered a major threat, off road driving is a major threat to Mojave desert tortoises (Doak et al., 1994; U.S. Fish and Wildlife Service, 2011). Direct mortality through accidental above-ground collisions as well as the accidental crushing of tortoises in their burrows from off-road driving are both major problems. Intentional killing of desert tortoises are is also an occasional issue (U.S. Fish and Wildlife Service, 2011). These mortality sources may be less severe for Sonoran desert tortoises as they seem to mostly select hills and rocky areas rather than low and flat areas (Pers. Communication, Sid Slone, Refuge Manager CPNWR).

Another example of a relatively small species on the CPNWR and the surrounding areas is the Pinacate beetle (or desert stink beetle) (*Eleodes* sp.). While some invertebrates avoid open areas, the Pinacate beetle, based on the observation of the authors (16 February 2021) seems to readily walk on the widened section of El Camino del Diablo. When threatened, for example through vibrations and the shadow of an approaching object (e.g. a car), it will stand on its head to prepare for squirting a noxious chemical. This behavior, as well as the width of the widened dirt road and the time involved to cross it, may make the Pinacate beetle susceptible to direct road mortality.

The species discussed above are examples of species that may suffer from direct road mortality. However, no systematic roadkill data are available; not for the “old” El Camino del Diablo, nor for the widened sections. Nonetheless, it seems that direct road mortality is likely very low for large mammals, and likely higher for smaller species groups such as reptiles and invertebrates. Small mammal mortality is likely to primarily occur with night-time driving (e.g. by Border Patrol).

Pinacate beetle (*Eleodes* sp.) on dirt road, El Camino del Diablo este, about 6.4 miles north of Tinajas Altas, Barry M. Goldwater Range West (BMGR-W), Arizona (32°24'9.234" N 114°4'22.134" W).

4.2.3. Barrier to Wildlife Movements

The widened El Camino del Diablo is unlikely to be a substantial barrier to large mammals such as desert bighorn sheep or mule deer (*Odocoileus hemionus*). While some species such as the Sonoran desert tortoise may be attracted to puddles on the dirt road after rain events, many small animal species (e.g. invertebrates, reptiles, small mammals) tend to avoid open areas, partly because of increased predation risk. In addition, small species may avoid the dirt road because of the heat, as there are no large rocks or shrubs to provide shade. The widened road (about 22 ft) likely increases the barrier effect for small species compared to the “old” road (about 13 ft wide). In addition, berms (often 1-2 ft tall, sometimes about 3 ft tall) alongside the widened dirt road can be a physical barrier to small species, including invertebrates, reptiles (e.g. Sonoran desert tortoise, especially juveniles), and small mammals.

Pinacate beetle (*Eleodes* sp.) scaling a near vertical sand berm along dirt road after walking alongside the berm for several meters, El Camino del Diablo este, about 6.4 miles north of Tinajas Altas, Barry M. Goldwater Range West (BMGR-W), Arizona (32°24'9.234" N 114°4'22.134" W).

The berms are partly the result of grading the dirt road (for the widening itself and for maintenance), and partly the result of erosion as water collects on the road and then flows down the road instead of in being transported in desert washes. Berms caused by grading stick out both above the road and above the surrounding landscape. Berms caused by erosion stick about above the road, but are mostly level with the surrounding landscape, indicating that soil has been “removed” from the roadbed. In some instances, berms caused primarily by one activity or process are exacerbated by the other. Note that there are also berms along the “old” El Camino del Diablo in some sections, mostly because of erosion. While erosion occurs along sections of both the old and the widened El Camino del Diablo, grading is restricted to the widened sections, and since grading is applied along the entire length of these road sections, the berms are present nearly everywhere along the widened road, over great lengths.

Berm (1-2 ft tall), primarily caused by grading, along a widened section of El Camino del Diablo, about 5.5 miles east of western boundary, Cabeza Prieta National Wildlife Refuge, Arizona (32°15'4.506" N 113°52'29.273" W).

Berm (1-2 ft tall), primarily caused by grading, with runoff eroding across the berm, along a widened section of El Camino del Diablo about 3.1 miles from western boundary, Cabeza Prieta National Wildlife Refuge, Arizona (32°15'53.004" N 113°54'42.503" W).

Berm (about 2.5 ft tall), primarily caused by erosion, along a widened section of El Camino del Diablo, about 7.3 miles from western boundary, Cabeza Prieta National Wildlife Refuge, Arizona (32°14'48.906" N 113°50'47.453" W).

Berm (over 3 ft tall), primarily caused by erosion, but initiated by grading, along a widened section of El Camino del Diablo, about 10.3 miles north of Tinajas Altas, Barry M. Goldwater Range West (BMGR-W), Arizona (32°27'14.837" N 114°5'57.467" W).

Berm, primarily caused by erosion, but initiated by grading, along a widened section of El Camino del Diablo, about 2.0 miles from western boundary, Cabeza Prieta National Wildlife Refuge, Arizona (32°16'15.09" N 113°55'45.827" W).

4.2.4. Decrease in habitat quality in a zone adjacent to the road

A decrease in habitat quality in a zone adjacent to a road corridor can be caused by a range of different parameters, and the distance of the road effect zone depends on the parameter, and the species or ecosystem attribute that is evaluated. Because the type of effects are very broad, the most relevant ones related to the widened dirt roads on CPNWR are discussed below.

A "better road" that allows for more comfortable driving in 2-wheel drive vehicles with low clearance at relatively high speed is likely to result in an increase in traffic. "Border wall tourism" seems to be somewhat of a phenomenon now, though it seems to mostly take place on the Barry M. Goldwater Range (BMGR). Increased human presence leads to increased effects on the ecosystem. Examples of the types of impacts that are likely to increase are human disturbance to large wild mammals (especially desert bighorn sheep), increased risk of poaching (e.g. desert bighorn sheep, mule deer) and illegal collection of animals (e.g. reptile species) (U.S. Fish and Wildlife Service, 2011), increase in noise, increase in dust in the air and dust depositing on plants affecting photosynthesis, chemical pollutants in air, soil, and water (exhaust, tires, fluids from vehicles), and the creation of new user-created, unauthorized routes off of the main road. A specific type of decrease in habitat quality is the diversion of water in the roadbed, decreasing or eliminating sheet flow or flow in desert washes downstream from where water meets the road (see later in this chapter).

4.2.5. Right-of-way as habitat and corridor

The road and edges of the road are heavily disturbed because of construction, and ongoing maintenance (e.g. grading). Non-native invasive weeds thrive in disturbed soil along roads. Non-native invasive weeds can not only spread along the road, but they can also invade the surrounding areas. Non-native invasive weeds were already a concern before the widening of El Camino del Diablo, but increased disturbance of the road edges is likely to further the spread of species that are already present such as Sahara mustard (*Brassica tournefortii*) and the spread of new species in this part of the Sonoran desert (e.g. Arizona Sonora Desert Museum, 2021).

Sahara mustard (*Brassica tournefortii*) along a widened section of El Camino del Diablo, about 5.0 miles from western boundary, Cabeza Prieta National Wildlife Refuge, Arizona 32°15'14.267" N 113°52'54.203" W).

4.2.6. Hydrology and Erosion

Probably the most severe ecological effect of roads in the desert is the effect they have on hydrology and erosion. The effects take place both on the road itself, and in a zone adjacent to the road (both “upstream” or “upslope” and “downstream” or ”downslope”). Because it is a severe effect and because it is somewhat complex, the effects of the road, and the widening of the road, on hydrology and erosion are discussed in this section and they are not integrated in the previous sections that relate to “habitat loss” or a “decrease in habitat quality in a zone adjacent to the road”.

While it does not rain often in the Sonoran desert, hydrology and associated erosion shape the landscape. Water flows across the landscape as “sheet flow” and collects in desert washes. Sheet flow is a thin film of water that flows over a large area, not concentrated in channels, and it does not transport a large amount of debris. When water does concentrate in the Sonoran desert, it collects in “desert washes” which can collect a massive amount of fast flowing water that transports a large amount of debris (e.g. sand, gravel, rocks, vegetation) during and just after a rain event. In contrast to a river, desert washes usually dry up quickly after a rain event. Roads in this ecosystem disturb sheet flow almost everywhere. Roads usually also cut through small and large desert washes. Ideally, both sheet flow and water in desert washes should cross the road unimpeded and continue their natural flow to and on the other side of the road. If the water cannot cross the road, it will concentrate on the road and be transported down the road, preventing it from reaching the other side. The “downstream” or “downslope” side of the road may be dewatered until the point where the water exits the road and re-enters the adjacent land (though new washes may be formed at these exit points if the concentrations of water on the road are significant). When the hydrologic and road systems interact in this way, they are “connected”. If the road system is “disconnected” from the hydrologic system, then roads will have significantly less impact on the hydrological system.

The hydrological and soil impacts of these connections can occur over great distances and with significant cumulative ecological effects. For example, downstream/dewatered areas will not support the same flora and fauna, as water availability will be limited or have will be distributed differently. As another example, water running along the road can cause very deep erosion of the roadbed itself and can lead to new perpendicular erosion channels in the adjacent land as a result. Significant erosion can occur in just a small number of flood events.

In addition to these ecological impacts, there are also transportation, safety, maintenance, and financial impacts. The flooding and associated erosion of the road can threaten the integrity and function of the road, worsening over time. These concepts hold for all dirt roads in arid environments, and the apply to both the “old” narrow El Camino del Diablo and the widened road sections. However, wider roads, higher traffic volume and inappropriate grading and maintenance practices can increase the hydrologic impacts and erosion problems as compared to smaller, lower impact dirt roads like the “old” Camino del Diablo. In other words, the widened dirt roads are more likely to have more severe impacts over shorter time periods.

The following images illustrate hydrological and erosion issues on both the “old” narrow El Camino del Diablo and the widened road sections.

"Old" section, just west of El Camino del Diablo, about 1.1 mile south-east of Tinajas Altas, Barry M. Goldwater Range West (BMGR-W), Arizona (32°18'23.267" N 114°1'54.749" W). This is the closest remaining “reference” for the “old” El Camino del Diablo west of Cabeza Prieta National Wildlife Refuge (CPNWR). Sheet flow crosses the road, no or little water flows down the road, no or little erosion.

"Old" section, just west of El Camino del Diablo, about 1.1 mile south-east of Tinajas Altas, Barry M. Goldwater Range West (BMGR-W), Arizona (32°18'22.997" N 114°1'54.851" W). This is the closest remaining “reference” for the “old” El Camino del Diablo west of Cabeza Prieta National Wildlife Refuge (CPNWR). A small desert wash crosses the road, no or little water flows down the road, no or little erosion.

“Old" section of El Camino del Diablo east of Tule Well, about 0.4 miles south-east of the junction with the Tule Extension road, Cabeza Prieta National Wildlife Refuge (CPNWR), Arizona. This is the closest remaining “reference” for the “old” El Camino del Diablo east of the widened section of El Camino del Diablo (32°11'47.231" N 113°43'22.59" W). Sheet flow crosses the road, no or little water flows down the road, no or little erosion.

Rolling dip (possibly natural topography rather than constructed) along the "old" section of El Camino del Diablo east of Tule Well, about 1.0 mile south-east of the junction with the Tule Extension road, Cabeza Prieta National Wildlife Refuge (CPNWR), Arizona (32°11'26.58" N 113°42'54.149" W). This allows water to cross the road rather than flow down the road. It minimizes the connection between the road system and the hydrological system. It results in no or minimal flooding and erosion on the road and it has minimal impact on natural hydrology, erosion, and sedimentation processes. This is the closest remaining “reference” for the “old” El Camino del Diablo east of the widened section of El Camino del Diablo.

Detail of a rolling dip (possibly natural topography at the wash crossing rather than constructed) along the "old" section of El Camino del Diablo east of Tule Well, about 1.0 mile south-east of the junction with the Tule Extension road, Cabeza Prieta National Wildlife Refuge (CPNWR), Arizona (32°11'26.573" N 113°42'54.144" W).

Berm with evidence of sheet flow entering the lower roadbed, primarily caused by grading, along a widened section of El Camino del Diablo, about 1.1 mile from the western boundary, Cabeza Prieta National Wildlife Refuge, Arizona (32°16'32.286" N 113°56'36.048" W). Ideally the sheet flow should continue on the other side of the road. Because the road is incised (because of a combination of grading and erosion), this can no longer happen. Instead the water concentrates on the road until it breaks through the berm on the other side and forms a small or large desert wash. Other areas on the “downslope side” of the road no longer receive sheet flow.

A small desert wash enters the roadbed, along a widened section of El Camino del Diablo, about 3.1 miles from the western boundary, Cabeza Prieta National Wildlife Refuge, Arizona (32°15'52.896" N 113°54'42.785" W). Ideally, the wash should exit the road on the other side and not somewhere else down the road.

Water has left the road by eroding through a berm (primarily caused by grading) along a widened section of El Camino del Diablo, about 3.1 miles from the western boundary, Cabeza Prieta National Wildlife Refuge, Arizona (32°15'53.261" N 113°54'43.038" W). This results in new desert washes on the downslope side, and other areas on the downslope side no longer receive sheet flow. The original wash also no longer receives the same amount of water on the downstream side of the road.

Desert wash blocked by a roadbed that is more than 3 ft above the wash bottom along a widened road section, Tule Extension road, about 1.9 miles south-east of the junction with El Camino del Diablo, Cabeza Prieta National Wildlife Refuge, Arizona (32°10'43.314" N 113°42'23.165" W). The roadbed and associated fill blocks the natural flow of water in the desert wash, acting as a dam across the wash. With large rain events, the wash may saturate and blow out the roadbed material. This threatens the integrity and functionality of the road, and has the potential to completely block access if the road fails completely at this point. Alternately, deep channels could cut through the roadbed creating a safety hazard for unsuspecting drivers.

Desert wash blocked/dammed by a roadbed over 3 ft tall, widened road section, Tule Extension road, about 1.9 miles south-east of the junction with El Camino del Diablo, Cabeza Prieta National Wildlife Refuge, Arizona (32°10'43.164" N 113°42'23.184" W). This is a detail of the previous image.

5. SUGGESTIONS FOR THE MANAGEMENT OF ROADS AROUND TULE WELL

5.1. Introduction

This section relates specifically to the widened section of El Camino del Diablo, the two widened access roads to the border wall, as well as one former access road to the border wall that was driven on despite being closed to vehicles. However, these types of effects and avoidance, mitigation, and compensation strategies also relate to other road sections in the area, including the “old” Camino del Diablo further to the east. The widened and graded road is likely to have more severe impacts though, and these effects are more likely to manifest in a shorter time span, compared to the “old” El Camino del Diablo. Furthermore, not all effects will occur on every road section and not all avoidance, mitigation, and compensation strategies will be relevant everywhere. Nonetheless, for the road sections of interest, the discussion below describes the different types of effects that are already present, or that are likely to occur in the future, and suggestions aimed at avoiding, mitigating, or compensating for these effects.

While different avoidance, mitigation, and compensation strategies are discussed below, a successful implementation of any strategy is depended on the purpose and need of the different road sections, and transportation needs in the area in general, and the viewpoints of the stakeholders. Stakeholders may include USFWS, Border Patrol, and individuals or representatives of organizations focused on natural and cultural resources, historical values, 4x4 enthusiasts, local government.

The sections below discuss a range of management strategies. Multiple strategies and combinations of strategies can be initiated at the same time on the same or different road sections. One does not necessarily have to select only one strategy.

- Strategy 1: No action, leave the widened road section as it was left after the work on the border wall was completed or halted.
- Strategy 2: Disconnect the road system from the hydrological system.
- Strategy 3: Rebuild the road surface along heavily eroded road sections.
- Strategy 4: Reduce or minimize the footprint of the road.
- Strategy 5: Eliminate off road driving as compensation for the widened roads.
- Strategy 6: Decommission duplicate roads and restore habitat.

These strategies are discussed in more detail in the following sections.

5.2. Strategies

5.2.1. Strategy 1: No Action

“No action” means: Leave the widened road sections as they were left after the work on the border wall was completed or halted. Grading is assumed to probably continue. The following types of effects are likely along selected road sections:

1. A large footprint on the widened roads will remain present (about 22 ft wide). In areas with flooding and erosion, the footprint will likely increase over time because of ever increasing erosion of the roadsides, and the development of a braided set of roads created by users to avoid areas that are flooded or heavily eroded (see later in this section for illustrations).
2. Some road mortality of large mammals, probably more substantial road mortality of small animal species groups (invertebrates, reptiles, small mammals).
3. Some barrier effect for large mammals because of human presence and disturbance, potential for increased poaching and illegal collection of animals (especially reptiles). Potential for substantial barrier effect for certain small animal species, including invertebrates, reptiles, and small mammals.
4. Disturbed hydrology and erosion processes on both upslope and downslope side of road with consequences for vegetation (e.g. dead trees and shrubs that are deprived of sheet flow, especially on the “downslope side”). Depending on the configuration of the desert washes in relation to the road, these effects may occur over great distances and areas, especially for hydrological and erosion processes. Water may end up in different washes than if the road wasn’t there.

Deeply eroded and incised road, collecting sheet flow and starving the downslope vegetation from water (dead trees), along Bates-Well road, Organ Pipe Cactus National Monument, Arizona (32°8'39.63" N 113°2'49.319" W).

5. Increasingly incised road because of erosion and an ever-widening footprint of the incision.

Heavily eroded section of the "old" section of El Camino del Diablo east of Tule Well, about 7.3 miles south-east of the junction with the Tule Extension road, Cabeza Prieta National Wildlife Refuge (CPNWR), Arizona (32°9'23.58" N 113°37'23.082" W). Water enters the road somewhere “upslope” flows down the road, and causes heavy erosion of the road, leaving the roadbed several feet (around 3 ft) lower than the surrounding area. As time passes and more rain events occur, the erosion and incision worsen, and the incision deepens and widens, also causing a widening footprint of the road. Flooding and erosion threaten the integrity of the road and likely encourage people to drive around, avoiding the inundated road section. This results in a “braided” road corridor with an ever-increasing footprint of the road corridor (increasing width), erosion, and disruption of the natural hydrology and erosion and sedimentation processes.

Deeply eroded and incised road (over 6 ft) near Cuerda de Leña and Kuakatch wash. Organ Pipe Cactus National Monument, Arizona (32°12'1.764" N 112°52'1.968" W).

Deeply eroded and incised road (over 6 ft) near Cuerda de Leña and Kuakatch wash. Organ Pipe Cactus National Monument, Arizona (32°12'1.847" N 112°52'2.088" W).

Deeply eroded side channel funneling water into incised road near Cuerda de Leña and Kuakatch wash. Organ Pipe Cactus National Monument, Arizona (32°12'1.836" N 112°51'39.059" W). The incised road and the side channel get wider over time, and the side channels eat further and further into the area adjacent to the road.

A side channel forms along heavily eroded and incised road, along Bates-Well road, Organ Pipe Cactus National Monument, Arizona (32°8'58.097" N 113°2'6.245" W). The side channel will progress further and further from the road, while also widening and deepening.

6. Potential for deep channels to form during and just after rain events where the roadbed has filled a wash. When this happens, it is likely a safety hazard for unsuspecting drivers.

Desert wash blocked by a roadbed over 3 ft tall along a widened road, Tule Extension road, about 1.9 miles south-east of the junction with El Camino del Diablo, Cabeza Prieta National Wildlife Refuge, Arizona (32°10'42.474" N 113°42'23.531" W). The road blocks the natural flow of water in the desert wash. With large rain events, the wash may saturate and blow out the roadbed material. This threatens the integrity and functionality of the road, and deep channels that cut through the roadbed could be a safety hazard for unsuspecting drivers.

7. The road may become impassable at times because of flooding in certain sections, and water flowing down the road (the road becomes a wash). This results in
   a. Temporary road closures (physically impassible).
   b. Travel delays (slower speed, vehicles getting stuck).
   c. Potential safety issues and loss of vehicles (drowning, vehicles lost in flooding).
   d. People driving around the flooded sections, resulting in an ever-widening braided road corridor (e.g. hundreds of yards wide), which results in increased habitat loss and increasing impacts on hydrologic and erosion processes.

Braided road corridor in the Las Playas area (pin is at 32°5'38.513" N 113°26'49.722" W). Drivers take different paths in response to loose sand, giant desiccation cracks, flooding events, and mud. This resulted in an ever-increasing width of the travel corridor. Here, the width of the braided road system is about 250 ft (only the major tracks, excluding minor tracks).

8. The road surface may erode to the point that it becomes difficult or impossible to drive on (deep ruts, rocks, loose silty sand) This results in people driving around these rough sections, resulting in an ever-widening braided road corridor (e.g. hundreds of yards wide), which results in increased habitat loss and increasing impacts on hydrology and erosion processes.

5.2.2. Strategy 2: Disconnect the Road from the Hydrological System

To disconnect the road from the hydrological system means implementing engineering and maintenance approaches that allow water to flow as naturally as possible from one side of the road to the other. Where washes intersect with the road system, the road alignment should be designed to transport the water across the road to the other side. Where the road is constructed on a slope, regular and effective dips and drains should be constructed to prevent water from concentrating and that allow dispersing that water to the other side of the road. Desert roads can be designed to prevent water concentration and to prevent situations wherein water from a wash reaches the road and then stays on the road and flows downslope until it finds a place to exit the road. These design and maintenance strategies are aimed at reducing unnatural erosion of the road and adjacent areas and limiting the hydrologic footprint of the travel corridor. They require regular maintenance.

a. The most effective strategy to disconnect the road system from the hydrological system is to install sufficient drainage to allow water to regularly escape the roadbed.
b. Where possible roads can be constructed in the highest areas e,g, on the crest or dome between two desert washes. This minimizes sheet flow that crosses the road. However, at some points, crossing more substantial sheet flow and desert washes is inevitable. In these instances, regularly placed road drainage structures to disperse water that is concentrating on the road, are critical to reducing hydrologic impacts to the road and the adjacent ecosystem.
c. Install culverts, bridges, or hardened wash crossings to allow water to cross the road at road/wash intersections. Do not construct a road across a wash with no water outlet across the road.

Desert wash blocked by a roadbed that extends more than 3 ft above the wash on a widened road, Tule Extension road, about 1.9 miles south-east of the junction with El Camino del Diablo, Cabeza Prieta National Wildlife Refuge, Arizona (32°10'43.314" N 113°42'23.165" W). The fill blocks the natural flow of water in the desert wash. With large rain events, the wash may saturate and blow out the roadbed material. This threatens the integrity and functionality of the road, and deep channels that cut through the roadbed could be a safety hazard for unsuspecting drivers. This road/wash crossing is highly unlikely to be sustainable (hydrology, erosion, integrity and functionality of the road, road safety).

Depending of the purpose and need of the road, a more sustainable desert wash crossing may consist of the following:

- Follow the natural topography with higher ground on both sides of the desert wash, the roadbed is the natural substrate, and the road crosses the wash close to perpendicular to minimize impact. This can be a characteristic of a “primitive” or “historic road”. This is typically done for very low use and very low speed roads or for roads for which the “primitive character” needs to be preserved. This may be relevant to sections of El Camino del Diablo.

Desert wash crosses the road with higher areas on either side of the wash, Bates -Well road, Organ Pipe Cactus National Monument, Arizona (32°13'18.353" N 112°53'36.174" W).

- Follow the natural topography with higher ground on both sides of the desert wash, the roadbed is hardened and can have additional anti-erosion measures in place to make passing easier during flooding and to minimize erosion. (e.g. gabion baskets upstream and downstream adjacent to the paved road surface). This is typically done for roads that receive more traffic, or where quick and safe passage is more important.

Road crosses a desert wash, Organ Pipe Cactus National Monument, Arizona. The road surface is paved where the road crosses the wash to reduce erosion (31°58'22.637" N 112°46'27.641" W).

- Install a "minimal" culvert. This may or may not be combined with the road following the natural topography with higher ground on both sides of the desert wash. However, during substantial rain events a culvert may not be sufficient, or it may become clogged with debris, thus diverting water over the road (flooding). If no additional measures are taken, erosion of the road bed (on the surface) is possible, and it is also possible the entire roadbed will be saturated and that the fill will fail, leaving the road potentially impassable until it is repaired. Note that a culvert that is not designed for large rain events may not be "sustainable".

Road crosses desert wash (culvert and dip), Organ Pipe Cactus National Monument, Arizona. The road surface is paved where the road crosses the wash to reduce erosion (31°58'23.172" N 112°46'27.443" W.

- Install a very large culvert or a bridge that spans the entire width of the desert wash. This is typically only done for roads that have substantial traffic, and roads where temporary road closures because of floods or severe erosion are not acceptable.

d. Create “rises” on the sides of desert washes.

Not all desert washes are large enough to contain the water and prevent it from flowing down the road. To “guide” the water and make the water stay in the wash rather than flow down the road, rises (banks) can be installed on both sides of the wash in the road. This is somewhat similar to “rolling dips” (see next section) but here the “rises” are on both sides of the wash (rather than only on the downslope side) and the dip coincides with the bed of the desert wash.

e. Create drainage structures, including rolling dips, at regular intervals to disperse concentrated water and to assist with the transport of water from one side of the road to the other to mimic sheet flow.

Sheet flow can enter the roadbed almost anywhere. If it cannot cross or exit the road, it will concentrate and flow downslope on the road, with increasing volume and speed, creating more severe flooding and erosion as a consequence. Therefore, it is good practice to create regular drainage structures to disperse concentrated water and move it from one side of the road to the other. Following the direction of the water flow, a "dip" is created in the roadbed, angling towards where the water should go (Figure 4). A "rise" is created just after the dip, increasing the functionality of the dip in guiding water off the road and preventing water to continue to flow along the roadbed.

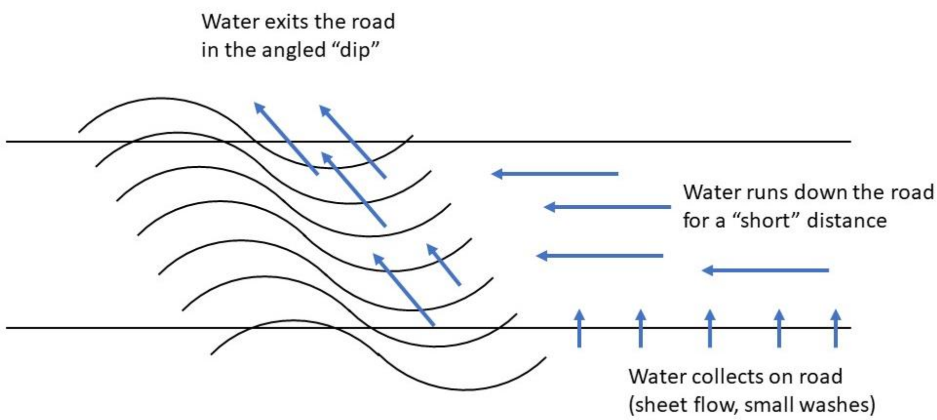

Figure 4: Concept of a rolling dip that drains water off the road.

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Constructed rolling dip (rock base), along Bates-Well road, Organ Pipe Cactus National Monument, Arizona (32°9'47.088" N 112°59'55.98" W). The length of the rise is one car length, and the slopes are half a car length of either side (total length is approximately two car lengths) (Pers. Communication, Rijk Morawe, Resources Management Chief, Organ Pipe Cactus National Monument).

Detail of a constructed rolling dip (rock base), along Bates-Well road, Organ Pipe Cactus National Monument, Arizona (32°9'47.315" N 112°59'56.124" W). These rises were constructed with 4 inch rocks, aggregate base, and soil, and compact (with water) (Pers. Communication, Rijk Morawe, Resources Management Chief, Organ Pipe Cactus National Monument).

f. Where the road has not been incised (yet), but where berms exist as a result of grading, removing or flattening the berms may restore sheet flow. Installing frequent drains across berms can reduce erosion and extend the life of the road.

5.2.3. Strategy 3: Rebuild the Road Surface along Heavily Eroded Road Sections

Deeply incised road sections have lost and are continuing to loose soil due to erosion. The effects are not only on the road, but they radiate into the surrounding areas (see illustrations in previous sections). While efforts to stabilize the erosion are good, they do not improve the situation. To ensure that it is safe to drive and that vehicles will not get stuck, the road prism may need to be stabilized with rocks to reduce erosion and increase drivability (Pers. Communication, Rijk Morawe, Resources Management Chief, Organ Pipe Cactus National Monument).

If the current situation is not acceptable, then rebuilding the roadbed may be required (Pers. Communication, Rijk Morawe, Resources Management Chief, Organ Pipe Cactus National Monument). This could be done by building “dams” or “sediment traps” on the roadbed. Water carries sediments during flood events. These sediments would be deposited upslope from the dams, raising the level of the roadbed. This can result in deeper water on the road and longer standing water on the road during and after rain events. The dams would eventually come up to the height of the surrounding landscape, perhaps in phases as the incised roadbed rises. This type of treatment is only appropriate on deeply incised roads and may require closing the road to travel depending on the design of the dams, so alternate routing may be required.

5.2.4. Strategy 4: Reduce or minimize the footprint of the road

One may choose to reduce the width of the road to accomplish a variety of objectives, e.g.:

- Reducing ecological impacts, including both hydrologic and terrestrial impacts (e.g. habitat loss).
- Reducing traffic speed (increase human safety, reduce direct road mortality of wildlife).
  - Reduced erosion of the roadbed.
  - Reduced forming of washboards.
  - Reduced grading and maintenance needs along with associated costs.
- Restoring (some of) the historical “primitive” character” of El Camino del Diablo (i.e. narrower, vegetation closer to road and vehicles, more “experience” of the road and the landscape rather than a road that is physically separated from the vegetated environment, potentially more uneven road surface (but not washboarded), potentially rocky, not graded or bulldozed through the natural topography but designed more consistently with the natural topography and landscape.

Washboards, Bates -Well road, Organ Pipe Cactus National Monument, Arizona (near 32°13'18.353" N 112°53'36.174" W).

The footprint of a road can be reduced in several ways. In the context of El Camino del Diablo, one may choose to restore the historical character of the road over the entire length. Here we describe a more limited approach based on bulb-outs and active habitat restoration in select areas (Figure 5).

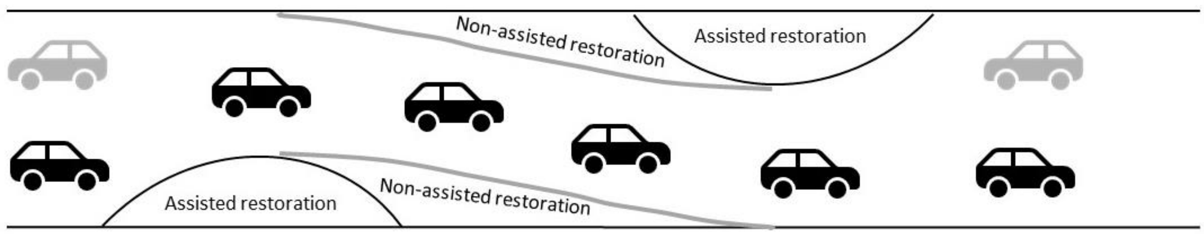


Figure 5: Reducing the footprint of the road in certain sections through assisted habitat restoration in "bulb-outs" and natural regeneration in the "shadows" of these bulb-outs. Bulb-outs can be combined with rolling dips that also affect the design speed of the road. In addition, water in and near the dip may allow for quicker vegetation restoration.

The bulb-outs illustrated above can be designed to allow large vehicles to travel on the road in order to accommodate border protection and associated infrastructure maintenance. However, the design would be intended to generally reduce the speed of travel and it would narrow the road to one lane in certain locations, while the road would remain two-lane in other places to allow more efficient travel.

Bulb-outs and associated restoration must include signage/reflectors and even vertical mulch (e.g. transplanting cacti (including dead cacti) as both a visual cue and a safety component to prevent cars from driving over the bulb outs. Natural regeneration may occur spontaneously in the "shadows" of the bulb-outs as vehicles will not drive there.

Another strategy aimed at reducing the footprint of the road, reducing the barrier effect of the road, and restoring sheet flow, is to address the berms caused by grading. Berms from grading stick up above the road surface and above the surrounding landscape. In some areas these berms are more than a foot wide, and they can be more than a foot high as well. If the berms only stick out above the roadbed and not above the landscape, then the berms are caused by erosion and would require a different treatment.

Berms caused by grading can be flattened to be level with the roadbed and surrounding areas. However, simply flattening these berms, without associated habitat restoration, would effectively widen the road surface. Combining restoration (see next section) with the effort to flatten berms can reduce the overall footprint of the road as the area formerly occupied by the berms would become natural habitat. The purpose of this tactic is to "bring the desert to the edge of the road". Of course, this is only possible if there will be no future grading or grading-associated berms.

Furthermore, removing these berms will make it easier for small animal species to cross the road. Finally, sheet flow can also enter and leave the road anywhere.
Habitat restoration of what used to be part of a road may include: the removal of unnatural substrate; soil decompaction; recontouring to match the natural topography; the placement of dead plant material to increase organic matter, create microclimate and visually camouflage the road; and protection from vehicles driving over the area (barriers). Such barriers may consist of natural materials (e.g. large pieces of dead cactus or shrubs or rocks), but they can also be unnatural (e.g. fence poles, metal guard rails or something similar). Note that these "bulb-outs" would need to be signed and marked (e.g. reflectors) for safety.

Border Patrol dragging tires to later track people that have crossed the road after crossing the border, Bates -Well road, Organ Pipe Cactus National Monument, Arizona. Habitat restoration efforts in bulb-outs would need to be protected from vehicles, and tires dragged behind vehicles by Border Patrol.

5.2.5. Strategy 5: Eliminate off road driving as compensation for the widened roads

The widened roads have a range of impacts, especially on hydrologic and erosion processes. While the effects can be reduced through various strategies (see previous sections), the effects can not be completely erased. As part of an analysis of the purpose and need of the widened roads and transportation needs in the area as a whole, an agreement between USFWS and Border Patrol) regarding off-road driving practices by Border Patrol could be revisited. To be clear, this is not about the use of management roads that are closed to the public. Off-road driving practices relate to driving off established roads, sometimes in a desert wash, sometimes outside of a desert wash. The sensitive cryptobiotic soil is disturbed, initiating hydrological and erosion processes, and some vegetation is destroyed. In addition, small animal species are likely to suffer direct mortality through direct vehicle hits or being crushed in their burrows (e.g. Sonoran tortoises, other reptile species, small mammals). Desert ecosystems take a very long time to recover from off-road driving. Even if off-road driving is limited to “rare situations”, the impacts are substantial and accumulate overtime (e.g. because of the very long recovery time of the cryptobiotic soil). The expansion and widening of the road is exacerbating this problem by bringing more visitors to the area. If they see an off-road track they may choose to drive on it as well. Thus a complete prohibition of off-road driving (at least by the public) should be considered. Addressing this issue with Border Patrol will be more complex, but there are alternatives that can be considered, such as helicopters and drones, instead of continuing to drive off-road to deal with border issues.

Desert wash, closed to vehicles, but there is vehicle use evidence anyway, about 1.1 miles south-east of Tinajas Altas, Barry M. Goldwater Range West (BMGR-W), Arizona (32°18'23.478" N 114°1'54.689" W).

Evidence of off-road driving, along Bates-Well road, Organ Pipe Cactus National Monument, Arizona (32°9'49.949" N 112°59'38.946" W).

Desert wash that has been driven on by an ATV, off El Camino del Diablo east of Tinajas Altas, Cabeza Prieta National Wildlife Refuge, Arizona (32°12'50.124" N 113°44'28.115" W).

Management road closed to the public off El Camino del Diablo, Las Playas area, Cabeza Prieta National Wildlife Refuge, Arizona (32°5'28.811" N 113°24'15.083" W). Note the fence posts that encourage drivers to keep their vehicles on the road.

Pull out, boundary staked with fence posts, along Bates-Well road, Organ Pipe Cactus National Monument, Arizona (32°9'32.334" N 113°0'56.621" W). Note the tracks on the lower left that indicate a vehicle drove over the erosion control roll.

Evidence of a vehicle driving off road across erosion control measures, at a pull out with boundary staked with fence posts, along Bates-Well road, Organ Pipe Cactus National Monument, Arizona (32°9'32.364" N 113°0'56.717" W).

Habitat restoration to restore impact of off-road driving, along Bates-Well road, Organ Pipe Cactus National Monument, Arizona (32°10'49.775" N 112°56'47.285" W). Note the use of dead cacti and branches to discourage driving in the area.

Habitat restoration to restore impact of off-road driving, along Bates-Well road, Organ Pipe Cactus National Monument, Arizona (32°11'6.408" N 112°56'8.579" W).

5.2.6. Strategy 6: Decommission Duplicate Roads and Restore Habitat

Roads that are not needed, for example because of alternative access, could potentially be completely closed to all access and then either decommissioned (physically blocked and hydrologically disconnected), or fully restored (blocked, decompacted, disconnected, and revegetated). If habitat restoration takes place on the former road, this can also be considered as compensation for increased impacts elsewhere, e.g. because of the widening of sections of El Camino del Diablo. The South Tordillo road to the border wall may be an example of such an opportunity.

6. RECOMMENDED NEXT STEPS FOR THE MANAGEMENT OF THE ROADS AROUND TULE WELL

The authors suggest the following steps. Note that these suggestions are not prescriptions, not for CPNWR, nor for any other organization.

1. Conduct a comprehensive analysis about the future purpose and need of different road sections, and transportation needs in the area in general. A clear understanding of the transportation purposes and needs in the area is essential to the implementation of any strategy aimed at avoiding, mitigating or compensation for impacts related to the roads and vehicles.
2. Assess the hydrologic and geomorphologic condition. Assess erosion potential along entire length of widened road, including associated impacts at deeply incised sections of the old road or other eroded road sections (e.g. Pinta Sands in Las Plays area).
3. With stakeholders (e.g. Border Patrol), conduct a field visit of the impacted roads and mitigation measures (rolling dips or rises or water bars, dams) and habitat restoration in Organ Pipe Cactus National Monument with Rijk Morawe.
4. For any roadwork (maintenance, reconstruction, or construction), require training (preferably with a certificate) in desert hydrology, geomorphology, and erosion processes for all personnel, especially equipment operators and supervisors. Alternatively, require specialized certified personnel in desert hydrology, geomorphology, and erosion processes to oversee road maintenance, reconstruction, or construction. This includes grading practices, e.g. indiscriminate/insensitive grading can remove rolling dips or water bars. In such instances, maintenance intended to improve vehicular travel may have the unexpected consequence of increasing potential erosion and long-term cumulative impacts of the road (and associated vehicular access issues). The overarching principle would be to “work with the natural topography and hydrology in harmony” which results in a more sustainable road with reduced maintenance needs over the long term.
5. Explore what such a training course (with certificate) in desert hydrology, geomorphology, and erosion processes would look like and how it could be organized.

7. EROSION ISSUES AND BRAIDED ROAD AT LAS PLAYAS AREA (PINTA SANDS)

The El Camino del Diablo in the Las Playas area, Pinta Sands, is a braided set of roads rather than one “road”. Loose silty sand, erosion, and occasional flooding and mud cause drivers to seek alternate routes to avoid the obstacles in this area. Giant desiccation cracks are a particular hazard in this area. Giant desiccation cracks are mud cracks or large soil cracks, but they occur on a very large scale. Our measurements showed that the holes and cracks in this area can be over 3 ft deep, but there was no formal or complete survey. The giant desiccation cracks are not always visible to drivers as the “ road surface” may still appear to be intact but there may be a sizeable hole or crack just underneath. It appears that there is a potential for damage to vehicles and risk to human safety, both with “visible” and “invisible” cracks as the latter may cause the surface to collapse under the weight of a passing vehicle.

Giant desiccation cracks along the El Camino del Diablo, Las Playas area, Pinta Sands, Cabeza Prieta National Wildlife Refuge, Arizona (32° 5'38.73"N, 113°26'49.66"W).

Giant desiccation cracks (here about 30 inches deep) along the El Camino del Diablo, Las Playas area, Pinta Sands, Cabeza Prieta National Wildlife Refuge, Arizona (32° 5'38.92"N 113°26'49.37"W).

Giant desiccation cracks (at least 26 inches deep but only a tiny crack is visible on the surface) along the El Camino del Diablo, Las Playas area, Pinta Sands, Cabeza Prieta National Wildlife Refuge, Arizona (32° 5'38.90"N 113°26'49.86"W).

Giant desiccation cracks along the El Camino del Diablo, Las Playas area, Pinta Sands, Cabeza Prieta National Wildlife Refuge, Arizona (32° 5'39.00"N 113°26'49.69"W).

Giant desiccation cracks along the El Camino del Diablo, Las Playas area, Pinta Sands, Cabeza Prieta National Wildlife Refuge, Arizona (32° 5'38.73"N 113°26'49.66"W).

8. FIELD REVIEW ROAD AT CHILDS MOUNTAIN OVERLOOK

8.1. Introduction

On top of Childs Mountain, in the north east section of CPNWR, north of Ajo, a viewpoint overlooks a portion of the refuge. The road to Childs Mountain Overlook currently has a gate that is locked (Figure 6 and 7). The road up to Childs Mountain Overlook may be opened to day-use and needs to be evaluated for its potential impacts and measures to address these impacts (Pers. Communication, Sid Slone, Refuge Manager CPNWR)

Figure 6: The road from the junction with Hwy 85 (right) to the overlook on the top of Childs Mountain (left) (total road length about 7.4 miles), Cabeza Prieta National Wildlife Refuge, Arizona.

Figure 7: The road from the locked gate (upper right) to the overlook on top of Childs Mountain (upper left), Cabeza Prieta National Wildlife Refuge, Arizona.

8.2. Findings

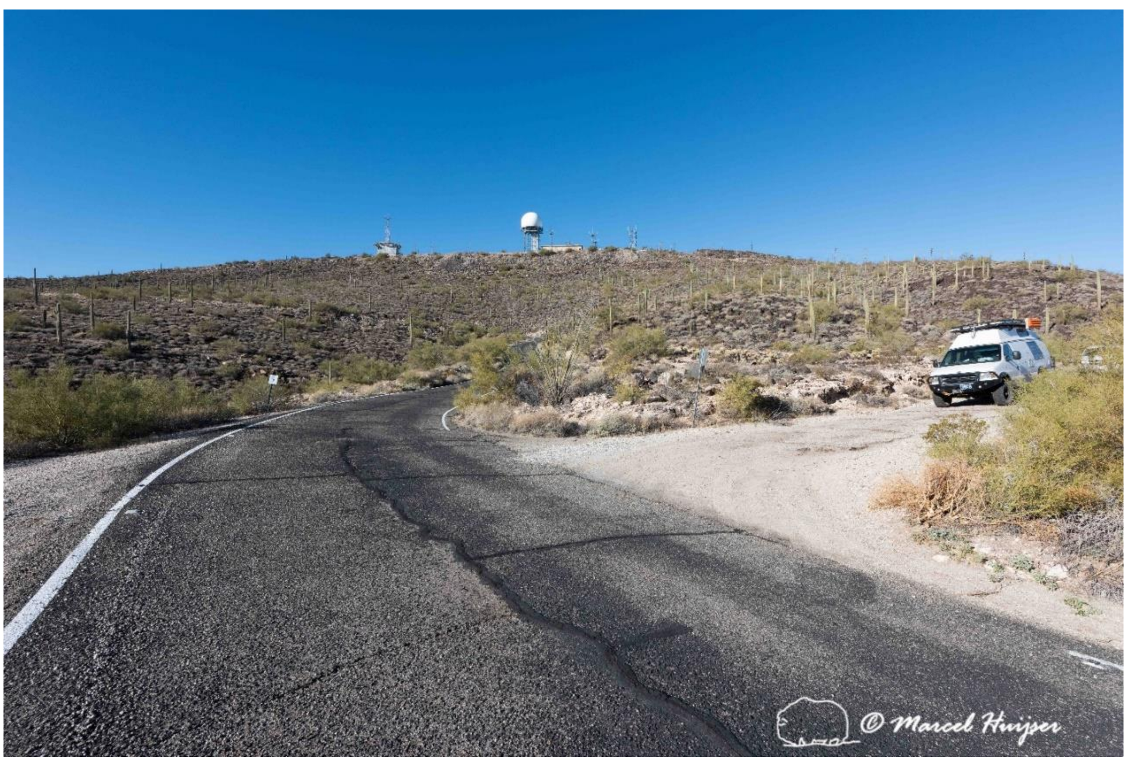
8.2.1. General conditions

The road to Childs Mountain is partially paved, and partially gravel. The gate on the road to Childs Mountain is normally locked and the road is only open to authorized personnel. The public can only access the overlook on certain days and certain times with a volunteer guard present at the overlook. The viewpoint has a parking area, a covered shelter and information panels. The road to the overlook is steep and windy along some road sections, with a posted speed limit of 25 MPH, and in places an advisory speed of 15 MPH. The road has many culverts.

The locked gate on the road to the overlook on Childs Mountain (about 3.4 miles from the junction with Hwy 85), Cabeza Prieta National Wildlife Refuge, Arizona (32°26'25.12"N 112°55'23.58"W).

The road to the overlook on Childs Mountain, Cabeza Prieta National Wildlife Refuge, Arizona (32°26'15.46"N 112°55'44.86"W).

The road to Childs Mountain paved from this location to the junction of the road to the radar post and the road to the overlook (32°26'10.28"N 112°55'55.76"W).



The junction of the road to the radar post (straight ahead) and the road to the overlook (right turn on gravel), about 6.4 miles from the junction with Hwy 85 (32°25'57.44"N 112°56'28.89"W).

The road to the overlook is steep and windy, Childs Mountain, Cabeza Prieta National Wildlife Refuge, Arizona (32°26'15.58"N 112°56'32.97"W).

The road to the overlook is steep and windy, Childs Mountain, Cabeza Prieta National Wildlife Refuge, Arizona (32°26'7.18"N 112°56'30.33"W).

The road to the overlook is steep and windy, Childs Mountain, Cabeza Prieta National Wildlife Refuge, Arizona (32°26'27.36"N 112°56'56.65"W).

The road to the overlook is steep and windy, Childs Mountain, Cabeza Prieta National Wildlife Refuge, Arizona (32°26'30.69"N 112°56'54.99"W).

The overlook on top of Childs Mountain, about 7.4 miles from the junction with Hwy 85, Cabeza Prieta National Wildlife Refuge, Arizona (32°26'32.63"N 112°57'3.39"W).

The overlook on top of Childs Mountain, Cabeza Prieta National Wildlife Refuge, Arizona (32°26'32.20"N 112°57'3.80"W).

The overlook on top of Childs Mountain, Cabeza Prieta National Wildlife Refuge, Arizona (32°26'32.24"N 112°57'3.72"W).

Culvert under the road to the overlook, Childs Mountain, Cabeza Prieta National Wildlife Refuge, Arizona (32°26'17.51"N 112°55'43.78"W).

8.2.2. Observed Problems or Potential Problems

The following problems or future potential problems were observed:

A. Clogged culverts

The soil is highly erodible and soil, rocks, vegetation, and other debris can clog culverts partially or fully. This can result in water building up on the upslope side of the road and eventually the water will flow over the road surface or it will saturate the roadbed and cause the road to fail and wash out.

Clogged culvert under the road to the overlook, Childs Mountain, Cabeza Prieta National Wildlife Refuge, Arizona (32°26'13.70"N 112°56'48.50"W).

Clogged culvert under the road to the overlook, Childs Mountain, Cabeza Prieta National Wildlife Refuge, Arizona (32°26'13.85"N 112°56'48.79"W).

Partially clogged culvert under the road to the overlook, Childs Mountain, Cabeza Prieta National Wildlife Refuge, Arizona (32°26'34.25"N 112°55'39.26"W).

Clogged culvert under the road to the overlook, Childs Mountain, Cabeza Prieta National Wildlife Refuge, Arizona (32°26'9.14"N 112°56'32.67"W).

B. Erosion gullies and cut slopes

There are several points where water is concentrated onto the road, e.g. at erosion gullies or along a two-track along the powerlines. Adequate culverts are not always present. In other cases a cut slope may erode.

The two-track along the power line is eroding and is a potential threat to the road to Childs Mountain (32°26'6.24"N 112°56'38.98"W).

An erosion gully crosses the road to the Childs Mountain overlook (32°26'9.26"N 112°56'32.43"W).

An erosion gully crosses the road to the Childs Mountain overlook (32°25'59.12"N 112°56'32.59"W).

C. Inboard ditch erosion

The inboard ditches and the adjacent roadbed are eroding in places.

Erosion of the roadbed into the inboard ditch along the road to the Childs Mountain overlook (32°26'53.58"N 112°55'41.10"W).

Erosion of the roadbed into the inboard ditch along the road to the Childs Mountain overlook (32°26'50.90"N 112°55'47.49"W).

D. Out-slope erosion

In places, the water cannot leave the road on the out-slope side. The berms along the road prevent the water from leaving the road and this can cause erosion.

The berm does not allow water to leave the road along the road to the Childs Mountain overlook (32°26'32.17"N 112°55'27.72"W).

The berm does not allow water to leave the road and a channel causes the roadbed to erode, along the road to the Childs Mountain overlook (32°26'38.43"N 112°55'28.40"W).

E. Potential roadkill of Sonoran desert tortoise

Increased use of the road may increase the likelihood of vehicles killing Sonoran desert tortoise. A sign is installed indicating that this may occur. Note that wildlife warning signs are not effective in reducing collisions with wildlife (e.g. review in Huijser et al. 2008).

Warning sign for Sonoran desert tortoise, Childs Mountain, Cabeza Prieta National Wildlife Refuge, Arizona (32°25'57.44"N 112°56'28.89"W).

8.2.3. Possible strategies to address current or potential problems

A. Clogged culverts

Clean out the existing culverts regularly. Consider installing much larger culverts that are less likely to clog.

B. Erosion gullies and cut slopes

Reduce erosion by slowing down water velocity and creating sediment traps in the gullies. This may include placing boulders, woody debris, straw wattles (with coir netting, not nylon), and revegetation. Place adequate culverts where gullies cross the road. A steep slope that is susceptible to erosion has been stabilized with shotcrete.

Shotcrete stabilizes a cut-slope along the road to Childs Mountain overlook (32°26'13.16"N 112°56'35.27"W).

C. Inboard ditch erosion

Place water bars and consider installing rolling dips to divert the water off the road at regular intervals. Regular placement of culverts is required to keep the inside ditch from eroding.

A culvert at an inboard ditch along the road ro Childs Mountain overlook (32°26'25.73"N 112°56'57.82"W).

D. Out-slope erosion

Flatten the berm in places so that water can leave the road surface. Additional measures may include water bars and rolling dips.

Here there is an opening in the berm allowing water to leave the road surface (32°26'35.74"N 112°55'28.39"W).

E. Potential roadkill of Sonoran desert tortoise

A substantial reduction in road mortality of tortoises can be obtained by installing barriers (fences) along both sides of the road. Because fences alone would result in a near absolute barrier of the road for tortoises, fences are typically combined with underpasses (e.g. culverts). However, desert tortoise roadkill may or may not be an issue along this road. Monitoring of roadkill is recommended though.

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